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CONTENTS

Sustainability in High Reliability Organizations Employing Digitized Automation Inspection Processes 3
Constantine Koursaris

Effect of gamma irradiation on morphology and local elemental composition of basalt-based composite material 8
Vladimir Oniskiv, Valerii Stolbov, Elvira Ibragimova

The Use Carbon Composite Material for Replacement of Postresection Bone Defects 19
NikolayBelokrylov, Aleksandr Sotin, Alexei Belokrylov, Tatiana Antipova

Observing the utilization of local e-commerce: a case study of a small and medium enterprise in Surabaya, Indonesia 32
Jessica Patty, Indrawati Yuhertiana

Cost-volume-profit analysis: practical aspects in e-commerce 48
Darya Rozhkova, Nadezhda Rozhkova, Daniela Gonzalez Serna, Uliana Blinova

How innovation influence organisational performance among SMEs in Ghana: The mediating role of organisational leadership 57
Esther Bentumaa Ofosu, Jerry Owusu Banahene, Kingsley Ofosu-Ampong

Sustainability in High Reliability Organizations Employing Digitized Automation Inspection Processes

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Abstract. Digitization technologies offer several advantages over manual methods of accomplishing job-related tasks. Accurately measuring, documenting, and reporting surface damages, due to volume calculation variations are vital in increased efficiency, productivity, and thus mainly, human performance. Several sensation and perception issues were identified, mainly with concerns about accuracy of visual measurements that take place during quality control inspections. This research project portrays High Reliability Organizations utilizing digitized systems and automation concepts, with emphasis in Sensation, Perception, and Human Performance. Problem areas in measuring and assessing damaged Thermal Protection System (TPS) tile surfaces are identified and documented. Analysis of performance issues, causes, and effects, of human error factors are analyzed.

Keywords: Digitization, Digital, Science, Technology, Engineering, Laser Scanner.

1. INTRODUCTION

In early 2000, the use of emerging digitization technology methods, were used to assess and report problems in the analysis of damaged tile surfaces with accuracy, efficiency, increased productivity, and performance. From a human performance, sensation, and perception points of view, a newly developed digitized system would eliminate the need of performing manually cumbersome and arduous calculations.

The result of this research project was the adoption of an operational digitized system as the set standard of the time, for efficiently assessing and analyzing surface damages during various stages of quality control inspections. The human-machine interaction is a very strong issue that human factors experts strive to understand with as much detail as possible. Understanding the modeling of human information processing and human performance is another key factor in applying new knowledge gained thus enriching the knowledge, in improving human-machine interactions. "Many human-machine systems do not work as well because they impose requirements on the human user, that are incompatible with the way people attend, perceive, think, remember, decide, and act, that is, the way in which people perform or process information [1]. The sensation and perception factors are related to how the brain works, rationalizes, and the feeling created by perception when a new system is introduced into the workforce. The processes that take place in the brain and the senses play a key factor in forming our own perceptual experiences especially if the new system is supported by Management directive within the organization. The main human senses that are "put to the test", are performed with tactile and visual senses, a hands-on type of work, performed by the quality control inspectors.

This digitization technology research project was a real-world application that brought together engineers, scientists, human factors experts, and users, from NASA, several contractors, and inter-departmental participation.

2. BACKGROUND

A main concern of the project team was the impact on the quality control (QC) inspectors to produce accurate problem reporting and corrective action based on the resulting scanned measurements. Situation awareness was a big factor due to the effects that that situation awareness played on the QC inspectors required to be on alert at all times. Not only safety was a major concern, like for example, slips and falls, but also the level of alertness was critical while taking the measurements and recording them on the problem reporting corrective action form, and transferring the recorded measurements onto the digitized form to be processed for corrective action. With that being said, there was little room left for any type of error, as the slightest miscalculation could result in a very costly repair.

The risk of making the wrong decision by the quality control inspectors was always a cautionary topic of concern. Prior to the electronic inspection tool implementation, a team of two quality control inspectors would be assigned the task to verify and validate the accuracy of damaged surface area tile measurements performed by another team of QC inspectors. The measuring of the length, width, and depth calculations were inefficient with the manual process, and often resulted in wrong calculations and analysis of surface damages. Due to the fact that the QC inspectors were required to document the problem reporting and corrective action forms, manually aw was the standard operating procedure, resulting in wasteful human performance by having to repeat the process when entering the data in the computerized electronic forms. Recording inaccurate information often resulted in the wrong decision being made to order replacement parts, or repair surface damages, as needed. The result was degradation of human performance, wasted employee productivity, and efficiency.

3. METHODOLOGY

Verifying and validating accurate volume measurements of damaged surfaces are essential decision-making determining processes against standardized specifications, performing a corrective action as a discrepancy that had to be either repaired, or replaced. One advantage of using digitized technologies as opposed to manual processes, is, also the implementation of the use of ergonomic tools to accomplish a set task.

The digitized tool should be capable of capturing the data and by multiplying the length, width, and depth measurements quality inspectors were able to populate the volume field on the graphical user interface, (GUI) with high level programming language calculations using Visual Basic [7]. This process involved capturing all the relevant data from the database, parse the data, and populate all of the necessary fields and information on the electronic version of the problem reporting and corrective action (PRACA) form for formal order processing of the damaged tiles [3]. Any relevant notes on the problem reporting or discrepancies were also noted and printed on the PRACA form.

4. RESULTS

The digitized tool became commonly known as the Electronic Inspection Tool (EIT) among the team members and officially referred to as the MOLD IMRESSION LAZER TOOL (MILT). Early versions of the tool were made with monochromatic grayscale shades and wired USB connection. [5].

Fig. 1. Initial Greyscale Model of the Electronic Inspection Tool [5].

Fig. 1 portrays the initial model of the Electronic Inspection Tool, connected to a laptop via a wired USB cable, with the ability to transmit captured data into a temporary storage location on the laptop hard drive. Once the laptop was connected to the network, it was possible to invoke a transfer command which in turn transferred the calculated data into the distributed database for permanent storage and retrieval.

Fig. 2 illustrates a quality control inspector using the first draft model of the Electronic Inspection Tool [4]. Notice the USB cable that connects the MILT to the laptop which is resting on the floor of the flat stand ladder that the QC inspector is standing on and raised to an appropriate height to reach the underneath the damaged surface.

Fig. 2. A QC Tile Inspector Using the Initial wired Model of EIT [4].

The updated revision of the Electronic Inspection Tool, as shown in Fig. 2, included the design of a wireless 3D scanner that used the same software developed to store the scanned data and process the volume damage area. The scanning process took approximately 5 seconds to complete. Scanning the damaged area produced and displayed the results in a 3D image on the laptop. The QC inspectors would have the opportunity to review the damaged area in 3-D as it was portrayed on the laptop screen. Figure 3 shows the newly designed wireless scanner in action [3]. Notice the improvement from the first model discussed previously. The colored image of the scanned tile damages matches the trichromatic theory of color vision.

Fig. 3. Updated Model of the Wireless Electronic Inspection Tool in Action [5].

Contrasting the scanned damaged tile from the initial model of the Electronic Inspection Tool is shown in Figure 4, it is evident, the damaged trichromatic color images on the right, are clearly visually perceived, compared to the grayscale image on the left. This gives the QC inspectors a much clearer sense of perception, in terms of length, width, and depth damages of the tile area scanned when magnified, in the analysis of results. We can clearly see that the trichromatic theory holds in this case, as the clarity of the color vision is illustrated [1].

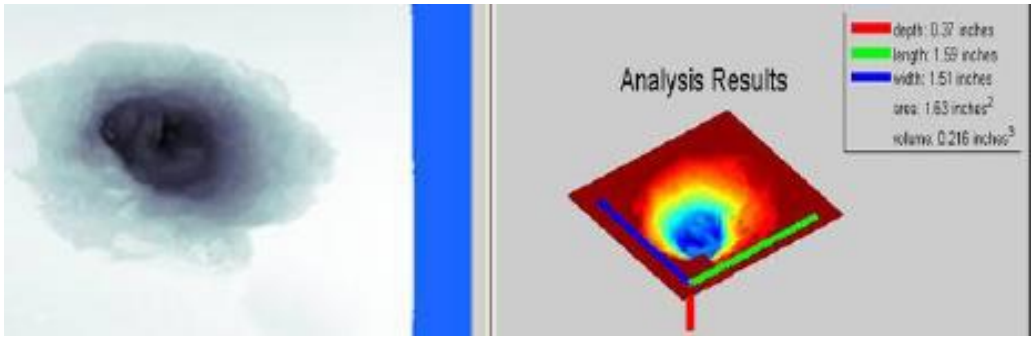

Fig. 4. Greyscale and Trichromatic Color Images of Damaged Tiles [7].

As a result of the research performed and implementation of EIT, NASA developed the Surface Inspection Tool, to perform real-time, visual inspections for optical detection of damaged orbiter widow surfaces [7].

5. CONCLUSION

This research encompassed the use of Systems Automation concepts with emphasis in Sensation, Perception, and Human Performance. The digitized designed system increased the performance of the quality control inspectors inaccurately assessing damaged volume surfaces. Several factors that impact sensation and perception were discussed. The previous state of the system prior to the design of the new system established several key issues that related to sensation, perception, and human performance.

These key issues were identified as problem areas and were tasked to be solved as the goals of accomplishing the newly designed EIT project successfully. Hindrance

of performance by manually calculating surface damages identified causes of human error factors when fatigue and duplication errors occur. The justification for the need analysis for a new digitized technology process became evident. The newly designed automated system in early 2000, was years ahead of its time by far, and improvements made from a sensation, perception, and human performance standpoints were notable feats of accomplishment for its time period. The implementation of the Electronic Inspection Tool solved the lengthy manual problems reported by the quality control inspectors. The implementation of EIT improved many human factors issues the Quality Control inspectors were facing, that proved to be a very reliable method to measure, assess, report, and analyze damaged tile surface areas so that the correct decisions could be made to repair or replace damaged tiles. Increased productivity was realized immediately, with the more reliable scanned results, proved to be accurate to within one thousandth of an inch. Efficiency was a big accomplishment as the newly designed method enabled the QC inspectors to complete their measurements in about 5 seconds or less, compared to the manual process that took several minutes to complete. In turn, employee productivity increased with the ability to do more by completing their assigned measurements analysis with considerably less time than the previous process. In this case, automation was unanimously embraced by all stakeholders of the EIT project, putting an end to the cumbersome and inaccurate method of the manual measuring process.

The EIT team was nominated to win several innovation and invention awards. Several other EIT nominations were awarded that were instrumental in accurately measuring damaged surfaces.

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Effect of gamma irradiation on morphology and local elemental composition of basalt-based composite material

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Abstract. Scanning electron microscopy (SEM) was used to examine the polished surface of samples made of basalt-based composite material before and after gamma irradiation. Morphology and local elemental composition changes in binder, filler and boundary of composite components depending on radiation dose were revealed. The samples were irradiated within a dose range of 5 to 15 Mrad. It has been shown that at radiation doses up to 10 Mrad, new intermolecular bonds are formed and the material is strengthened. With large doses of radiation, the destruction of bonds and the formation of a gas phase is observed. This results in softening of the composite. A sufficiently large amount of nitrogen has been detected in the highly irradiated binder. A possible mechanism has been proposed to explain this phenomenon.

Keywords: SEM, basalt composites, gamma irradiation, morphology, local elemental composition**.**

1. INTRODUCTION

The widespread use of composites based on natural minerals is often limited by their insufficient strength. In the previous works of the authors [1, 2], the results of mechanical testing of samples from a basalt composite modified by gamma irradiation are presented. It is shown that irradiation can affect the elastic and strength characteristics both in the direction of improvement and in the direction of deterioration. In works [2, 3], using IR spectrometry, an attempt was made to substantiate the mechanisms of hardening and softening of the material depending on the irradiation dose (ceteris paribus, except for the diffusion or relaxation time). The main reason is believed to be the appearance of new intermolecular bonds and their destruction. In this case, the IR spectrometry method provides summary information about the molecular structure of the irradiated basalt composite as a whole. However, it is of interest to study the changes that occur under the influence of gamma rays on a microscale, both in the epoxy binder and in the filler (basalt), separately. In this work, for this purpose, we used the method of scanning electron microscopy with a built-in analyzer of the elemental composition, starting with the light elements B, C, O, N… (SEM-EDS) [4]. It allows one to study separately the local elemental composition of the organic and mineral components of the composite, as well as the boundary of their adhesion at increasing doses of radiation.

2. LITERATURE REVIEW

Studies related to the study of the mechanical properties of basalt composites and the use of this material for various products and structures have been the subject of considerable attention of many Russian and foreign scientists, for example [5-13]. Basalt composite has serious potential for its widest application, offering an excellent cost-quality ratio, high resistance to aggressive environments of alkalis and acids, good dielectric properties, heat resistance, radio transparency and simple manufacturing technology for various products. A simplified procedure for the production of continuous basalt fiber is as follows. First the basalt raw materials are heated to melting temperature (1500 C^0). The melt is then transported via a drain device to the platinum-rhodium spinning machines for drawing and winding on the spindles. The energy cost for the production of basalt continuous fiber (BCF) is 20 times less than that of steel and rolled metal, and its specific tensile strength significantly exceeds the same indicator for alloy steels [6]. The production of basalt fiber requires significantly less energy than the production of fiberglass or carbon fibers [13]. It should be taken into account that basalt belongs to the number of minerals widely distributed on the surface of our planet, which makes it very accessible. In fact, basalt is a mineral derived from a solidified volcanic rock that has poured onto the surface of the earth. It is important to note that basalt rocks are among the most durable natural silicate rocks. Unlike the raw materials for the production of fiberglass, for example, basalt rock is a ready-made natural raw material for the production of fibers. This allows us to have comparable production costs for BCF and fiberglass. Basalt fiber has a developed cluster surface and exhibits good sorption properties [14]. At the same time, the hygroscopic properties of basalt fiber are 6-8 times lower than those of glass fibers. This quality is certainly very important for such an industry as shipbuilding. Basalt fibers, in comparison with glass fibers, have a much wider operating temperature range. Despite the fact that BCF has significantly displaced fiberglass, it should not be considered as a direct competitor. Each of these materials has its own area of use. In addition, the idea of their hybrid use is very attractive.

The aforementioned qualities of basalt and basalt-composites allow us to speak about good prospects of their use in medicine. Primarily in the field of external fixation systems for bone fractures and injuries. Basalt fibers are used in the development of high-performance, flexible and low-cost prostheses [15]. Its use in the development of industrial exoskeletons would be reasonable. There is a successful experience in the use of basalt in dentistry [16]. Titanium and chromium alloys with the use of basalt are quite common materials for hip and knee arthroplasty. Meanwhile, the required fatigue strength and surface compatibility are still the subject of research.

Numerous active attempts of researchers to improve certain characteristics through the introduction of nanotubes into the binder, gamma irradiation, fiber milling, as well as the use of various compositions of the binder itself attract attention [17-23]. For example, in [21], the effect of modification of the material under study is achieved by microwave radiation and the introduction of carbon nanotubes into the material. In [22], crushed ochre is used as a filler. In this paper, the modification is carried out by processing the material with gamma-ray streams at different doses. The purpose of such modification is usually to achieve a high level of adhesion between the fibers and the polymer matrix. The properties of the filler, basalt fiber, are fully realised when this is achieved.

The development of hybrid polymeric materials seems very promising [24,25]. For example, the composition of carbon filaments and basalt fibers allows you to obtain strength characteristics 60% higher than those of fiberglass. In addition, such hybridization increases water resistance by 70% and significantly reduces the cost [25].

The purpose of this study is to investigate the effect of gamma radiation dose on the mechanisms of molecular destruction and intermolecular crosslinking, leading to changes in the mechanical properties and structure of basalt composite. This work is a follow-up to the previously performed works on the study of the mechanical characteristics of modified basalt composites [26]. In the current study, an attempt is made to substantiate the physical effect of gamma irradiation on the mechanical properties of basalt composites.

There are two points of view on this issue in the scientific literature. The first one (which may be conventionally called "structural") suggests that the process of "cross-linking" and the formation of a new structure characterized by new mechanical properties takes place due to the impact of gamma-quanta on the material [27]. At the same time the process of "cross-linking" is accompanied by a process of bond failure ("destruction"). As the absorbed dose from radiation exposure increases, the degradation process begins to dominate and the material gradually breaks down. As the experiments of the authors [1,26] have shown, noticeable degradation of investigated basalt-composite is evident at irradiation doses higher than 15-20 Mrad. The second point of view (conditionally, it can be called "energetic") is that due to the influence of a concentrated stream of gamma quanta, additional energy is "pumped" into the material, allowing the process of structuring the material to continue, which also leads to a change in mechanical properties. In the authors' opinion, both points of view can be used to justify the effect of gamma irradiation on material properties. However, only additional research and well-founded hypotheses will fully understand and explain the physical nature of this phenomenon.

Various methods have been used to study the structure of the material. In particular, in [28], a scanning electron microscope (SEM) was used to study the structure of a polymer composite material after its modification by introducing carbon nanotubes and processing with high-frequency radiation treatment. However, the application of this method requires high surface quality of the samples and is convenient for the material that is electrically conductive. Therefore, in this work, the method of infrared spectrometry (IR) was used to assess the level of intermolecular bonds. It has proven itself in many studies. For example, in [29], the use of spectrometry made it possible to qualitatively assess the appearance of new structural bonds under radiation exposure to the material under study. In [2], IR spectrometry is used to study the structure of the irradiated basalt-composite as a whole.

However, in these works there are no results describing the evolution of the structure of the components of the composite in the process of exposure to concentrated fluxes of gamma rays in various doses. The availability of information on changes in the composition and structure of epoxy resin and basalt at different doses of irradiation will make it possible to more convincingly substantiate the mechanisms of strengthening and softening of the material at the molecular level. And also understand the conditions of their competition. This, in turn, will make it possible to more accurately select the conditions for the radiation modification of composite materials based on basalt in order to improve their mechanical properties. Therefore, the topic of the article seems to be important and relevant for the problems of radiation materials science.

3. DATA AND METHODOLOGY

Samples of a composite material based on basalt, made at the Ural Research Institute of Composite Materials, were studied. The constituent parts of the composite were the epoxy binder EDT-10P and basalt roving. Their characteristics are given in [2]. Before testing, the samples were divided into four groups. The first group included comparison samples that were not subjected to the procedure of gamma irradiation, but passed all measurements under identical conditions. The ^{60}Co radioisotope was

used as a source of ionizing electromagnetic radiation. It emits gamma rays with energies of 1.17 and 1.33 MeV. The remaining three groups of the basalt composite were irradiated with gamma rays in the open atmosphere at doses of 5, 10, and 15 Mrad, respectively, at a dose rate of 12.5 rad/s. The exposure time certainly depended on the planned dose and was about 14 days for 15 Mrad. The small size of the samples compared to the geometry of the gamma irradiator suggests that the irradiation was uniform [30]. It is known that under intense high-energy irradiation, the material absorbs energy and leaves the thermodynamic equilibrium state. After the cessation of irradiation, in accordance with the laws of thermodynamics, the material relaxes in the direction of lowering the internal energy to a state of equilibrium. In order to stabilize the state of the material, samples were tested three months after irradiation (5 times the exposure time). During this period, the samples were stored under normal conditions at room temperature in a dark room, to exclude photochemical processes. To ensure the surface quality required for SEM-EDS, the material was poured with an epoxy binder and the required area was finely polish (Fig. 1).

Fig.1 Samples prepared for SEM-EDS and IR spectrometry. Source: [2].

Scanning electron microscopy (SEM) and local elemental composition - SED (electron dispersion spectrum) were carried out on the polished surface of the samples (viewing area about 1 mm^2) at the Japan Technology Center of the Tashkent Polytechnic University on a JEOL JSM-IT 200 microscope. Measurement conditions: electron beam voltage - 20 kV, aperture - 3 (wide), magnification - x80, color map mode.

4. RESULTS

Let us consider the elemental composition of some components of the composite before irradiation. The non-irradiated epoxy binder is characterized by the ratio C/O = 2/1. The composition of the non-irradiated area of basalt is characterized by the ratio C/O <½. Silicon (Si), aluminum (Al) and magnesium (Mg), which are part of basalt, usually correlate in the proportion 3/2/1. Note that, due to the different valences of the cations, the structural positions of oxygen and the bonds in them are not symmetrical.

The visible region is enriched in Na and Ca. The visible grain is aluminosilicate crystallites. A more detailed complete composition is given in Tables 1 and 2. After irradiation, the elemental compositions of the epoxy binder and basalt undergo

changes. Fig. 2, 3 and 4 show typical SEM images and SED spectra of the epoxy component basalt and basalt/epoxy resin interface area, respectively.

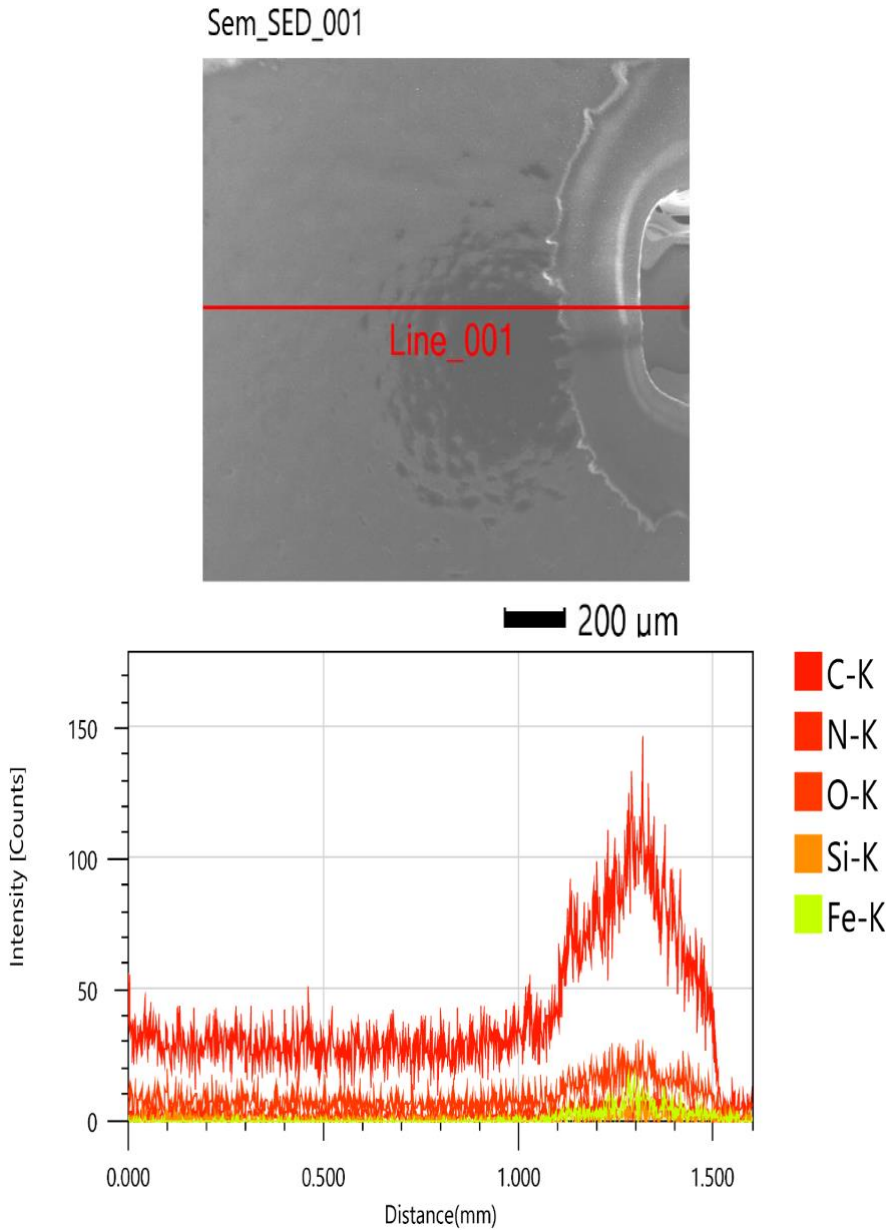

Fig. 2. Example of SEM (above) and SED (below) results of the epoxy component of the composite after gamma irradiation with a dose of 10 Mrad (along line 001 1.5 mm long, over which the composition was averaged. The area includes a microbubble).
Source: [32].

The formation of microbubbles and gas release in resins during gamma irradiation was noticed even in the first experiments due to the increase in pressure in sealed ampoules. The first assumption, that this is the result of the radiolysis of the C-H bond with the release of H2, has not been confirmed. The appearance of the C-

O bond in the IR spectra was attributed to the interaction with atmospheric oxygen, but it was also refuted by irradiation in an evacuated ampoule.

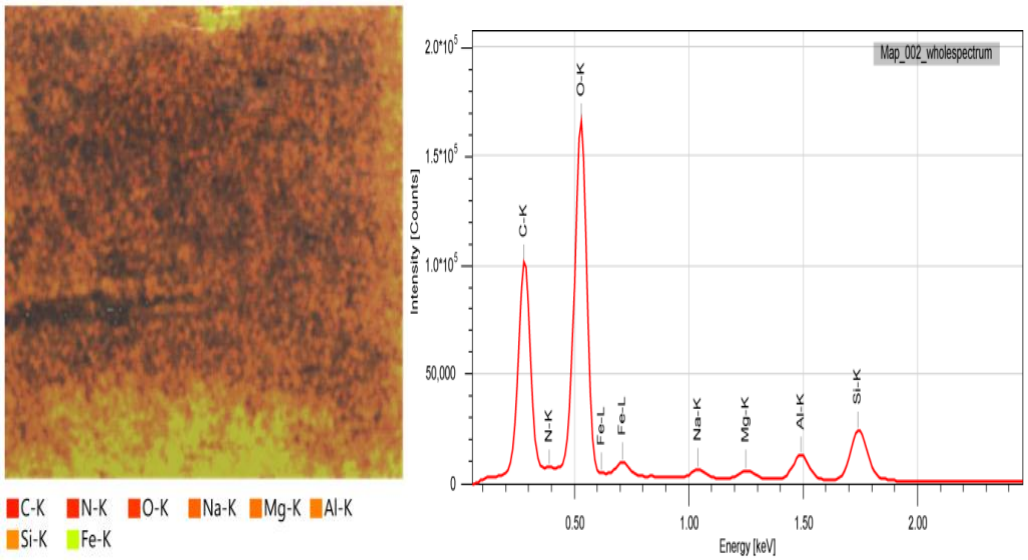

Fig. 3. An example of the results of SEM and SED of the basalt component of the composite after gamma irradiation with a dose of 10 Mrad (visible grains are aluminosilicate crystallites, micropores and a microcrack on the left are black). Source: [32].

This indicates that the process of formation of new intermolecular bonds (crosslinking) occurs in the material with the formation of organo-silicate compounds –C–O–Si-. According to the authors, this is due to the fact that the silicate group of basalt is the most widespread and active, and the C–H bond in the epoxy binder breaks quite easily even under UV irradiation. Gamma rays have an energy above 1 MeV, which is certainly enough to excite any nucleus and chemical reaction. Thus, three-dimensional structures with chemically embedded basalt filler are formed, including the formation of an aluminosilicate compound Si-O-Al, which is observed during SEM (Fig. 3). These results confirm the conclusions made by the authors after studying the irradiated basalt composite using IR spectrometry [2].

Fig. 4 shows the microstructure map of the composite near the boundary of the basalt (left) with the epoxy binder (right), as well as the SED results.

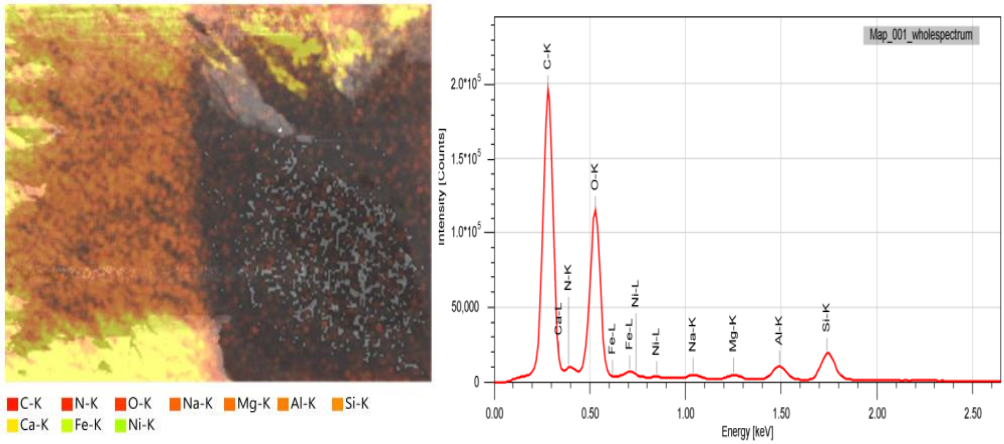

Fig. 4. An example of the results of SEM and SED of the basalt/epoxy resin interface area after gamma irradiation with a dose of 10 Mrad (basalt – on the left, epoxy resin – on the right).

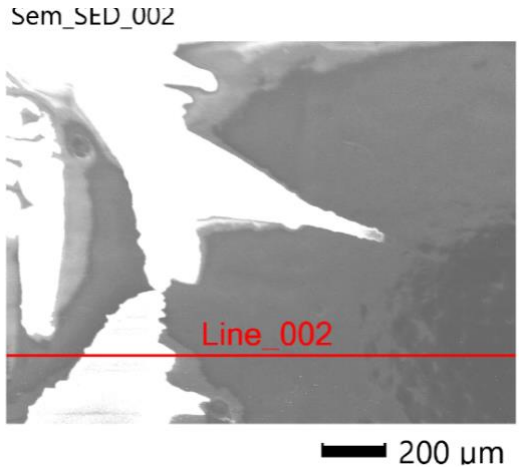

Fig. 5. Line 002 along epoxy binder (light areas) near basalt (dark areas) 1.5 mm long, over which the composition is averaged

The local elemental composition along line 002 is shown in Table 1.

Table 1. Mass and atom fractions of the basalt/epoxy resin interface area elements after irradiation 10 Mrad

Element	**Line**	**Mass, %**	**Atom, %**
C	002	60.47±0.15	66.67±0.17
O	002	32.63±0.31	27.01±0.26
N	002	6.47±0.28	6.11±0.27
Al	002	0.16±0.01	0.08±0.01
Si	002	0.27±0.02	0.13±0.01
Total		**100**	**100**

It should be noted that when irradiated with a dose of 10 Mrad, a sufficiently large amount of nitrogen appears in the composite material, which negatively affects

the strength properties of the material. One of the possible mechanisms explaining this fact is given at the end of this article.

The results of SED for the components of the composite were summarized in Table 2 and 3. It can be seen that after irradiation of the material with a dose of 5 Mrad, the mass fraction of carbon in the epoxy binder sharply decreases, but the fraction of oxygen increases and silicon appears. In basalt, on the contrary, the proportion of carbon increases, while that of oxygen and silicon decreases. The decrease in C and at the same time an increase in O were not detected until the appearance of spectral analyzers of light elements of the SED or EDS type.

Table 2. Mass fraction of epoxy binder elements before and after exposure, %

Element	Radiation dose, Mrad			
	0	5	10	15
C	82,0	68,49	63,53	70,10
O	18,0	31,39	29,98	22,60
Si	0	0,12	0,09	0,07
Al	0	0	0	0,05
Mg	0	0	0	0
Na	0	0	0	0.05
Ca	0	0	0	0
Fe	0	0	1,08	0
N	0	0	5,32	7,13

Source: [32].

Table 3. Mass fraction of basalt elements before and after irradiation, %

Element	**Radiation dose, Mrad**			
	0	**5**	**10**	**15**
C	23,56	29,53	38,17	32,01
O	69,50	64,32	56,58	63,46
Si	4,68	3,51	2,50	2,30
Al	1,12	1,85	1,32	1,05
Mg	0,56	0,74	0,49	0,32
Na	0,24	0,3	0,78	0,56
Ca	0,36	0,06	0	0
Fe	0	0	0,17	0,15
N	0	0	0,05	0,12

Source: [32].

With further irradiation up to 10 Mrad, the crosslinking process continues, but its rate decreases. Microbubbles are observed in the epoxy binder, which indicates an excess of irradiation energy necessary for the process of formation of new intermolecular bonds (Fig. 2).

At an irradiation dose of 15 Mrad, the reverse process (destruction) is observed, in which the destruction of intermolecular bonds and, consequently, the weakening of the composite, which was previously noted in [1], occurs.

The study revealed an interesting fact associated with the appearance in the area of a highly irradiated epoxy binder large enough to detect the amount of nitrogen and iron. The appearance of nitrogen could be explained by adsorption from the atmosphere, but this option is not acceptable for iron. It seems logical to consider the possibility of initiating nuclear reactions by ^{60}Co gamma quanta. An absorbed dose above 10 Mrad corresponds to ~10^{17} gamma quanta/cm2, which can at best form the same number of product nuclei. The authors suggest that during gamma irradiation

of the polymer CH, a hydrogen proton enters the carbon nucleus and it transmutes into the nitrogen nucleus according to the formula:

$$(^{12}C_6 + {}^{1}H_1) + \gamma\ (1.17 + 1.33\ \text{МэВ}) = {}^{13}N_7\ (9.96\ \text{min}\ \beta^+, \text{no}\ \gamma).$$

However, to create a stable $^{14}N_7$ isotope, the positron-active $^{13}N_7$ isotope must capture the neighboring hydrogen (proton + electron). Hydrogen, due to the annihilation of an electron with a positron, will turn into a neutron in the excited $^{14}N_7$* nucleus, which then relaxes to a stable state and appears in small amounts in the EDS and FTIR spectra.

Another option is possible: it is known that the nuclei of oxygen and carbon are α-cluster nuclei, where bonds between α-clusters have an energy of about 2 MeV [31]. Thus, an intense ^{60}Co gamma field can lead both to the decay of $^{12}C_6 \rightarrow 3\alpha$ and $^{16}O_8 \rightarrow 4\alpha$, and to the capture of $^{12}C_6 + \alpha \rightarrow {}^{16}O_8$. These reactions can explain the observed decrease in the content of C and the increase in O, as well as the formation of microbubbles filled with helium (He). Under conditions of high ionization in a gamma field, it is quite easy for an alpha particle to attach 2 electrons and become an He atom.

5. CONCLUSION

The conducted studies allow us to understand and substantiate the mechanisms of the effect of gamma rays on composite materials based on basalt. It can be asserted with a high degree of certainty that, upon gamma irradiation of the composite with doses up to 5 Mrad, an intensive process of cross-linking of molecules occurs with the formation of a three-dimensional framework and the material is strengthened. In the range from 5 to 10 Mrad, the crosslinking process continues with the simultaneous destruction of intermolecular bonds. Irradiation of the material with doses greater than 10 Mrad leads to intense destruction of intermolecular bonds, softening of the composite, formation of micropores, gas microbubbles and microcracks. Thus, gamma irradiation can be recommended as one of the methods for modifying basalt-based composite materials in order to strengthen them. However, the radiation dose should not exceed 10 Mrad, and the radiation power - 12 rad/sec.

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The Use Carbon Composite Material For Replacement of Postresection Bone Defects

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Abstract. In studying the use of various implanted materials, the authors found no case reports of carbon composite material for children in the available literature. The boundaries of carbon composite material use are not clear, and indications and contraindications for its applying are not outlined. Therefore, the authors decided to share the initial experience of its use for the replacement of post-resection bone defects for children. The paper presents the results of surgical treatment of 8-16-year-old children with extensive bone defects after resection of pathological tissue with the use of highly porous cellular carbon in isolation and in combination with autografts. During the study, children with damage to long bone segments - tibia, shoulder, and femoral were operated on. The clinical and radiation results of this study have been evaluated based on the Musculo Skeletal Tumor Society Score Scale. 100% of treated patients were rated as good for period from 7 to 12 years after surgery. There were no complications in the operated patients. Full integration of the implantable materials was observed with good clinical and radiological results.

Keywords: carbon composite material, transplantation of tissues replacing bone, autograft, allograf.

1. INTRODUCTION

The replacement of bone defects for children is very relevant and does not lose its acuteness in case of benign cystic formations or diseases. Such pathology in childhood is very common and tends to increase in frequency, second only to infectious diseases, cardiovascular diseases, respiratory diseases and diabetes mellitus [1].

Orthopedic traumatologists are actively improving both conservative and operative treatment methods using various innovations and improved transplantation materials [2]. The search for implantable materials for replacing defects after removal of tumors or tumor-like areas of altered bone continues to this day [3, 4, 5, 6]. The processes of bone reaction to the introduction of implanted materials and subsequent bone formation continue to be studied [7, 8, 9]. Much attention is paid to the use of inert materials (e.g., carbon-carbon composites), which by their physical and chemical characteristics are close to the organic structure of the human body. Research on carbon composites for the replacement of bone defects and cavities continues both in the field of implant fabrication

technologies and in improving the effectiveness of applying this material to different anatomical areas [10].

In the USSR, specialists have long been interested in alternative methods of full replacement of bone defects, in how to effectively apply the replacement of bone defects with carbon composite materials, studied how the body behaves in this case, what conditions should be provided to obtain the best result, attempts were made to improve regeneration by electrostimulation [11]. The transition to high-porosity cellular carbon-carbon materials is a natural outcome of further study of carbon composites.

The successful use of porous carbon in adult traumatology and orthopedics was the result of in-depth research and numerous studies. In clinical use, this material has proven itself well, which was sufficient reason to introduce this technology in children with a certain degree of caution and under mandatory dynamic monitoring [5, 12, 13, 14].

It is important to note that all materials other than autogenous bone are non-autogenous grafts. However, harvesting autologous bone, especially in children, is an additional operation that causes additional trauma to the child. Donor resources in childhood are limited, there is a risk of infection or even fracture in the area of autologous bone extraction, there are cosmetic disorders, there is a risk of complications in more than 15-20% of observations. This motivates specialists to search for effective bone replacement materials.

2. LITERATURE REVIEW

Recently, bio composite grafts have competed quite well with their predecessors. The use of composite materials is a whole direction in clinical traumatology [15 - 23]. In parallel with other alternative studies, the direction of using carbon materials for bone void replacement is developing [11, 12, 24]. The choice among these materials is also differentiated for different patient groups. Constructs for bone void replacement made of the carbon-carbon material "Uglekon-M" have not been used in pediatric practice due to difficulties in material remodeling [10]. At the same time, high porosity cellular carbon has become a great prospect, especially for use in the metaphyseal area to fill post-traumatic defects in adult patients [25]. We have not seen any reports on the use of such materials in pediatric practice. The advantage of implants made from this material is that its mechanical properties are close to those of native bone, the material is inert to living tissue, but no one has taken advantage of the possibility of using these already proven composite materials in children [5, 12]. Our experience with the use of highly porous honeycomb carbon material in children has demonstrated its high efficacy, with clear boundaries for the use of this material in young patients [26]. However, accumulated clinical experience has revealed additional aspects of working with carbon composites.

Both biological and purely mechanical mechanisms of survival of implants made of this material are of interest; the problems of biomechanical behavior of the bone-implant system under functional loads in the conditions of a growing organism have not been studied.

The further consequences of these materials' use in children and the peculiarities of the implant interactionwith the surrounding tissues are curious.

The main purpose of this work is to study our accumulated clinical material on the use of carbon composite material in children after resection of benign tumor masses and to discuss the revealed biomechanical aspects of its application.

3. DATA AND METHODOLOGY

In the period 2002 - 2022 were operated 12 children aged from 8 to 16 years in whom we replaced the formed bone defect with carbon composite material during surgery with removal of pathological bone in fibrous dysplasia, aneurysmal cyst, nauseous bone fibroma, solitary bone cyst. All tumors were benign, in fact the cavities were cysts with weakened structure, thinning of the compact surrounding bone. The cavities were treated with osteotomes, Folkman rongeurs and burrs, leaving visually unaltered bone tissue. Highly porous cellular carbon with a high implant porosity of 70 to 90% was used to replace the formed bone defects in all patients [26].

Tissue replacement was carried out on the clavicle, humerus, femur, tibia and calcaneus. Technically, in the vicinity of the growth zone, we tried to isolate it from the implanted material using spongy autobone, which we consider to be one of the necessary conditions for the use of composite implants. However, this was an exercise in caution in the initial application of the material. We successfully replaced the rest of the defect with carbon composite. The bone walls were preserved by working with sharp instruments or burrs "to the bloody dew" to ensure that the quality of the native bone was adequate. A combination of implant material and native autogenous bone was used in 3 patients.

Highly porous cellular carbon is itself a lightweight material, almost pure carbon. It is easy to work, can be cut with a knife and the implant can be given any shape corresponding to the formed bone defect (Fig. 1). The cellular structure of carbon facilitates its processing, promotes the integration of bone tissue into hollow cells and the porosity of the material reaches 90%.

Fig. 1. Processing of highly porous cellular carbon with a scalpel.
Source: authors'elaboration.

It is understandable that the clinical application of highly porous structures required caution and a preliminary assessment of the possible biomechanical consequences of implanting this material. In 9 patients, we managed with isolated application of the carbon composite without any particular concern for bone

weakening. However, when the focus of destruction was found in the highly loaded region of the femur, we had to perform some additional studies.

In order to study the influence of the bone destruction Centre (Fig. 2) on the load-bearing capacity of the loaded skeletal segments, a spatially inhomogeneous anisotropic linear-elastic finite element model of the hip joint was constructed in collaboration with scientists from the Perm National Research Polytechnic University (Fig. 3). The model was individualised using spiral, three-plane computed tomography data and the patient's anthropometric parameters.

Fig. 2. Localization of the destructive focus according to computed tomography of the hip joint of patient T., 14 years old.
Source: authors'elaboration.

The digital model is represented by femur and pelvis bones with articular cartilage. The cartilage was modelled as a homogeneous isotropic layer of complex geometric shape. In this problem formulation, the contact intercartilage interaction was not investigated. A cartilage thickness of approximately 4 mm, corresponding to the width of the radiological joint cavity, was assumed, taking into account both contacting cartilage layers. The finite element method was used to calculate the stress-strain state of the bone tissue.

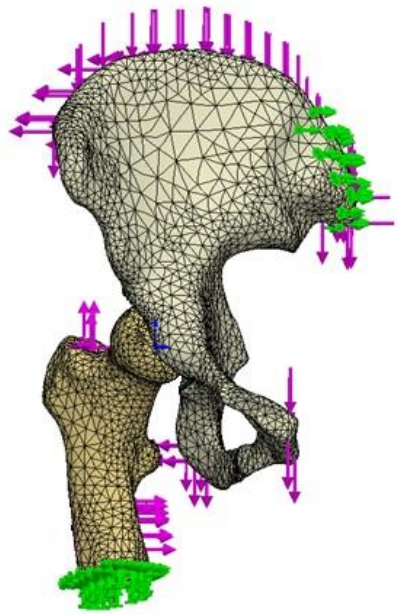
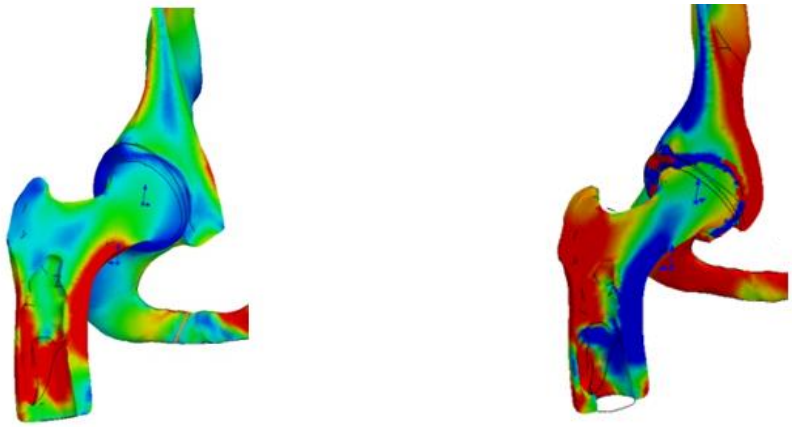


Fig. 3. Computer model of the hip joint. Arrows indicate functional loads and kinematic boundary conditions. Source: authors'elaboration.

The results of the stress-strain state calculation of bone tissue are shown in Fig. 4.



A B

Fig. 4. Stress (A) and strain (B) fields in bone tissue in the presence of a cyst in the femoral metadiaphyseal zone.
Source: authors'elaboration.

Obviously, the presence of the cavity leads to a redistribution of stresses in the bone tissue around the defect and creates conditions for the formation of dystrophic changes at the base of the femoral neck. In such a case, Adams' arch, the vertebral

area above the cavity and the destructive area of the cyst itself become the zone of potential risk of fracture. The walls of the cyst, which are in a critical state due to overloading of the cortical layer, are at greater risk of destruction the larger the cyst itself is. As a result, the risk of pathological fracture increases significantly, which becomes a serious reason to decide on the need for additional measures to stabilise the segment.

This clinical case clearly demonstrates that computer modelling of the development of possible complications depending on the size and location of the cyst allows us to weigh the risks of conservative treatment, determine the need for additional osteosynthesis, and formulate recommendations on the sequence and characteristics of rehabilitation.

In this patient, the analysis of the results of the calculations allowed us to formulate the following statements: critical areas of overload are an indication for surgical correction; in the area of Adams' arch, at the base of the femoral neck and at the level of the cyst itself, foci of bone tissue weakness are created, predisposing to pathological fractures. This allowed the surgeon to decide preoperatively on the need for additional fixation and to select a fixator option.

The ISOLS system proposed by the International Society for Organ Preserving Surgery was used to assess long-term outcomes. The system used also included all similar significant clinical features of the MSTS (Musculo Skeletal Tumor Society Score). In the scoring systems, six clinically relevant parameters were scored on a 5-point scale, and the clinical outcome was represented by the sum of the scores. An excellent outcome ranged from 23 to 30 points, a good outcome from 15 to 22 good points, a satisfactory outcome from 8 to 14 points, and an unsatisfactory outcome from 0 to 7 points. In drawing conclusions, we categorised excellent and good outcomes as 'good' because the differences in outcomes were not significant. Treatment efficacy was assessed as a percentage, reflecting the difference between the increase in score after treatment compared to the patient's baseline score, which is conventionally taken to be 100%. Thus, 30% efficacy means that the increase in postoperative score was 30% of the patient's preoperative baseline score. All clinical data had radiological verification, which was important to assess the integration of the implanted materials into the bone. [14].

4. RESULTS

The replacement of bone tissue defects was performed exclusively using carbon-carbon composite implantable material consisting exclusively of bioinert carbon with porosity of 70-90% in 9 patients, and in combination with autografts in case of extensive defects in 3 patients. In the latter patients the material was used in order to reduce the amount of autograft used (2 patients), and in 1 patient the carbon composite was applied in the metaphyseal zone of the tibia in combination with spongy autograft for isolation from the growth zone. The application of the material did not imply further axial load on the replacement material, so 2/3 of the patients had temporary limitation of the total load on the limb for 4-6 weeks, in the rest there was no such necessity, in our opinion.

We believe that the situations in which combined plasty of the bone defect formed after removal of a bony benign tumor was performed were very favorable. The limited possibilities of graft taking, the desire to reduce the graft quantity were one of the reasons for the additional use of cellular carbon-carbon composite. In young children the wing of the iliac bone can be very thin additional traumatization is undesirable. We have always predicted with high probability a positive outcome of such combined plasty, which has always been justified. The walled location of such defects, initially with a preference for the metaphyseal region, was considered by us

to be favorable conditions for replacement of the defect with carbon material. This is well illustrated by the presented clinical case.

Clinical example. Patient K., 10 years old. A solitary bone cyst of the metaphyseal region of the femur was detected; he was referred because of pain, lameness, and contracture in the hip joint (Fig. 5).

Fig. 5. Patient K., 10 years old. Radiographs of a solitary cyst in the thigh region, the edges of the cyst are sclerosed, traces of multichambered structure. Source: authors' photography.

The patient underwent combined autoplasty of the defect in combination with carbon-carbon composite (2/3 of the total volume), the defect was replaced with bone and modeled carbon pieces, the original size of the defect after cyst removal was 5x3x3 cm. A fragment of the bone cap on the periosteum was cut out at the access and used at the end of the surgical intervention to close the defect by subcutaneous sutures (Fig. 6).

Fig. 6. The same patient K., intraoperative view of the replaced bone defect and the moment of cyst replacement with carbon cellular material. Source: authors' photography.

Wound healing by primary tension. Immobilization was not performed. After wound healing, the patient moved for 3 weeks on crutches, then full load was allowed. Already six months after the operation, the restoration of the structure, complete bone tissue remodeling was noted, there was no recurrence. Observation for more than 12 years. Full recovery of the hip movement amplitude 4 months after surgery, leg length is the same, the supporting function of the operated limb is not disturbed.

Whenever possible, we used at least some of the usable cortical wall in the intervention after appropriate treatment for implant closure (Fig. 7).

Fig. 7. Patient P. 8 years old. A part of the suitable wall of the diaphyseal bone section was used to close the implanted block. Source: [31].

The maximum length of the defect replacement was noted on the tibia at the removal of the foci of fibrous dysplasia and amounted to 11 cm (Fig.8).

Fig. 8. Patient T. 12 years old. Source: [31].

Fig. 8 illustrates treatment and replacement process of the humerus defect with carbon composite. The bone wall is not suitable for plasty. The carbon material is covered with periosteum.

In principle, replacement with carbon composite did not differ from other methods; we used variants of closing the external wall with a preserved part of the cortical wall or simply covered the material with periosteum. No significant differences in the application of these methods of placement and fixation of the material were revealed. The whole material of isolated application of carbon composite amounted to 9 observations.

A few words should be said about the use of combined bone grafting with carbon composite material when it is necessary to use an additional resource in the form of the patient's own bone. This is, on the one hand, a question of the volume

of the bone lesion, and on the other hand, an anatomical need due to the proximity of the epimetaphyseal bone growth zone. In most observations, the cystic formation did not sprout through the growth zone. However, with the proximity of the growth zones, we believed that in any case, the physeal plate should be isolated from the affected bone and from the implant with autologous bone.

When bone autografts were taken in the case of combined interventions, no complications were observed at the site of donor bone harvesting, although this manipulation involves known clinical risks [27].

None of our operated patients had specific complications when using these materials, complete reconstruction of grafts occurred within 6 months to 1 year. There were no recurrences in the future, the follow-up period was from 10 to 20 years, there was no need in repeated surgeries.

The clinical results, performed as an additional study, fully coincided with the applied grading systems according to the MSTS schemes. In general, the results in 100% of treated patients were evaluated as good. The treatment efficiency according to the ISOLS system was +56.8% after treatment in the group after plasty with carbon composite. These data are not inferior to the effectiveness of treatment with the use of other artificial materials and are close to the results with the isolated use of autologous bone, which is recognized by all authors as the most physiologically justified [3, 5, 9, 26].

The use of a mathematical model to be able to predict the behavior of the implanted carbon material was a great help in making the decision to perform such an operation. We had no literature data on the use of composite carbon materials in children, so any clue in this regard was very valuable to us. The mathematical model gave an idea of the loading of the implant itself, its surrounding zones, allowed us to predict biologically favorable conditions and assess the risks of pathological fractures, helped in choosing the optimal accesses and their sizes.

The aim of our study was to present the long-term results of treatment of children with the use of highly porous cellular carbon for the replacement of tumor and tumor-like bone defects of the type of extensive cysts in children after resection of pathologically altered tissues. The nature of the process was clarified by histologic examination. The use of highly porous cellular carbon or other composite carbon materials in pediatric traumatology and orthopedics is not covered in the literature available to us. Carbon materials in the form of nanostructured carbon implants were used in foot surgeries, but the authors did not obtain the expected formation of a true bone-carbon block [28]. Maybe the loaded bone area, or the structural features of the implanted material did not produce the expected results. The results, however, are regarded as good; bone fouling of sufficiently inert implants was achieved.

The porosity of the materials we used is 70-90% or more, so we did not count on their support and relied on the biocompatibility of the carbon itself. The successful use of this material in adult practice gave us confidence in the possibility of its use in children. Nevertheless, we were quite cautious about this material at the beginning of its clinical use, and limited its use to extensive bone defects in the metaphyseal, metadiaphyseal region and at the level of diaphyses of long bones.

The peculiarities of the surgical access without weakening the supporting, intact compact part of the bone ensured its sufficient strength after surgery. We believe that clinical results allow us to assert the osteoconductive effect due to the high porosity of the material, its inertness, and biocompatibility, which demonstrated its use at the level of bone marrow and spongy areas of the metaphysis. The usual localization was metaphyseal, metadiaphyseal part, especially in marginal lesions, and bone marrow cavity at the level of diaphysis. In the case of a limited cortical defect, we relied on subsequent remodeling of the periosteum over the implanted material, which is what we actually observed.

In all cases where the material was used, the patient and their representatives were informed, justification was provided, and consent was obtained in all cases for the use of this still uncommon material.

The achieved clinical results indicate the effectiveness of replacement of extensive diaphyseal, metaphyseal or metadiaphyseal bone defects with carbon composite material. We have used autografts in addition to the above implants in case of significant cavity size, when additional stimuli of regeneration are required, when there are nearby areas of bone tissue with critical nutritional conditions along the lines of force loads or in areas with reduced blood supply, in the vicinity of physeal zones, when there is a threat to weaken the bone tissue to a critical state. We remain convinced that the growth zone should be isolated by autografts from contact with the implanted material.

In general, the use of carbon composites for bone void fillers is justified. Highly porous carbon, by virtue of its porous structure, is thought to be an osteoconductive material that ensures the ingrowth of its own bone with true osteointegration. The "filling" of porous bone areas with blood elements is, in our opinion, the basis of such structural reorganisation. Comparison with other authors' data suggests that the attribution of osteoinductive and osteoconductive properties to composite materials by other authors is more wishful thinking than reality. The question remains open. In our opinion, the use of combined bone autograft and carbon composite material in the replacement of extensive bone defects offers the opportunity to exploit all these positive properties of grafts. Other possibilities for the combined use of this composite material need to be investigated in both children and adults. Highly porous cellular carbon consists almost entirely of carbon, which is inert to the human body. This makes it safe to use. The material is easy to work with, can be cut with a knife and the implant can be shaped to suit the bone defect. The porosity of the material reaches 90% and more. Early studies have also shown that bone elements grow into the implant cavities, and the material does not cause autoimmune or allergic reactions, which is also confirmed by our experience.

It is difficult to draw conclusions from a single observation with the treatment of recurrences with fibrous dysplasia, but it can be assumed that in some cases with extensive defects allografts may be ineffective, insufficiently effective and prone to recurrence. And in this case the use of highly porous carbon may be the method of choice.

Further wider application of this material for the replacement of lower limb defects is associated with certain difficulties and requires solving a number of engineering and clinical problems. First of all, we should pay attention to the fact that the segments of the lower limb are subjected to significant functional loads, which can cause implant failure. That is why it is very important to estimate the biomechanical consequences of the choice of the material, size and shape of the implant, the volume and character of the intervention already at the preoperative stage. A promising way to solve this problem, in our opinion, is the use of computer modeling methods, because with the help of a digital twin of the limb segment of interest it is possible to conduct a computational experiment and calculate the fields of stresses and deformations occurring in the bone. The use of digital twins (computer models) to solve clinical problems (calculation of biomechanical consequences of the choice of implanted material) was demonstrated by us in [29, 30].

It should also be emphasised that the mechanical properties of carbon composite materials can vary over a wide, clinically significant range, and the technology of manufacturing implants (grafts) from this material allows the production of samples with a pre-designed, heterogeneous distribution of mechanical properties. Determination of individual loads on lower limb segments and engineering calculations will allow to avoid possible clinical complications

associated with failure of the implanted construct during bone grafting of limb segments. The above allows us to consider this material as promising from the point of view of the manufacture of personalised implants, and the application of this technology (bone grafting with carbon-carbon composites) of different porosity and strength can be generalised to the lower extremities after appropriate engineering calculations. In general, biomechanical problems should be solved taking into account the favourable biological compatibility of the proposed carbon material, and the place, favourable conditions and limitations of its application should be clearly defined.

5. CONCLUSION

The use of carbon composite material for the replacement of post-resection tumor and tumor-like bone defects is considered highly effective in children aged 8 to 16 years. The efficiency of treatment according to the ISOLS system was +56.8% after plasty using carbon composite, which was confirmed by radiation studies and improvement of quality of life. In 10-20 years after the operation, 100% of the children had good results, and there were no complications when using these implants alone or in combination. When comparing artificial plastic materials, we should recognise the most promising - fine-porous variants, in particular highly porous cellular carbon, due to its inertness and high affinity to living tissues. The biomechanical properties of the implanted material need to be further studied using computerised digital duplicates. The results of the computer modelling allow the surgeon to assess the risks of continuing with conservative treatment, to decide on the need for additional fixation and to select a fixator variant in the preoperative phase. The digital twin is an addition to the surgeon's arsenal of tools used to assess the influence of the shape and location of the defect on the risk of possible bone separation. The use of digital tools makes it possible to quantify high-risk clinical situations and justify the need to remove the pathological focus and restore the bone structure. Finally, the proposed approach will allow a wider application of high porosity carbon implants and improve their vitalisation conditions. In conclusion, the method developed and applied in the clinic for the treatment of post-resection bone defects using carbon composites is effective and promising.

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Observing the utilization of local e-commerce: a case study of a small and medium enterprise in Surabaya, Indonesia

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Abstract. The objective of this study is to conduct an analysis of the local e-commerce platform developed by the Surabaya Government, known as E-Peken. This research observes the operations of small and medium companies operating within the textile industry sector over a period of nine years, specifically focusing on the Jarak Arum MSMEs. This qualitative study spanned a duration of six months and was done in a field setting. The research methodology employed involved the observation of both internal and external documents, such as the e-peken website, as well as conducting interviews with a total of eight informants. This study reveals that the success of implementation and adoption is contingent upon the personality traits exhibited by the owner.

Keywords: MSMEs, local e-commerce platform, E-Peken, Sales.

1. INTRODUCTION

The global outbreak of the coronavirus disease (COVID-19) in early 2020 had a profound impact on multiple sectors across different regions, including Indonesia [1]. The economic sector in Indonesia has seen significant shocks that have resulted in a substantial reduction in income generated by business entities, particularly in the Micro, Small, and Medium Enterprises (MSMEs) sector. These MSMEs have played a crucial role in supporting the Indonesian economy thus far [2]. According to the news release issued by the Coordinating Ministry for Economic Affairs of the Republic of Indonesia and published on the official website ekon.go.id, it was elucidated that Micro, Small, and Medium Enterprises (MSMEs) constitute a fundamental cornerstone of the Indonesian economy. According to data provided by the Ministry of Cooperatives and Small and Medium Enterprises (SMEs), the total number of actors involved in Micro, Small, and Medium Enterprises (MSMEs) in 2018 was recorded at 64.2 million. These MSMEs made a significant contribution to the Gross Domestic Product (GDP) of Indonesia, accounting for 61.1 percent [3]. This data underscores the crucial role played by MSMEs in bolstering the country's economy.

Small and Medium Enterprises (SMEs) play an important role in strengthening the national device by establishing a vital position, developing overseas trade, and working on the local economy [4]. SME became Indonesia's savior during the COVID-19 pandemic [5]. In the technological era, digitalization has become a necessity to be implemented in all types of industry, including MSME [6]. Many MSME entrepreneurs have difficulty adopting technology to develop their business [7]. Thus, it is important to examine how MSME entrepreneurs adopt technology. The research question of this study is: How a MSME (Jarak Arum) uses a digital platform created by the local government to make it easier for MSMEs to sell their products. This research question

arose to answer and understand the impact of the use of local e-commerce (e-peken) on increasing sales of Jarak Arum MSME. This research was conducted in the city of Surabaya, Indonesia where this application was created (e-peken).

The rapid spread of the virus has forced the Indonesian government to form a series of rules or regulations as a form of breaking the chain of transmission of COVID-19, one of which is regarding Large-Scale Social Restrictions (PSBB) [8]. The implementation of policies not to carry out activities outside the home, to maintain distance, and to stay at home according to government recommendations ultimately changed the total habit of the community, which previously interactions could be carried out directly, freely, and openly, now interactions indirectly or through telecommunications devices, closed and limited. Not only that, implementing these policies will, of course, also affect an economic downturn so that people's purchasing power decreases, affecting the circulation of money in the market and resulting in a further slowdown of trading activities [9].

A shift has also occurred with the Covid-19 pandemic, where previously, consumers could directly visit shops or supermarkets. However, due to restrictions and government regulations, sales are also made online via e-commerce, including for MSME players who need to adjust developments so that their businesses can continue [10]. One strategy that MSMEs can implement to survive is to sell online or through e-commerce, starting with digital promotions to reduce promotion costs and build and optimize marketing relationships with customers [11]. Entering the new average period, the government is increasingly showing its role in helping MSME players create a strategy so that the businesses they are undertaking can survive and run even though economic conditions are still recovering [12].

The form of support provided by the Surabaya city government to MSME actors to restore the economy is by creating innovation by issuing an online shopping application assisted by the Communication and Information Service (Diskominfo) called Pemberdayaan dan Ketahanan Ekonomi Nang Suroboyo (PEKEN) which brings together grocery stores and MSMEs, one of which is Jarak Arum MSMEs. Jarak Arum is an MSME engaged in the batik textile industry, which produces stamped batik, hand-written batik, and eco print batik. The MSME owner said that the difficulty or challenge in increasing sales through e-peken was the need for more digital and digital sales knowledge. So, without sufficient digital knowledge, maximizing the use of e-peken to increase sales will be a challenge.

This study aims to analyze how the application of the e-peken application to MSMEs in increasing sales. E-peken was created as a form of sustainability carried out by the government by trying to overcome digital literacy problems in MSMEs through existing applications. This research has novelty because it is research to see how the effectiveness of the government's role in helping MSMEs continues. Therefore, this analysis is used to find out how MSMEs struggle to absorb technological developments so that qualitative research is carried out with interviews so that they can in depth understand the phenomena that occur in the field. This research was conducted by selecting one of the MSMEs in Surabaya because Surabaya is the second largest city with great concern about how MSMEs can continue. This topic is very relevant to research on the grounds that it can accelerate digital transformation [13] so that MSMEs decide to switch to e-commerce because market reach and target market become wider [14], makes transactions easier for consumers by saving time and money [15].

Research conducted by Fachrina & Nawawi with the title "Utilization of Digital Marketing (Shopee) in Increasing Sales at MSMEs in Marelan" shows that the shopee sales approach is perfect, which makes purchases for customers and sellers more

comfortable. In addition, all manufacturers have access to the shopee market segmentation because of the convenience it offers, there are promotional elements that can increase sellers' sales profits, so the shopee application is ideal for use as a sales channel [16]. Aisyah, Imamsyah, et al.'s research with the title "Implementation of Digital Transformation Through Tokopedia Seller Apps to Expand Marketing to MSME Actors in Medan City (Case Study on Pelita Petshop Medan)" shows the results of the study that MSMEs experienced significant changes as a result of implementing digital transformation through Tokopedia Seller Apps, including improving customer service without the need for in-person visits, the ability to easily share promotional content with a broad audience to increase awareness of MSME pet shops, easier cost management due to no advertising costs, and increased operational efficiency [17]. The novelty of this research is the e-peken application developed by Surabaya government to support local MSMEs, different from other e-commerce such as shopee, tokopedia, and the like, owned and operated by private companies or individuals. Furthermore, e-peken uses a business model that focuses on the interests and sustainability of MSMEs, while private e-commerce generally uses a business model that prioritizes profitability.

This study addresses the research question by employing comprehensive observations and interviews with the proprietors of Jarak Arum Micro, Small, and Medium Enterprises (MSMEs), as well as various stakeholders including employees, MSME assistants, the village head of Putat Jaya Subdistrict, and consumers. The aim is to gain a comprehensive understanding of the phenomena occurring in the field. This study will thereafter examine literature reviews pertaining to the topics of digitalization and financial management. It will also address the research methodology employed, specifically interpretive qualitative methods. The subsequent sections will present the results and discussion, aiming to identify key findings derived from the research. Finally, the study will conclude by summarizing the outcomes of the conducted research.

2. THEORETICAL REVIEW

2.1. Digital Literacy

Digital transformation has become a significant phenomenon recently [18]. Digital transformation relies on digital technologies, such as artificial intelligence, machine 4.0, blockchain technology, big data analytics, and IoT [19] to increase the openness, inclusiveness, and generativity of MSMEs [20]. Digital content creation refers to the capacity to create digital content while complying with copyrights and licenses; information literacy concerns knowledge about browsing, searching, and filtering data and digital content; interaction and collaboration about communicating through digital tools and working with other organizational members and external networks; safety capabilities aim to protect devices, personal data, privacy, health, and well-being [21].

The American Library Association (ALA) defines digital literacy as the ability to use information and communication technology, find the information needed, evaluate the suitability of the information obtained, and use the information needed effectively and appropriately [22]. Digital literacy is a skill set that is broader and more complex than the simple use of digital technology, the most important of which is the need to contextualize the internet and other ways of presenting information in unrelated formats [23]. It can be concluded from the description above that digital literacy is a skill that includes the ability to use technology, information and communication tools,

social skills, learning abilities, and critical, creative, and inspirational thinking as digital competencies.

Digital literacy in a global context can be said to be the ability to assess the reliability and usefulness of information from various sources, carry out tasks by collecting information, and refer to various competencies related to skills in using computers and information technology [24]. Digital literacy in society aims to train people to use technology and communication, use digital technology and communication tools or networks to find, evaluate, use, manage, and create information intelligently and creatively [25]. As the digital age develops, good digital literacy is becoming increasingly important in today's society, from managing digital in a home context to operating a business [26]. The goals of the digital literacy movement include: increasing the active involvement of the community, institutions, or agencies in providing digital literacy reading materials, increasing the use of digital media and internet networks in providing information and public services, increasing the ease of access and internet users (literacy) in an area.

2.1.2. Technology Acceptance Model (TAM)

Technology Acceptance Model (TAM) is a theory expressed by Venkatesh and Davis (2000), which is an appropriate concept for explaining user behavior toward new information technology systems. TAM is a type of theory that uses a behavioral theory approach widely used to study the process of adopting information technology [27]. The TAM model has developed into an essential tool for understanding human behavior indicators for possibly adopting or rejecting technology [28].

The Technology Acceptance Model (TAM) utilizes five factors influencing and predicting how technology users will accept and behave when utilizing information technology. The five constructs are 1) perceived benefits, a person's perception of the benefits of technology determines whether they think the technology will help the company perform better; 2) perceived comfort, a person's comfort at the point where they think using a particular system is easy or up to the point where using technology will free them from several efforts is known as perceived comfort; 3) social pressure, perceived social pressure is the idea that having specific skills in an organization will increase one's social status; 4) attitude of use, attitude of use refers to a person's perception of how use technology in their profession, whether they accept or reject it; and 5) the intention to use, the behavioral tendency to stick with a technology is called the intention to use [29].

The criteria of usability and user-friendliness of the end user are considered while implementing the TAM model so that the usefulness of this model and the perceived ease of use impact consumer behavior about any service [30]. Technology Acceptance Model (TAM) can help MSMEs understand the factors that influence the acceptance and use of technology. As MSMEs, technology adoption can help improve efficiency, productivity, and competitive advantage. The TAM model can help SMEs to evaluate whether the technology under consideration has sufficient usability value and ease of use to be accepted and used by employees and customers. By understanding the perceptions of usability and ease of use, MSMEs can take action to improve and enhance the features and functions of the technology offered.

2.1.3. Empowerment Theory

Community empowerment is obtaining the necessary resources and understanding one's social environment [31]. People gain skills through this process,

which help them become independent problem solvers and decision makers that require participation in organizations or communities at the individual level, shared leadership and decision-making at the organizational level, and government, media, and other accessible public resources [32].

Community empowerment is a new concept and theory in the economic development approach that encapsulates social values that reflect a community-centered development paradigm, participation, empowerment, and sustainability [33]. Community empowerment is an effort to develop community potential and power by encouraging, motivating, and increasing awareness [34]. Community-based development is associated with creativity and initiative, the most critical development resources. The comperation of emprowering and empowered as describe at Table 1.

Table 1. Analysis of the Comparison of Empowering Outcomes and Empowering Processes at Different Levels

Level of Analysis	Process (Emprowering)	Outcome (Empowered)
Individual	Learning decision-making skill Managing resources Working with other	Sense of control Critical awareness Participatory behaviors
Organizational	Opportunities to participate in decision-making Shared responsibilities Shared leadership	Effectively compete for resources Networking with other organizations Policy influence
Community	Access to resource Open government structure Tolerance for diversity	Organizational coalitions Pluralistic leadership Residents' participatory skills

Source: [31].

2.1.4. Financial management

Financial management is a science that studies the financial management of a company in terms of finding sources of financing, allocating funds, and distributing company profits [35]. According to Armereo, financial management is an activity related to financial management, starting from obtaining sources of funds, using funds most efficiently, to allocating funds to investment sources to achieve company goals [36]. The phrase strategic financial management refers to financial practices with long-term objectives consistent with the strategic objectives of an enterprise to maximize the financial wealth of business owners by managing not only the flow of funds throughout the organization but also by aligning them with corporate goals and objectives [37]. The purpose of financial management is so that companies can manage resources, especially those related to finance, to generate maximum profits and ultimately maximize the welfare of business owners. Four basic frameworks in financial management are planning, record keeping, reporting, and controlling [38].

2.1.5. Micro, Small and Medium Enterprises

Micro, Small, and Medium Enterprises are independent, productive business units controlled by individuals or entrepreneurs in any economic sector (Raharja & Natari, 2021). MSEs are one of the private businesses recognized as having a significant impact on job creation and a more equitable income distribution, as well as the promotion of competition, increased productivity, and innovation [39]. MSMEs also have several advantages over large companies, namely innovation in product development, the ability to employ many employees, flexibility, and the ability to adapt to rapid market changes compared to large companies (Suyadi et al., 2018).

According to Indonesian Law No. 20 of 2008 concerning Micro, Small, and Medium Enterprises are:

a. Micro business is a form of business that operates independently and is run by people or organizations that are not included in the category of large or medium-sized business subsidiaries or branches but are owned, controlled, or integrated directly or indirectly into it [40]. Micro businesses have assets of IDR 50,000,000 to IDR 300,000,000 (not including land and buildings) in annual sales.

b. Small business is an independent, productive economic business, which is carried out by individuals or business entities that are not subsidiaries or affiliated companies that are owned, controlled, or become part either directly or indirectly of medium or large businesses that meet the criteria for small businesses [41]. Small businesses have assets of IDR 300,000,000 to IDR 2,500,000,000 (excluding land and buildings) in annual sales.

c. Medium Enterprises are businesses that operate independently and are run by people or organizations that are not subsidiaries or branches of large or small businesses owned, controlled, or integrated directly or indirectly into it [42]. Medium-sized businesses have assets of IDR 2,500,000,000 to IDR 50,000,000,000 (excluding land and buildings) in annual sales.

3. METHOD

The method used in this research is interpretive qualitative. Research using interpretive qualitative tries to explain different points of view regarding certain social or cultural events and the experiences of the objects studied [43]. According to Klein and Myers, interpretive research also assumes that social constructs such as language, consciousness, shared meaning, records, instruments, and other artifacts produce knowledge about reality and various meanings for different people. Nurdin and Pettalongi argue that social construction in online social media tools can also generate interpretations of digital material created and consumed by social media users and help understand social media usage better [44]. This suggests that interpretive techniques are appropriate for online or social media-based research to gain a deeper understanding of the subject under investigation.

The purpose of qualitative research is to understand the problems that occur in the community because researchers want to provide an overview of the activities carried out and how they impact their lives [45]. The purpose of this study is to understand how MSMEs adopt digital literacy, in this case, the e-peken application. The object of this study is an MSME engaged in the textile and fashion industry, especially batik, in Surabaya. Jarak Arum MSMEs was chosen because it has been established for nine years by owners with a solid determination to develop their business.

This study used the snowball sampling technique of eight informants, including MSME owners, MSME assistants, MSME employees, and tailor partners from Jarak Arum MSMEs, to obtain data and information related to the relevance and role of informants related to research topics and problems.

Table 2. Survey Respondent Information

N	Name	Age	Education	Marital Status	Position or Role
1	Mrs. FA	44 years old	Senior High School	Married	Owners, business actors, and financial managers at Jarak Arum MSMEs.

2	Ms. FP	23 years old	Senior High School	Not married yet	Jarak Arum MSME's assistant, especially in the IT section.
3	Mrs. UN	52 years old	Senior High School	Married	Employees of the department draw batik patterns.
4	Mrs. F	41 years old	Senior High School	Married	Employees draw and color batik.
5	Mrs. IT	54 years old	Senior High School	Married	Tailor partners for processed batik fabrics.
6	Mrs. N	60 years old	Junior high school	Married	Tailor partners for processed batik fabrics.
7	Mr. BIM	31 years old	Bachelor's Degree	Married	Head of Putat Jaya Subdistrict, MSME Assistant
8	Mrs. MJK	54 years old	Senior High School	Married	Customers from Jarak Arum MSMEs

Source: Author's Field Survey

The data collection technique in this study was carried out using field studies through direct observation three times, interviews for two consecutive days with a total time of 2.5 hours, as well as documentation in the form of the batik process carried out at the Jarak Arum MSMEs, the products of Jarak Arum, the financial records of UMKM, photos of the activeness of Jarak Arum owners in several training activities.

Testing the data's validity is a credibility test, transferability test, dependability test, and confirmability test. The credibility test in qualitative research assesses researchers' trust in the data studied. If what the researcher says and what happened to the thing being studied are similar, the data can be considered credible [46]. Testing the credibility of the data in this study uses triangulation to compare data from various sources, methods, and time. Source triangulation is done by checking the data obtained through various sources, namely MSME assistants, MSME employees, and tailor partners with Jarak Arum. Technical triangulation is carried out by checking the same. However, with a different technique, namely, data related to increased sales in 2020 obtained through in-depth interviews with MSME owners, information is rechecked through evidence of increased sales. Time triangulation is the process of re-verifying data from the same source at different times, especially using previous informants who have conducted in-depth or repeated interviews in various settings. The researcher may repeat the test until data certainty is achieved if the results still provide conflicting information.

The transferability test in qualitative research depends on the number of readers and the extent to which the results can be used in different contexts. The research results can be very transferable if the reader understands the context and focus of the research, such as an explanation of how MSMEs adopt e-peken applications to increase sales. The dependability test is carried out by reviewing the research process series mechanism. The researcher must show that several research procedures have been followed to ensure reliable research findings. A confirmability test is a technique used by researchers to communicate their conclusions about the methodology and the main focus of the research, providing an opportunity for other parties to assess/review the research to obtain agreement.

4. RESULTS AND DISCUSSION

4.1. Personality Factors of MSMEs Owners

Personality is an essential factor for micro and small business owners, mainly because they see and respond to environmental changes and determine behavior patterns that can significantly impact internal business strategy and processes [47].

The personality factors of MSME owners can influence the management and development of the business they are undertaking. MSME owners who are persistent and dare to take risks tend to be more innovative and willing to try new things in their business. Business actors may better handle uncertainty and take advantage of opportunities leading to business growth.

Before closing the dolly localization, the MSME owner (FA) worked as a clothes tailor for ladies night workers.

> "Previously, the income earned came from selling clothes for night workers, but since the closing of Dolly in 2014, I had to rack my brains on how to continue my life. In the end, I took part in training starting from training in mat embroidery and food, but I was more inclined to sew, leading me to make batik" (FA).

The opportunity for batik training provided by the government was put to good use by Mrs. FA so that it lasted for nine years and became one of the proofs that the owner of Jarak Arum MSMEs was able to get back up even though it was a challenge how to make a living, take lessons from the events that happened, and keep trying to achieve the goals they want. Maintaining the long-term viability of MSME companies requires resilience and tenacity.

Continuing an MSME business does not only require tenacity and persistence but also requires creativity and innovation. MSME owners with creative personalities can generate new ideas, develop products, and develop attractive marketing strategies. Creativity and innovation can help MSMEs differentiate themselves from the competition and attract customers' attention. Creativity and innovation are owned by the owner of the Jarak Arum SMEs in the area, which is proven by the fact that during the pandemic, there were leftovers of batik cloth which were processed into cloth masks and sold via Whatsapp. Many interested people bought them, so during the pandemic, when many businesses eventually went out of business, the Jarak Arum SMEs continued to produce and generate turnover.

4.2. The Financial Management of Jarak Arum MSMEs

For MSMEs, sound financial management is critical because poor management affects bookkeeping and makes income and expenses unclear. Effective financial management will help check the source of income and expenses of the business. Initial capital in starting a business is also a sustainable factor for the sustainability of a business.

Jarak Arum SMEs obtained initial capital from selling batik products while participating in the training because when participating in the training, all the tools and materials were provided by the government. When it became batik cloth, it was sold and generated money used to buy tools and materials independently. Jarak Arum SMEs has just borrowed from a bank or any party when choosing to open a batik business.

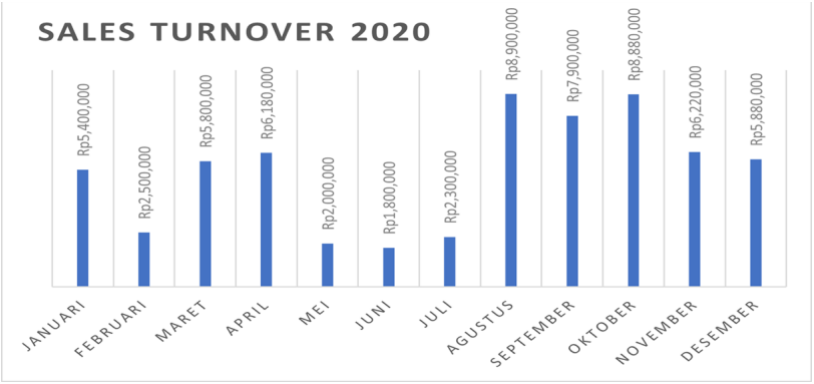
> "In the past, during the training, ten people were given cloth one at a time, then when the batik was sold, the proceeds from the sale were made to repurchase materials, and then they played it. However, after that, there was also financial assistance from the social services, which made me buy materials, mannequins, and materials for the exhibition so that at the time of the exhibition, I had everything, no need to borrow anymore" (FA).

The financial records owned by the Jarak Arum SMEs are in a book that contains description, debit, and credit columns. The description column contains information on items selling well, purchasing materials and fees, and turnover expenses.

As the owner of an MSME as well as the financial manager of the MSME, Mrs. FA manages business results by prioritizing her family and personal needs because

this business is her livelihood, after which it is used to purchase stocks of batik materials such as cloth, wax, dyes, and so on. One of the weaknesses of MSEM is the need for more financial planning in the production process. Even Mrs. FA admits that she tends to forget to record expenses if the number of orders is small, but turnover can still be remembered. Responding to this is very unfortunate because financial records are vital in running a business so that one can transparently see the financial flows of MSMEs, determine what steps to take, and carry out financial evaluations. Regarding the financial records of the UMKM, Jarak Arum still uses traditional methods. However, the strategy for running its business still exists and even generates a sizeable turnover, as evidenced by the turnover recap in 2020 (Picture 1).

Picture 1. Sales Turnover in 2020



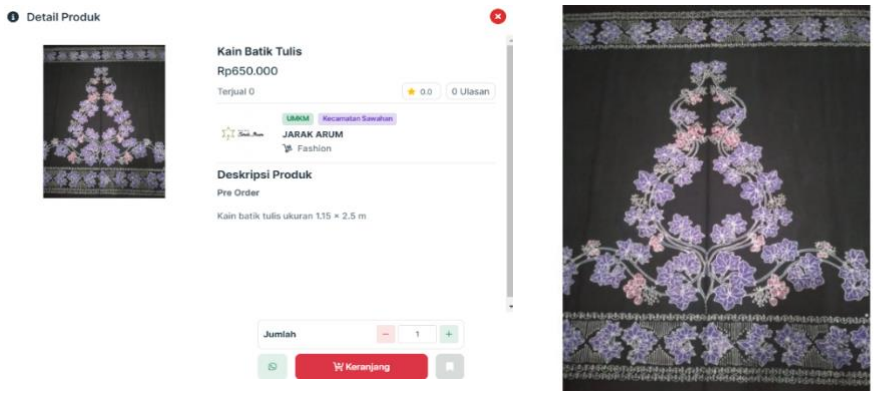
Source: Author's data processing based on the financial records of the Jarak Arum SMEs

4.3. Factors for the Success of Using E-Peken in the Jarak Arum MSMEs

Factors that can influence success in adopting e-peken at Jarak Arum MSME as a sales medium include: The right marketing strategy by identifying the intended target market and making effective marketing by determining the right selling price. The marketing strategy used in Jarak Arum SMEs is to make sales at prices that can still be reached without reducing the quality. When batik artisans sell written batik cloth with a price range already in the millions, Jarak Arum sticks to its strategy, but its sales are still sustainable.

> "In Jarak Arum, the marketing strategy is to make sales at prices that are still affordable. For example, the written batik that sells starts at Rp. 250,000. When batik artisans sell written batik cloth with a price range already in the millions because the manufacturing process takes a long time and is meticulous in cutting, stick to the price I have set. (Picture 2). The important thing is that the orders continue, even though the materials used are the same" (FA).

Picture 2. Product Information Details



Source: Jarak Arum Store in e-peken website (peken.surabaya.go.id)

Furthermore, have a good experience with customers by providing complete information regarding the products being sold, such as details on sizes, colors, and materials used, even adding clear product photos. Furthermore, to have a good experience with customers by offering secure and flexible payment methods. All payments are made in collaboration with Bank Jatim so that the receipt goes directly to the seller's account. The customer, when ordering, is immediately asked to pay off even though the item has yet to be made and confirms the order via WhatsApp. However, if there are many orders, Mrs. FA confirms by coming to the buyer's place and asking for a down payment of a few percent of the total payment, and then the payment will be given after the goods are finished.

Supporting infrastructure and technology such as mobile devices and software is needed to run e-peken to help MSMEs maintain stability, speed, and reliability in operating e-peken. According to the results of research observations, the owner of Jarak Arum SMEs, in operating the e-peken uses a smartphone with adequate technology and good enough software so that it is very feasible to use in running a business online. Also having healthy competition by offering quality products to build a good reputation and establish good relationships with customers, and as a seller, must select quality raw materials, carry out strict quality control, and provide products according to customer orders.

4.4. Benefits and Challenges of Implementing E-Peken for Jarak Arum MSMEs

E-peken is an innovation that refers to the process of buying and selling products or services online through a digital platform so that it can further advance the Indonesian economy through the MSME sector, which the Surabaya city government manages. However, the novelty of this innovation produces several benefits.

Through e-peken, sellers can achieve more comprehensive market access without being limited by geographical boundaries. With the existence of an e-peken platform, products or services can be accessed by consumers in various regions, cities, and even countries that are far from the seller's physical location. This opens up new opportunities to reach a broader market. The statement from one of the employees at Jarak Arum also strengthens the argument that e-peken is expanding

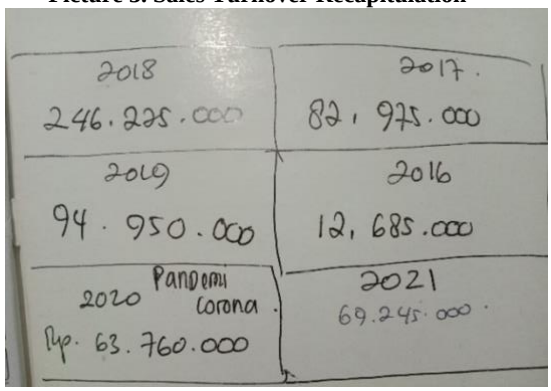
market share, and in terms of payments, it is also more efficient, namely by bank transfer.

> "I feel that sales have increased quite a bit because sales are also done online so anyone can see. The market share has also become wider. In terms of payment, it is also made easy by bank transfers, especially nowadays, almost everyone seems to have an ATM with m-banking, so it is easy to pay for orders. Having e-peken helps us. We are also happy that there will be orders in large and small quantities every month. The important thing is to have income" (F).

The e-peken allows Jarak Arum SMEs to promote its products more effectively. Through the e-peken platform, Jarak Arum can present product photos, descriptions, and other information to potential customers. Jarak Arum SMEs can also use social media and other digital marketing tools to reach a broader range of customers and build a strong brand image. The product marketing target of Jarak Arum is employees in the Surabaya city government and is currently developing in several hotels in Surabaya.

Furthermore, with e-peken, Jarak Arum SMEs can experience an increase in the number of orders received. With an easily accessible e-peken platform, customers can quickly find and buy batik products, as seen from the total turnover in 2021 reaching IDR 69,245,000, meaning that there will be a significant increase in 2021 with the existence of e-peken. MSMEs can also collect and analyze sales data in detail so that by analyzing the data, Jarak Arum SMEs can identify new sales opportunities, optimize marketing strategies, and develop products that suit consumer needs. Implementing e-peken can help Jarak Arum to reduce operational costs. Because there is no need to pay for renting a physical store or related operational costs, the Jarak Arum can allocate its resources more efficiently. In this case, Jarak Arum SMEs produces in his private house. Using e-peken platforms can also reduce traditional promotional costs such as print advertisements, radio advertisements, or exhibitions.

Picture 3. Sales Turnover Recapitulation



Source: Author's Observastion - Notebook of Jarak Arum MSME

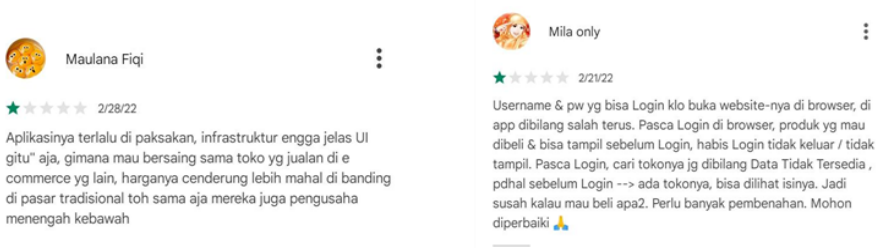
Not only do they benefit from the existence of e-peken, but Jarak Arum SMEs is also faced with specific challenges, including the need for knowledge and technological skills from the owner of Jarak Arum. Hence, they need the help of their daughter as a companion for MSMEs in operating e-peken.

> "I do not understand how to run e-peken, but I am assisted in studying with my child. Sometimes I have learned, but I forget how to do it again. I understand I am a bit stuttered in technology" (FA).

4.5. E-Peken Application Findings

As an application that is still new among the public, much still needs to be improved regarding the e-peken system. In Picture 4, the review section on the Play Store, netizens leave comments regarding the e-peken application, which needs to be upgraded again due to the lack of guidance on using e-peken and its features. The findings from the e-peken application are that users or buyers can only access the website because the Playstore account is available only for sellers. However, new sellers who want to join must have a registered guide. Sometimes the e-peken application also often experiences errors in the form of no incoming notifications, so the seller does not know if there is an incoming order.

Picture 4. Complaints and Protests related to E-Peken Application



Source: User Reviews in Comments Section from Play Store

Some steps that can be taken so that the findings of weaknesses in the e-peken application can be resolved is to develop a guide for e-peken users that is concise, in-depth, and easy to understand so that users can understand the features contained therein and the uses of these features. Then, provide training for new e-peken users, fully explaining application functionality, practices, and other information. Furthermore, it can update and develop applications based on user feedback by receiving input from e-peken users so that deficiencies can be handled quickly and the e-peken application can be more optimal.

5. CONCLUSION

This study aims to analyze how the application of the e-peken application to MSMEs in increasing sales. The method used in this research is interpretive qualitative. The object of this research is Jarak Arum MSME which operates in the textile and fashion industry, specifically batik. The data collection techniques used were direct observation, interviews, and collecting documentation in the form of the batik making process and product results, financial records of Jarak Arum MSMEs, photos of the activity of MSME owners in several training activities.

The conclusion based on the results of the research and discussion, the personality factor is one of the factors for the sustainability of the business owned by the owner of Jarak Arum MSME, namely perseverance and high enthusiasm in running a business by continuing to be creative and innovating to produce new products. Regarding financial management, Jarak Arum MSME has financial management that is quite good by continuing to purchase stocks of batik materials and tools after being allocated for family needs, but recording income and financial expenditure must be routinely carried out to make it easier to prepare financial reports.

Factors that influence the success of using e-peken in the Jarak Arum MSME are marketing strategies in terms of prices that are cheaper than other competitors

but still provide good quality, have a good impression and experience for customers, have supporting technology in the form of smartphones that are adequate in operating e-peken. Apart from this, Jarak Arum MSME achieves more comprehensive market access, more effective promotions, increased sales results due to the large number of orders received, and reduced operational costs for renting business premises. The challenge of implementing e-peken for Jarak Arum MSME is the need for knowledge and technological skills from the owners of the Jarak Arum MSME. The e-peken application still has weaknesses, so it needs to be improved and updated by providing further guidance in registering an account as a new seller who wants to join e-peken.

The practical advantage lies in its ability to offer input and information pertaining to the utilization of the e-peken application, with the aim of enhancing sales performance and fostering public interest in the purchase of products affiliated with Micro, Small, and Medium Enterprises (MSMEs) in Surabaya. In the context of this discussion, the theoretical value pertains to the advancement of business theory, specifically in its application to the formulation and examination of theories related to the adoption and utilization of e-commerce technologies by micro, small, and medium enterprises (MSMEs). Moreover, the results of this research were employed as a case study in the realms of management, business, and technological education and training.

The limitation of this research is that the author could not obtain an in-depth interview with one of the informants due to time constraints. Further research warrant encompasses the augmentation of data sources, the execution of a more extensive comparative examination that juxtaposes the utilization of indigenous electronic commerce (e-commerce) in Surabaya against other urban centers to attain a more comprehensive outlook, and the scrutiny of the societal, economic, and environmental repercussions of micro, small, and medium enterprises (MSMEs) in Surabaya that engage in local e-commerce to enhance comprehension of the advantages and hazards involved.

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Cost-volume-profit analysis: practical aspects in e-commerce

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Abstract. As a result of the COVID-19 pandemic, e-commerce has experienced a significant increase. For Russian companies it's quite hard to compete with international organizations, mainly due to companies' size and constant investments. The article addresses the issues that e-commerce companies face in terms of business models, costs, pricing and reaching a break-even point. We have studied the financial metrics of Ozon (leader company in Russian e-commerce market and have predicted net income for Ozon in 2023-2028. We outlined the limitations of break-even analysis in real-world scenarios for digital platforms.

Keywords: cost volume profit analysis, breakeven point, digital platform, decision making.

1. INTRODUCTION

Management accounting has a whole arsenal of techniques and methods that allow company, its director, and managers to process and summarize the initial information [1]. The cost-volume-profit analysis is a powerful analytical tool for planning and decision-making that is used by managerial accountants to help managers make better decision. A company uses CVP analysis to reach important benchmark like break-even point. The CVP analysis helps in budgeting by determining: the number of units that must be sold to break even; the impact of a given reduction in fixed costs on the break-even point; the impact of an increase in price on profit.

E-commerce development has come a long way from being a simple, one-sided ecommerce companies to appearing a massive ecosystem. The good example is Amazon. Today it has incorporated various units within its business model, including a one-sided platform, two-sided marketplace, web services, kindle marketplace, an app store, prime video, game studio, and even retail stores. Moreover, COVID-19 related restrictions accelerated e-commerce adoption by consumers. As a result of the COVID-19 pandemic, online platforms such as Ozon experienced a significant increase in the number of new active buyers, higher demand for products on their platforms and an inflow of third-party merchants.

The aim of the work is to provide particularities of CVP analysis in e-commerce.

2. LITERATURE REVIEW

The point of opening and running any business is to make a profit. Entrepreneurs and companies need to assess the prospects of the industry before starting a business, investing in a startup, as well as when developing and introducing new products or services to the market. Knowing a profitability of different types of products, a company can competently redistribute its resources to more promising areas and remove unprofitable positions.

In literature it has been developed a theoretical understanding of the reasons why a company should calculate the BEP. There are several reasons which can be formulated as these:

- determination of the profitability of a new product, considering what equipment and technologies are used by a company, how much products can be produced and sold. This metric calls for riskiness (including force majeure events) and the prospects of the chosen direction [2]. The calculation of the break-even point is one of the key indicators in any feasibility study of a business project [3];
- planning sales volumes that cover all the company's expenses and allow a company to earn a given amount of profit [4;5];
- formation of an effective pricing policy. Even though prices in highly competitive industries are formed by the market, a company need to understand whether the average market value of the product covers the costs of it. Knowledge of the critical point of the product makes it possible to form optimal price lists for different categories of customers (retail, wholesale, dealer price, etc.), as well as promotional conditions. The calculation of the break-even point shows how much a company should produce when the price decreases or how a growth in productivity can affect profitability [6;7];
- nomenclature optimization. Calculating the profitability of each product in nominal and monetary terms, a company can choose the optimal structure of the assortment with a focus on the demand and capabilities of the company. The calculation of zero profitability for each individual product allows to identify products that are unprofitable as well as the most profitable positions. It is necessary to try to minimize low-profit products in the product line [8].

The general formulas for BEP are presented in formula 1 and 2.

$$Break\ even\ point\ (in\ units) = \frac{Fixed\ costs}{Selling\ price\ per\ unit - Variable\ costs\ per\ unit} \quad (1)$$

$$Break\ even\ point\ (in\ monetary\ form) = Break\ even\ point\ (in\ units) * Selling\ price\ per\ unit \quad (2)$$

3. DATA AND METHODOLOGY

In this research we will use a case study method to "contribute to our knowledge of organizational phenomena" [9].

The e-commerce market in Russia consists of four categories of business with different characteristics and business models. The first category includes multi-profile businesses that operate only online. This group could include Ozon, Wildberries and Beru. The second category is the narrowly focused online-only business (Lamoda, Citilink, Apteka.ru). The third category includes multi-channel businesses using not only online but also physical shops. These include MVideo, Eldorado, DNS, Detsky Mir and IKEA. The fourth category includes cross-border businesses that deliver to Russia.

OZON.RU is an e-commerce platform in Russia (5th in the top of the most expensive Russian Internet companies according to Forbes.) OZON was one of the first companies to start developing the e-commerce sector in the Russian market, representing the direction of industries' digitalization [10;11]. Originally started as an online bookstore, OZON has now evolved into an innovative platform or ecosystem that is driving the e-commerce market.

In early 2019, the company was the first in Russia to launch consumer credits for multi-category purchases, as well as a bank card with a cashback for customers, and launched a deferred programme for multi-category purchases, became the largest network of its own parcel machines in Russia, launched express delivery of goods in Moscow and a referral programme for customers. The fee for using the site depends on the scheme chosen for working with the warehouse.

The company's main product is an online e-commerce website with delivery capabilities. The company works with suppliers (B2B) and sells to customers (C2C). The revenue stream received by the company is made up of two parts: the independent sale of goods through its store and the commission from the sales of partners who place their goods on the marketplace. In table 1 we present the business model of Ozon. It uses a platform business model with multiple business units and distribution models.

Table 1. Business model of Ozon

Key partners	**The main activity**	**Value proposition**	**Customer relations and channels**	**Customer segment**
Sellers Logistic companies; Individual entrepreneurs; Owners of pickup points; Banks;	It is an online e-commerce platform with the possibility of delivery. Working with suppliers (B2B) Selling to customers (B2C)	*To sellers:* Ozon takes care of all issues in logistics and marketing, reducing costs for small businesses *To buyers:* - Fast delivery to pick-up points within walking distance from home - Delivery in 1 hour (Ozon Express)	Mobile application Website Social media pages Technical support Contextual advertising on the Internet	*Sellers:* Russian small, medium and large businesses; International companies *Buyers:* Russians, for personal use

Gross merchandise value (GMV) is the total value of goods sold on the marketplace, excluding returns, exchanges, and discounts. Leaders of the rating in Russia: Wildberries has almost doubled the sales, to 805.7 billion rubles, the Ozon this figure has increased 2.3 times - 446.7 billion rubles. Sales Citilink, which was the third leader, in 2021 grew by a quarter - to 163.4 billion rubles.

Table 2. The biggest e-commerce companies in Russia

№	**Company**	**GMV, mln, rub**	**Increase %**	**Orders, thousands**	**Increase %**	**Average order, rub**	**Increase %**
1	Wildberries.ru	805700	95	771900	153	1040	-23
2	Ozon.ru	446700	126	221200	199	2020	-24
3	Dns-shop.ru	185300	41	16200	14	11400	24
4	Citilink.ru	163400	24	13200	7	12400	16
5	Mvideo.ru	132600	15	13000	20	10200	-4
6	Market.yandex.ru	122200	180	29700	151	4110	12
7	Aliexpress.ru Russia	106100	116	48000	152	2210	-14
8	Lamoda.ru	71200	34	14100	15	5050	17
9	Petrovich.ru	62200	41	3990	4	15600	36
10	Vseinstrumenti.ru	61900	52	9700	40	6380	9

Source: April 2022 data from Data Insight

The dynamic of some financial indicators of Ozon we present in table 3. The company has achieved significant scale (revenue and number of active buyers) and continues to grow the business rapidly, while focusing on achieving future profitability.

Ozon is an online retailer and web service provider. The company provides products such as apparel, auto and industrial items, beauty and health products, electronics, grocery, books, games, jewellery, kids and baby products, movies, music, sports goods, toys, tools and other related products. It also provides related support services, including home delivery and shipping, cloud web hosting and other web related services. The company merchandises these products through company-owned online and physical platforms. These platforms are also used by various third parties for selling their goods.

Table 3. Financial indicators of Ozon

Year	2022	2021	2020	2019
Loss for the period, bln RUB	(58,187)	(56,8)	(22,3)	(19,4)
Number of active buyers, million	35,2	25,6	13,8	7,9
Adjusted EBITDA, bln RUB	(3,215)	(41,2)	(11,7)	(15,8)
Total revenue, bln RUB	277,1	178,2	104,4	60,1

Ozon reached cash flow from operations break-even point in 2020 and reached operational break-even point. This company is a great example of size effect and log-term effect of capital investment directed to cover fixed costs and increase contribution margin per unit by developing new technologies, expanding network of delivery points and assortment on the market. Ozon introduced variety of most modern trends on the retail/marketplace markets which made him one of three greatest marketplaces in Russia. However, Ozon is still unprofitable by net income.

The Ozon Company's accounting policy is based on the principles of fair value, materiality, and consistency. Fair value is used to measure the value of assets and liabilities, while materiality and consistency are used to ensure that all accounting decisions are made in the best interests of the company and its shareholders. The company also adheres to the Generally Accepted Accounting Principles (GAAP), International Financial Reporting Standards (IFRS) and Russian Accounting Standards (RAS). In addition, Ozon Company has adopted the Financial Accounting Standards Board's (FASB) Accounting Standards Codification (ASC) as its primary source of authoritative guidance. This policy also requires the company to assess the impact of new accounting pronouncements on the company's financial statements.

Concerning the sales scheme of Ozon company, sales can be conducted in three different ways. They are closely connected with the models of logistics.

The first model is FBO or fulfillment by operator (in our case it is Ozon). The seller transfers and keeps its products in one of Ozon warehouses, then the company acts in the role of the intermediary and sends the products to other cities or transfers goods directly to clients.

The other model is FBS or fulfillment by the seller. In this case the seller of products again uses Ozon like the intermediary to connect with the clients and send them the products, however it is a more "independent" way of providing sales comparing with FBO. It means that the seller stores its products in an owned or rented warehouse. The seller collects, packs, and marks all the goods according to Ozon requirements by himself. Then, he just transfers products to the sorting center or to the points of issue.

The sale of goods and services of Ozon works according to the FBS (Fulfillment by Seller) scheme in which the seller is responsible for the storage and delivery of the products (Fig. 1).

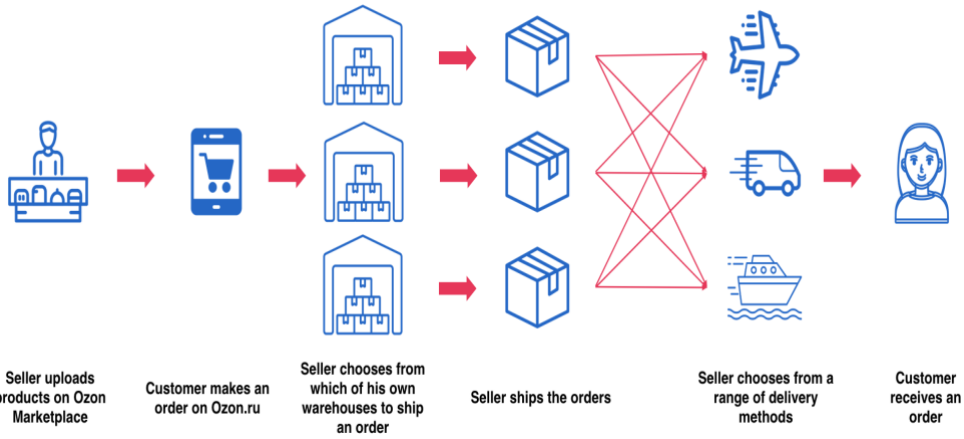

Fig.1. Model "Fulfillment by Seller"

The last one to be mentioned is FBS+ model. The seller works independently and provides direct sales to the clients. Ozon does not have a part in this kind of operation, it only places goods on its website. The seller stores, packs and delivers its products by himself. This model serves good to big stores with their own delivery structure by saving money on Ozon delivery fees.

Within all 3 models, the payment scheme is as follows: the buyer pays for the goods on Ozon - Ozon retains the commission and other payments - transfers the remaining amount to the seller. There is always a commission for the goods, but other payments depend on the model and may include fees for storage, delivery, etc. Ozon pays sellers 2 times a month, but recently, the daily payments function appeared.

Another scheme presents the franchising. Individual entrepreneur opens Ozon's order pick-up point as a franchise. Ozon earns money as a fraction from the total value of orders going through a particular pick-up point.

Fig. 2. Model "Franchising"

Each seller sets their own pricing strategy on the Ozone website.

For marketplaces you can specify the coefficient by which the price is multiplied. You can change the price both upwards and downwards. For example, with a price of 900 rubles on the market and a multiplier of 1.1 the product will be priced at 900 x 1.1 = 990 rubles.

In myAlpari the system will automatically create a «Follow-the-market-price strategy», which includes online shops with multiplier 1. All products with auto-application of prices enabled in advance will be automatically added to this strategy.

If the pricing strategy and auto-application of promotions are enabled at the same time, the product price is affected first by the strategy, then by the promotions.

Ozon operates on the marketplace model, where each seller can place their goods on the site for a fixed percentage - a commission.

The commission is calculated on the seller's set price, including VAT, plus any discounts or promotions specified by the seller. There is no need to pay for the commission and other expenses separately - all expenses for the calculation period are considered when calculating the payment amount.

If there is no category for an item or the category has been temporarily removed for technical reasons, our commission for sale will be 9%.

The commission depends on the category and in some cases on the subcategory. If you want to determine which category your product belongs to, you can check it or compare it with an existing product.

4. RESULTS

The overall implementation of the CVP analysis can be conducted by several steps that simplified can be called as the following:

- to determine the fixed costs required for the operation of the company;
- to calculate variable costs;
- to determine the amount of revenue;
- to calculate BEP.

Cost classification of Ozon:

1) Advertising & promotion costs (online marketing, offline media, personnel costs, which are also included in the "marketing and sales").

2) Logistics costs (storage and transportation of goods)

3) Technology costs (automation of internal processes, improvement of the payment system through Ozon card, launch of new high-tech products).

So, cost structure of Ozon is rather simple: there are fixed costs depending on the total number of open points of distribution, salaries and rents, and there are also some variable costs which depend on GMV of Ozon.

To conclude, Ozon may experience significant fluctuations in results of operations and growth rate:

- Ozon has incurred significant losses in the past and is going to continue being unprofitable till it reaches its break-even point, which can only be reached through size effect as in the past in 2020 and 2022 he achieved cash flow from operations break-even and operating profit break-even.

- Ozon has significant risks connected with usual business risks such as risks of brand – which means that company name will suffer from some cases which cannot be fully controlled, risks of industry – means that company will lack speed and adaptability to new reality while its rivals continue to follow the trend.

Ozon have certain problems connected with its business model and cost structure. The most significant cost factor is the lack or couriers or work force and the price of labor, which means that Ozon can face huge problems in the future.

Theoretical aspects of the BEP that we have studied are understood, and it may be seemed like an easy thing to do because we don’t need a lot of specific data. However, some aspects of calculating and its difficulties for digital platform can be highlighted:

- the calculation formula is simple and clear if there is an understanding of all fixed and variable costs, but these indicators are not always constants. Namely, expenses tied to the volume of output - the amount of wages of employees who are involved in the manufacture of the product, the cost of raw materials and other costs associated with the production and sale of finished products. If raw materials or components rise in price, the total costs increase, the contribution margin of the goods

will decrease and, accordingly, the break-even point will change;

- in common calculation ideal conditions are taken - the volume of output is equal to the volume of revenue. But in fact, there is work in progress, may be failures in the production cycle, reducing the number of products. In addition, not all manufactured products can find their buyer;
- the most difficult this is a revenue calculation. In case of a digital platform, it will be calculated based on GMV. So, we think that GMV will be the main metric.

Based on the summary table of Ozon's key operating and financial metrics (Table 4), we have calculated the planned net income (Table 5).

Table 4. Summary table: key operating and financial metrics

Rub in millions, unless indicated other wise	**For the three months ended December, 31**			**For the year ended December, 31**		
	2022	**2021**	**% of change**	**2022**	**2021**	**% of change**
GMV	296,019	176,805	67	832,240	448,260	86
Number of orders	174,6	92,1	90	465,4	223,3	108
Annual order frequency	13,2	8,7	52	13,2	8,7	52
Total revenue	93,626	66,298	41	277,115	178,215	55
Adjusted EBITDA	3,933	(15,886)	-	(3,215)	(41,156)	(92%)
Loss for the period	(11,212)	(20,794)	(46%)	(58,187)	(56,779)	2%
Net cash generated from (used in) operating activities	8,534	15,266	(44%)	(18,753)	(13,626)	38%

We can say that the main feature of Ozon is working at a loss. The company is widely known in the marketplace market and occupies a leading position but often irrationally uses packaging materials and logistics. We can assume that Ozon needs to improve its expenses management because it had operating losses from 2021 to 2022. In table 5 we have presented the budget for net income for 2023-2028 using assumptions of CVP analysis.

Table 5. Net income budgeting for Ozon

Ozon, bln rub	**2021 2q**	**2022 2 q**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
GMV	89	170,6	236,1965	277,9206	301,4702	313,9831	320,4329	323,7074
Price	2,405405	2,916239	3,211002	3,369375	3,451467	3,49326	3,514345	3,524936
Revenue(price* GMV)	37	58,5	73,55851	82,48433	87,34554	89,88255	91,17855	91,83355
COGS (VC=VCU* GMV)	11,89	33,24	52,18979	63,37097	69,17441	72,12113	73,61367	74,36731
SG&A (FC)	22,764	16,269	17,37772	18,12237	18,17113	18,75242	19,56488	21,46624
EBITDA	-9,1	0,2	9,5	18,8	28,1	37,4	46,7	56
Net income	**-15,233**	**-7,202**	**-6,171**	**-5,171**	**-4,771**	**-2,171**	**-0,171**	**0,829**

From our calculations in Table 5 (based on the tendences of previous years), we can see that break-even point can be reached between 2027 and 2028. According to the long-term forecast, Ozon plans to show a positive operating profit in 2024.

It is very important to provide possible variants and solutions for continuing positive tendency of Ozon in becoming closer to its break-even point.

First, to continue horizontal expansion by attracting new customers and work force

to operate with greater GMV on the marketplace. Next possible growth catalysator is continue of providence of new technological solutions for clients, which must make their experience better as in long-term as in short-term. Moreover, loyalty programs must be competitive with Yandex.Plus because Yandex is going on unprofitability of Plus just to attract and retain clients.

At the same time, the key direction is work with businesses. B2B segment, letters of credit, analysis of sales and key metrics must be provided to such type of users too. Ozon has very strong competitors in B2B segment such as MTS, Wildberries.

5. CONCLUSION

To conclude, let's summarize the limitations of break-even analysis in real-world scenarios for digital platforms.

First, the most obvious and significant problem of break-even analysis for digital platform is that such analyses do not consider changes in sales volumes: the break-even point is calculated based on the current sales volume (GMV). However, when the sales volume changes, the break-even point will also change. Moreover, the "price" or commission that digital platform receives (depending on the type of the products). It forces an analyst to make dynamic models with different scenarios, where it will be possible to predict movement of the break-even level depending on the case in industry or in the economy, including all long-term effects and possible solutions of occurring problems.

Second, CVP analysis for digital platform does not consider factors affecting demand: competition, fashion changes, etc. Such structural and qualitative industry peculiarities are not included in break-even point analysis, however company's capex and M&A deals can be directed on break-even point improvement, such as decreasing of this level. So break-even point calculation cannot consider qualitative industry trends, but in predictions and forecasts of break-even point industry unique qualities can be included.

Third, CVP analysis for digital platform does not consider the impact of changes in exchange rates: if the company deals with foreign suppliers or buyers, changes in exchange rates may affect the break-even point. Such factors must be calculated in different non-classical break-even point ways of calculation, but in scenario-analysis they can be considered. These different factors considered as positive, neutral, and negative in scenario analysis and can be included in calculation if analyst is calculation some break-even point which depends on some variables, which can be changes through time.

In conclusion, it is worth saying that calculation of break-even point can be different. It can depend on scenario analyses based on micro- and macroeconomics, margin efficiency, operating efficiency, supply-chain improvements, and fluctuations of prices and other variables.

One of the main applications of break-even analysis is making decisions about changes in prices for goods or services in e-commerce. If a company plans to decrease the commission, it must make sure that it will allow it to reach the break-even point and make a profit. To do this, it is necessary to conduct a break-even analysis and determine what changes need to be made to prices to achieve the desired result taking into consideration GMV.

Break-even analysis can also help companies manage and optimize costs. It shows which costs need to be reduced or optimized to reach a lower break-even point. This helps companies improve their efficiency and reduce their costs. In addition, break-even analysis allows companies to take into account seasonal fluctuations and other factors that may affect demand and costs.

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How innovation influence organisational performance among SMEs in Ghana: The mediating role of organisational leadership

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Abstract. The purpose of the study is to investigate the relationship between organisational leadership, organisational performance and innovation among small and medium-sized businesses (SMEs) in Ghana. We hypothesize organisational leadership as a mediator between innovation and organisational performance. Thus, we investigated how innovation and organisational leadership directly influence organisational success. The study uses quantitative methodology and adopts a survey approach to collect data from SMEs (n=380) in Ghana. The results indicate that organisational leadership and performance are positively correlated. Further, we found that organisational leadership within SMEs affects the relationship between innovation and organisational performance. By identifying the positive effects of innovation and organisational leadership on organisational performance, this study encourages SMEs to invest in innovation and develop strong leadership capabilities.

Keywords: Innovation, organisational Performance, SME, Organisational Leadership, SMEs.

1. INTRODUCTION

Innovation has become the bedrock of organisations and has a tremendous influence on economic development [1]. To acquire a competitive advantage, innovation has become an essential component of corporate strategy that helps with market expansion, market share expansion, and customer perception improvement [2]. Innovation also gives the business a strategic viewpoint to overcome obstacles while pursuing a long-term competitive edge. Recently, a lot of businesses have invested a huge amount of money in research and development (R&D) [3]. Motivated by the intensifying global rivalry and the ongoing changes in the difficult market, many industries have begun to recognize the value of innovation and adapt their production processes and systems to strengthen and maintain their competitive advantage [4]. In this regard, an improved and strengthened innovation both in products and services is one potential strategy to increase competitiveness [5].

In this post-COVID era, coupled with a dynamic and complicated business environment, innovation research has been getting more attention as a necessity for business growth in developing countries [6]. Although research on innovation is not a new field, more research is being done as a result of the advent of new invention forms and shifting global conditions such as COVID-19. The worldwide lockdown caused by the coronavirus disease 2019 (COVID-19) pandemic led to the closure of several key enterprises, a global economic downturn, and a severe problem for

businesses [7]. Several business and business processes have undergone significant upheaval, and according to [8], innovation is a crucial tactic for firms to endure and recover from the crisis. Businesses must overcome these obstacles because so many industries have been negatively impacted and markets are unclear. The crisis is also creating waves of innovation initiatives [9].

Several studies [10; 11] have reiterated the importance of leadership in achieving organisational success in the post-COVID era. Leadership entails motivating all team members to work toward a shared goal to create potential and find answers to challenges from fresh ideas. Employee creativity is influenced by leadership and the environment of mutual support at work [10; 11]. Therefore, leadership is an internal predictor of organisational performance, with some leadership styles being more performance-boosting than others [12]. In Ghana, where hierarchy is respected and the chain of command is strictly followed, leadership orientation is a key component of organisational development. Our study therefore addresses this gap by examining the mediating role of leadership in the relationship between innovation and performance in this post-COVID era. Globally, SMEs are known as the driving force of economies, primarily developing and under-developed economies [13]. The SME sector in Ghana contributes a significant portion of the nation's GDP [14]. About 90 % of Ghana's employment is in this industry, making it the most significant employment level [14]. This indicates Ghana's economy is largely based on its SME sector. However, despite their significant economic contributions, it is suggested that SMEs lack the resources necessary to reach their full potential [15]. SMEs are more likely to fail at a higher rate than big businesses. Reports indicate that the SME failure rate has increased in the post-Covid era [17]. Very few post-covid, innovation and performance nexus research [8; 9] has been focused on large firms mostly in a developed country context, leaving a literature gap, when it comes to SMEs in developing countries like Ghana. Therefore, it is critical to investigate how organisational leadership's innovation orientation offers the strategic fit for innovation strategy to favourably influence SME performance in Ghana.

The study aims to examine the mediating role of organisational leadership in the relationship between innovation and organisational performance. The specific objectives include:

- Investigate the impact of innovation on the organisational performance of SMEs in Ghana.
- Explore the influence of organisational leadership on the organisational performance of SMEs in Ghana.
- Assess the moderating role of organisational leadership in the relationship between innovation and organisational performance in Ghana.

2. LITERATURE REVIEW

2.1. Small and Medium Enterprises (SMEs)

Small and medium firms dominate all economies on the planet. Even though SMEs make a commendable contribution to the global economy, there is no universally accepted definition of what qualifies as a micro and small business [18]. Businesses with fewer than 10 employees are categorized as small-scale enterprises by the Ghana Statistical Service (GSS), while those with more than 10 employees are classified as medium- and large-sized organisations. A small-scale enterprise employs no more than nine people. It has plant and machinery worth no more than ten million cedis (US$ 9506 at the time of the 1994 exchange rate or US$ 1419 at the time of the 2000 exchange rate), according to the National Board for Small Scale Industries in Ghana (NBSSI) [21]. Small-scale enterprises, however, are defined by [19] companies with less than 30 employees. In this regard, the GSS nor the NBSSI

distinguishes between micro-businesses and small businesses in their definitions; rather, they include them as a subset of small-scale organisations. However, [20] divided small businesses into three groups: micro-businesses employing fewer than six people; (ii) very small - businesses employing six to nine people; and (iii) small - businesses employing between 10 and 29 people, indicating that micro and small businesses have fewer than 30 employees. When compared to medium and large-scale businesses, SMEs stand out because they have fewer resources and managerial, marketing, and human capital capabilities. They also have fewer physical assets and financial resources. However, exhibiting the organisational leadership needed for the strategic organisation of their activities efficiently and effectively is difficult due to the heterogeneity of the resource and capability base of SMEs [16]. The fact that SMEs are typically informal is another characteristic of them. For instance, SMEs in Ghana may fall under the urban or rural enterprise category.

2.2. Innovation

Innovation is the creation and effective implementation of a technical, organisational, business-related, institutional, or social solution to a problem that is regarded as ground-breaking and novel, accepted by the target audience, and pursued by innovators in anticipation of success [22]. Based on literature insights, we classify innovation as the process of introducing novel goods and services to a target market and is grouped into five categories a) the development of a new source of supply for raw materials or other inputs, b) a change in industrial organisation, c) the introduction of a new product or a qualitative change in an existing one (product innovation), d)process innovation and e) the opening of a new market (market innovation)[23].

The primary driver of corporate growth and performance is product innovation, which is quantified as a component of new product development. Product innovation is the enhancement of original goods, modification of recognized goods' designs, or application of new materials in the production of recognized goods [24]. Thus, most businesses rely on product innovation to make money in the long run. From a business viewpoint, product innovation includes the creation of new products, enhancing the quality and technical specifications of an existing product, or developing new materials, components, or useful features. It includes improving products and services or creating new categories [25]. Product innovation is typically the result of three major tendencies: intense global competition, a difficult market, and differential and rapid technological change.

Process innovation encompasses improved tools, materials, equipment, and other technologies that have a direct impact on the businesses that are implementing innovations. Process innovations and product innovations—new or enhanced product technologies that a business offers to satisfy customers or its clients—are very different from one another [26]. Implementing a new or minimally improved manufacturing, production, or delivery system is known as process innovation. It makes it possible to produce a certain amount of goods and services using fewer inputs. The latter can be explained in terms of environmental efficiency. Process innovation can involve minor adjustments or more significant ones and can result in significant changes to tools, procedures, or software. Process innovations work to boost value and worth, decrease the unit cost of production or delivery, or create or provide new or improved products [27]. Process innovation has significant strategic potential and makes it possible to formulate something superior to that of rival companies. Companies can develop a very valuable competitive edge through process innovation [30].

Organisational innovation is the application of a unique organisational technique in the workplace, industrial organisation practices, or external relations [28].

Precisely, organisational innovation is an improvement or change in organisational practices and knowledge management in an organisation [29]. Businesses that participate in organisational innovation or creativity have a variety of goals in mind, including boosting the company's value, increasing profits, improving organisational performance, and lowering costs. Additionally, it aims to increase labour productivity, improve workplace satisfaction, gain access to non-tradable assets like uncodified information, and reduce the cost of goods. Other elements, such as those relating to the market, goods, quality, and the capacity to learn how to implement changes within the company, maybe the driving forces behind organisational innovation [29].

2.3. Organisational Performance

The performance of an organisation involves the productivity of a firm that is measured by planned productivity or goals. The ability of a company to achieve its aims and objectives with the aid of talented management, sound governance, and a consistent commitment to achieving business objectives has been defined as organisational performance [31]. Organisational performance is a measure of how successfully a company achieves its objectives. One of the key concepts in management research is organisational performance [31]. A very broad notion, "organisation performance" includes all aspects of management excellence, operational excellence, and competitive excellence of an organisation and its operations.

2.4. Innovation and Organisational Performance

The research on innovation and performance points to a favourable relationship between innovation and performance. Organisations with higher levels of innovation respond to the environment more effectively, find it simpler to enhance organisational performance capabilities, and solidify a long-term competitive advantage [32]. Organisational performance is directly impacted by innovation [33] and innovation gives businesses a chance to capture a larger market share. Adopting an innovative culture can create "isolation mechanisms" because competitors cannot access the knowledge created through innovation [34]. This feature enables the organisation to enhance performance, increase profits, and acquire and maintain a competitive advantage. Additionally, innovation significantly contributes to enhancing organisational performance. As a result, increased innovation enables a company to better adapt to its surroundings, enhance its skills, and keep a competitive edge [35].

2.5. Moderating Effect of Organisational Leadership

Good organisational leadership has been identified as one of the important factors that contribute to the success of SMEs [36]. Prior studies posit that the main reasons why SMEs fail are due to inadequate and subpar leadership abilities [37]. Due to this, SMEs must strengthen their leadership behaviours to lead their businesses through all circumstances, even times of crisis. Proper leadership behaviour is a crucial component in preventing organisational failure and having high organisational performance [36]. Organisational success is therefore internally predicted by leadership, with some leadership philosophies more conducive to performance than others [12].

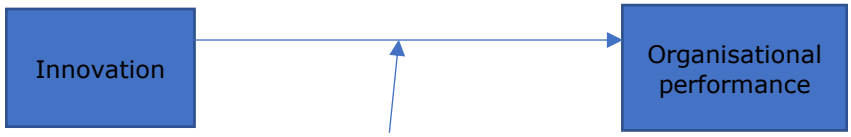

Fig. 1. Conceptual framework

Based on the review of the literature and research objective, we proposed that there is a relationship between innovation, organisational performance, and organisational leadership. We assume that innovation impacts organisational performance. Fig. 1 shows how organisational leadership moderates the relationship between innovation and organisational performance.

3. METHODOLOGY

In this study, an explanatory study design is employed. The study's target population is registered and active SMEs in Ghana. Ghana's growing SMEs, which are distributed across the country but concentrated in the Greater Accra region, are the reflection of the country's rising economy. According to [38], there are about 20,000 registered and active SMEs in Ghana, which constitutes the population of the study.

Determining the sample for a study is very important for any study. It determines the portion of members of a population that can represent the entire population. Thus, we estimated 380 out of the 20,000 population manufacturing firms belonging to the Association of Ghanaian Industries.

3.1. Sampling Technique

This study employed a stratified sampling technique to gather data from the sample unit. To ensure full representation of the private sector businesses across all sectors, the study will treat the various sectors of the economy as strata and therefore sample from each stratum. The stratified sampling procedure ensures that each group of the private sector being micro, small, and medium businesses within the various sectors, has adequate representation. A survey method is used to collect primary data from the managers or owners of the sampled SMEs with semi-structured questionnaires. The survey method is considerably easy to build and conduct, as well as being cost-effective due to its ability to be administered online and circumvent geographical limitations.

3.2. Data Processing and Analysis

The data received from the questionnaire is coded and inputted into SPSS version 24. First, the means, standard deviations, and correlation matrix of the four constructs were generated. The study also generated the factor analysis of the four constructs to reclassify each construct into one factor. Next, the reliability of the constructs was examined by computing the Cronbach alpha of the four constructs. The minimum reliability measure for Cronbach's alpha is 0.70. Furthermore, the Average Variance Extracted (AVE) measure is also generated to account for the discriminant validity of the measurements.

The discriminant validity measure checks whether the constructs are divergent such that no two constructs measure the same concept. For each study objective, the KMO and Bartlett tests assess all relevant data and give a cohesive answer. A KMO value of over 0.5 and Bartlett's test significance level of less than 0.05 indicate a significant correlation in the data. Furthermore, variable collinearity refers to the degree to which one variable is associated with another. The sampling appropriateness of data to be used for Factor Analysis is determined by a Kaiser-Meyer-Olkin (KMO) test; as a result, researchers employ Factor Analysis to confirm

that the variables used to assess a given concept are measuring the concept intended. All factors with loadings less than 0.6 will be excluded to increase the KMO value for this study. Finally, the Structural Equations Model (SEM) is employed to test the hypotheses.

Respondents were not allowed to provide their names or phone numbers on the questionnaire, to ensure anonymity. Thus, respondents were confident that their personal information would not be released to the public or used for any other purpose in the study. The study ensured data confidentiality by assuring participants that all information provided was kept private.

4. RESULTS AND DISCUSSION

4.1 Demographic Profile

Table 1 depicts the descriptive percentages of the demographics of the respondents.

Table 1. Demographic Variables

Variable	Frequency	Valid Percent
Sex		
Male	200	52.6%
Female	180	47.4%
Age		
20-29 years	100	26.3%
30-39 years	120	31.6%
40-49 years	80	21.1%
50-59 years	60	15.8%
60 years and above	20	5.3%
Marital Status		
Single	150	39.5%
Married	180	47.7%
Divorced	30	7.9%
Widowed	20	5.3%
Religion		
Christian	280	73.7%
Moslem	50	13.2%
Traditionalist	30	7.9%
Others	20	5.3%
Highest Educational Level		
No formal education	20	5.3%
Basic/JHS	40	10.5%
SHS	80	21.1%
Diploma/HND	100	26.3%
Bachelor's degree	100	26.3%
Master's degree	40	10.5%
Number of Years in Operation		
Less than a year	40	10.5%
1-3	120	31.6%
4-6	160	42.1%
7 or more	60	15.8%
Total	**380**	**100.0%**

Table 1 presents the distribution of data for various demographic variables collected in the study. The variables analysed include sex, age, marital status, religion, highest educational level, and number of years in operation. The study engaged 380 participants. Regarding the variable of sex, the data indicates that 52.6% of the participants identified as male, while 47.4% identified as female. In terms of age, the majority of the participants fell within the age range of 30-39 years (31.6%), followed by those in the 20-29 years category (26.3%). The distribution of

participants across marital status shows that 47.4% were married, 39.5% were single, 7.9% were divorced, and 5.3% were widowed. Regarding religion, most participants identified as Christians (73.7%), followed by Muslims (13.2%), Traditionalists (7.9%), and others (5.3%). The highest educational level attained by participants varied, with the largest group having a Bachelor's degree (26.3%) and Diploma/HND (26.3%). The least represented category was individuals with no formal education (5.3%) or a Master's degree (10.5%). In terms of the number of years in operation, the highest percentage of SMEs (42.1%) had been operating for 4-6 years, followed by 1-3 years (31.6%), 7 or more years (15.8%), and less than a year (10.5%). Overall, the sample is comprised of SME owners and managers with diverse demographic characteristics. This ensured the data was representative of the population. The results are presented below in the various tables.

Table 2 provides the means, standard deviations, and correlation matrix for the variables in the study. Table 2 includes 11 constructs, namely Organisational Performance, Product Innovation, Process Innovation, Organisational Innovation, Marketing Innovation, Innovation, Transformational Leadership, Transactional Leadership, Authoritative Leadership, Laissez-Faire Leadership, and Organisational Leadership.

The mean values represent the average scores for each construct, indicating the participants' ratings of those variables. The variables with the highest means in descending order are Transformational Leadership (4.22), Organisational Performance (4.22), Process Innovation (4.15), Innovation (4.12), Organisational Leadership (4.09), Marketing Innovation (4.08), Organisational Innovation (3.96), Authoritative Leadership (3.94), Product Innovation (3.89), Transactional Leadership (3.87), and Laissez-Faire Leadership (2.98). The standard deviations (SD) provide a measure of variability within each construct, showing how much the responses vary around the mean. The variables with the least standard deviations in descending order are Authoritative Leadership (0.72), Organisational Performance (0.75), Product Innovation (0.76), Innovation (0.79), Process Innovation (0.82), Organisational Leadership (0.83), Laissez-Faire Leadership (0.85), Marketing Innovation (0.88), Transformational Leadership (0.89), Transactional Leadership (0.91), and Organisational Innovation (0.95).

The correlation matrix presents the pairwise correlations between the constructs. The correlation coefficients range from -1.00 to 1.00 and provide insights into the relationships between the variables. The asterisks indicate the significance levels of the correlation coefficients, with *** representing $p < 0.001$ and ** representing $p < 0.05$. Analysing the correlation coefficients, several important findings emerge. Firstly, Organisational Performance exhibits a strong positive correlation with Product Innovation (0.70*), Process Innovation (0.65*), Organisational Innovation (0.61*), Marketing Innovation (0.55*), and Innovation as a whole (0.76*). These findings suggest that higher levels of innovation are associated with better organisational performance among SMEs in Ghana.

Regarding the leadership styles, Transformational Leadership demonstrates positive correlations with all innovation constructs, ranging from 0.49* to 0.67*. This suggests that Transformational Leadership may play a crucial role in fostering and promoting innovation within SMEs. Transactional Leadership and Authoritative Leadership also show positive correlations with innovation constructs, albeit to a lesser extent. Laissez-faire leadership exhibits weaker positive correlations with innovation constructs. Furthermore, when examining the correlations with Organisational Leadership, it shows positive associations with all other constructs. Notably, Organisational Leadership exhibits moderate to strong positive correlations with Product Innovation (0.76*), Process Innovation (0.80*), Organisational Innovation (0.72*), Marketing Innovation (0.76*), and Innovation as a whole

(0.80*). These findings indicate that effective organisational leadership is closely related to promoting innovation within SMEs.

Overall, the results highlight the importance of innovation and leadership in enhancing organisational performance among SMEs in Ghana. The positive correlations indicate that higher levels of innovation, particularly in product, process, and organisational domains, are associated with better organisational performance. Additionally, the correlations suggest that Transformational Leadership may be particularly influential in fostering innovation within SMEs.

Table 2. Mean, Standard Deviation, and Correlations Table

	Mean	**SD**	**1**	**2**
Organisational Performance	4.22	0.75	1	
Process Innovation	4.15	0.82	0.65*	0.80*
Innovation	4.12	0.79	0.76*	0.80*
Marketing Innovation	4.08	0.88	0.55*	0.76*
Organisational Innovation	3.96	0.95	0.61*	0.72*
Product Innovation	3.89	0.76	0.70*	0.76*
Transformational Leadership	4.22	0.91		
Organisational Leadership	4.09	0.83		1
Transactional Leadership	3.87	0.91		
Laissez-Faire Leadership	2.98	0.85		
Authoritative Leadership	3.94	0.72		

P=<0.05, <0.01***

4.2. Discriminant Validity Assessment

Discriminant validity is a measure of construct validity that investigates the extent to which two theoretically unrelated constructs are unrelated. To calculate the average variance derived from the CFA data, according to the immediate authors, the sum of the squared standardised loadings should be computed and then divided by the total number of indicators. To determine the discriminant validity, it is first necessary to compute the square root of the extracted average variance and then to evaluate the correlation coefficients between the various constructs. The results of the Average Variance Extracted are displayed in Table 3.

Table 3. Average Variance Extracted

Latent Construct	**The sum of the Squared of the Standardized Loadings**	**Number of indicators**	**Average Variance Extracted (AVE)**
Innovation	2.861	4	0.715
Organisational Leadership	2.921	4	0.730
Organisational Performance	6.192	9	0.688

The convergent validity of a particular latent construct is supported by an average variance expected greater than 0.5. All of the latent constructs demonstrated convergent validity, as their AVEs were greater than 0.50, as shown in Table 3.

4.3 Reliability Test

Cronbach's Alpha, the metric used to quantify the test's reliability, demonstrates the degree of internal consistency among the constructs. Cronbach alpha values between 0.7 and 0.8 are acceptable, those with a Cronbach alpha

between 0.8 and 0.9 are good, and values greater than 0.9 are exceptional. The reliability test results for the numerous constructs were extracted.

Table 4. Reliability Statistics Output

Construct	Cronbach's Alpha
Innovation	.869
Organisational Leadership	.818
Organisational Performance	.922

From Table 4, it is evident that Innovation and Organisational Leadership are good constructs, while Organisational Performance is an excellent construct. Hence, all constructs in this study have strong internal consistency.

4.4 Hypotheses Testing

Hypotheses testing in the Structural Equations Modelling (SEM) involves evaluating whether the proposed relationships between variables are statistically significant. This study tested three hypotheses to determine the relationships between Innovation and Organisational Leadership on Organisational Performance.

From the analysis, we found a significant relationship between innovation and organisational performance and organisational leadership and firm performance. Table 5 reflects the result of the hypotheses testing.

Table 5. Hypotheses Testing

Independent Variable – Dependent Variable	Unstandardized Estimate	S.E	p-value
Innovation – Organisational Performance	.451	.170	<.000
Organisational Leadership – Firm Performance	.319	.139	<.000

Table 5 provides the results of the hypotheses testing for the relationship among Innovation, Organisational Leadership, and Organisational Performance. The hypotheses test the relationship between the independent variables and the dependent variable. The first hypothesis tests the relationship between Innovation and Organisational Performance. The related a priori hypothesis states that Innovation has a positive and significant impact on Organisational Performance. The result shows that Innovation has a significant positive effect on Organisational Performance, with an unstandardized estimate of .451 (S.E = .170, $p < .000$). This result suggests that higher levels of innovation lead to better organisational performance. Therefore, the hypothesis that Innovation positively influences Organisational Performance is supported.

The second hypothesis tests the relationship between Organisational Leadership and Organisational Performance. The related a priori hypothesis states that Organisational Leadership has a positive and significant impact on Organisational Performance. The result shows that Organisational Leadership has a significant positive effect on Organisational Performance, with an unstandardized estimate of .319 (S.E = .139, $p < .000$). This result suggests that higher levels of leadership within the SMEs lead to better organisational performance. To wit, the hypothesis that Organisational Leadership positively influences Organisational Performance is supported.

Squared Multiple Correlations (SMCs) quantify the proportion of the variance in the dependent variable that can be attributed to the independent variables in a multiple regression analysis. It is the proportion of variance in the dependent variable

that can be predicted by the squares of the independent variables. Higher SMC values indicate a stronger association between the independent and dependent variables. Squared Multiple Correlations (SMCs) for "Organisational Performance" as the dependent variable is .703. SMC is a measure of the proportion of variance in the dependent variable that is explained by the independent variables included in the model. In this case, the SMC of 0.703 indicates that about 7.03% of the variance in Organisational Performance can be explained by the combination of independent variables in the model, which include Innovation and Organisational Leadership.

4.5. The Moderation Effect of Organisational Leadership on the Relationship between Innovation and Organisational Performance

In this sub-section, the hypothesis to capture the moderation effect of Organisational Leadership on the relationship between Innovation and Organisational Performance is tested.

Table 6. Hypotheses Testing

Independent Variable – Dependent Variable	Unstandardized Estimate	S.E	p-value
Innovation x Organisational Leadership – Organisational Performance	.392	.065	<.039

The third hypothesis of this study states that there is a moderating effect of Innovation on the relationship between Innovation and Organisational Leadership. The result in Table 6 shows that Organisational Leadership has a significant positive moderating effect on the relationship between Innovation and Organisational Performance, with an unstandardized estimate of .392 (S.E = .065, $p < .05$). This implies that higher Organisational Leadership levels strengthen the relationship between Innovation and Organisational Performance. Therefore, the third hypothesis is supported by the empirical results.

The squared multiple correlations for the moderating effect of Organisational Leadership on the relationship between Innovation and Organisational Performance is .591. The SMC of 0.591 indicates that about 59.1% of the variance in Firm Performance can be explained by Organisational Leadership as a moderator in the relationship between Innovation and Organisational Performance.

4.6 Discussion of Findings

In this section, the findings of the study are discussed in line with extant literature.

The positive relationship between Innovation and Organisational Performance implies that as SMEs in Ghana embrace and implement innovative practices, they are more likely to achieve better performance outcomes. Innovation can manifest in various forms, including product innovation, process innovation, organisational innovation, and marketing innovation [22]. By introducing new and improved products or services, optimizing operational processes, implementing innovative organisational structures or practices, and adopting effective marketing strategies, SMEs can enhance their performance.

The findings highlight the importance of fostering a culture of innovation within SMEs in Ghana. Encouraging and supporting innovation initiatives can lead to increased competitiveness, improved market position, and enhanced financial performance, as agreed by [39]. SMEs should invest in research and development, promote creativity and idea generation among employees, and create an environment that nurtures and rewards innovation. This may involve providing resources, training,

and incentives to employees, fostering collaboration and knowledge sharing, and being open to experimentation and learning from failures.

Additionally, the results emphasize the need for SMEs to develop innovation capabilities and continuously adapt to changes in their business environment. Keeping pace with technological advancements, market trends, and customer preferences is crucial for SMEs to identify opportunities for innovation and stay ahead of the competition [40]. Engaging in partnerships or collaborations with external entities such as universities, research institutions, or industry networks can also facilitate access to expertise, resources, and networks that can support innovation efforts.

Overall, the significant positive relationship between Innovation and Organisational Performance suggests that SMEs in Ghana can enhance their performance by embracing innovation as a strategic driver. By fostering a culture of innovation, investing in research and development, and continuously adapting to changes, SMEs can position themselves for sustainable growth and success in the dynamic business landscape of Ghana.

The positive relationship between Organisational Leadership and Organisational Performance implies that effective leadership within SMEs in Ghana is crucial for achieving better performance outcomes. Organisational Leadership refers to the ability of leaders to influence and guide their teams toward achieving organisational goals [36]. Effective leadership practices, such as transformational leadership, transactional leadership, authoritative leadership, and laissez-faire leadership, can significantly impact the performance of SMEs [41].

The findings highlight the importance of strong leadership capabilities within SMEs in Ghana. Leaders who exhibit transformational leadership qualities, such as inspiring and motivating their employees, fostering innovation and creativity, and providing individualized support, can create a positive work environment that enhances employee engagement and performance [42]. Transactional leaders who establish clear goals, provide rewards and recognition, and maintain effective communication channels can ensure that tasks are executed efficiently, leading to improved performance outcomes [43]. Moreover, the results emphasize the significance of authoritative leadership in SMEs. Leaders who exhibit authoritative leadership behaviours, such as providing clear direction, making informed decisions, and effectively communicating the vision and goals of the organisation, can create a sense of purpose and direction among employees, ultimately driving improved performance.

The findings have important implications for SMEs in Ghana. It highlights the need for SME leaders to invest in developing their leadership skills and competencies. Leadership development programs, mentoring, and coaching initiatives can help SME leaders enhance their abilities to inspire, motivate, and guide their teams effectively. By improving their leadership capabilities, SME leaders can create a positive and conducive work environment that fosters employee engagement, innovation, and productivity.

Additionally, the results highlight the need for SME leaders to adopt a flexible leadership approach based on the context and needs of their organisation. Different leadership styles may be more effective in specific situations, and leaders should be adaptable and responsive to the dynamic nature of their business environment.

Overall, the significant positive relationship between Organisational Leadership and Organisational Performance suggests that effective leadership is a critical factor in driving performance outcomes for SMEs in Ghana. By developing strong leadership capabilities, SMEs can create a motivated and engaged workforce, foster a culture of excellence, and improve overall organisational performance and competitiveness. This result confirms the empirical findings by [36].

The moderating effect suggests that the relationship between innovation and organisational performance is influenced by the level of organisational leadership

within SMEs. Thus, the effect of innovation on firm performance varies depending on the level of organisational leadership exhibited by the organisation. This finding highlights the importance of considering the joint effect of both innovation and organisational leadership in understanding and predicting performance outcomes.

The implication of this result for SMEs in Ghana is that the effectiveness of Innovation in driving performance depends on the level of Organisational Leadership implemented by the organisation. SMEs that have strong and effective leadership practices in place are better equipped to harness the potential of innovation and translate it into improved performance outcomes. Specifically, the result implies that a high level of transformational leadership can enhance the positive impact of innovation on performance by promoting employee engagement, creativity, and commitment to organisational goals among Ghanaian SMEs. Also, by providing structure, incentives, and accountability, transactional leaders can ensure that innovations are effectively implemented, leading to improved performance outcomes among Ghanaian SMEs. In the case of authoritative leadership, by centralizing decision-making and controlling employee autonomy and creativity, such leaders may harness innovation and prevent tunnel vision resulting in improved organisational performance among Ghanaian SMEs. Last, in the case of laissez-faire leadership, subordinates may be empowered to develop their creative abilities as observed in intrapreneurship resulting in improved organisational performance among Ghanaian SMEs.

To leverage this moderating effect, SMEs in Ghana should focus on developing and nurturing effective leadership capabilities that support and facilitate the implementation of innovative practices. This involves fostering a leadership culture that encourages open communication, collaboration, and empowerment of employees. Leaders should provide clear direction, set strategic goals, and provide the necessary resources and support to foster innovation within the organisation [44].

Additionally, SME leaders should actively promote a learning and adaptive mindset within the organisation. This includes promoting continuous learning, experimentation, and a willingness to embrace change. Leaders should encourage employees to generate new ideas, provide platforms for knowledge sharing and collaboration, and create a supportive environment that encourages risk-taking and learning from failures. Furthermore, SMEs should invest in leadership development programs and provide training opportunities for their managers and leaders to enhance their skills in areas such as innovation management, strategic thinking, and change management. By developing strong leadership capabilities, SMEs can effectively guide and nurture the innovation process, ensuring that it aligns with the overall goals and objectives of the organisation [11].

To sum up, the significant moderating effect of Organisational Leadership on the relationship between Innovation and Organisational Performance highlights the importance of effective leadership in driving the impact of innovation on performance outcomes for SMEs in Ghana. By fostering a culture of strong leadership and providing the necessary support for innovation, SMEs can enhance their competitive advantage, drive growth, and achieve sustainable success in the dynamic business landscape.

5. CONCLUSION

In conclusion, the study examined the effect of innovation on organisational performance among SMEs in Ghana, with a particular focus on the mediating role of organisational leadership. The research findings provide valuable insights into the relationships among innovation, organisational leadership, and performance outcomes in the context of Ghanaian SMEs. The results of the study indicate that innovation positively influences organisational performance in SMEs. This implies that SMEs that prioritize and embrace innovation in their products, processes, marketing

strategies, and overall organizational practices are more likely to achieve better performance outcomes. Innovation plays a crucial role in enhancing competitiveness, customer satisfaction, and overall business success in the dynamic and competitive landscape.

Furthermore, the study highlights the significance of organizational leadership in driving organizational performance. Effective leadership, characterized by transformational and transactional leadership styles, was found to have a positive impact on performance outcomes in SMEs. Strong leadership practices that inspire and motivate employees, encourage collaboration, and provide guidance and support contribute to improved performance levels.

The study also identified the moderating role of organisational leadership in the relationship between innovation and organisational performance. Transformational and transactional leadership styles were found to enhance the impact of innovation on performance outcomes. This highlights the importance of aligning leadership practices with innovation initiatives to maximize the benefits of innovation within SMEs.

The implications of the research suggest that SMEs in Ghana should place a strong emphasis on fostering a culture of innovation and developing effective leadership practices. By creating an environment that encourages and supports innovation and by cultivating leadership styles that inspire and engage employees, SMEs can achieve sustainable growth and competitive advantage in the market.

The findings of the study may have practical implications for SME owners and managers in Ghana. They underscore the need for strategic decision-making that prioritizes innovation and the development of leadership capabilities. SMEs should invest in innovation programs, provide training and development opportunities for leaders, and create supportive structures and processes that facilitate innovation implementation. Overall, the research highlights the importance of innovation and organisational leadership in driving performance outcomes in Ghanaian SMEs.

Despite the valuable insights obtained from the study on the effect of innovation on organisational performance among SMEs in Ghana, several limitations should be considered. the study may be limited in its generalizability due to the specific context of SMEs in Ghana. The study focused on Accra, Ghana, and may not fully capture the diverse characteristics and dynamics of SMEs in other countries or regions. Therefore, caution should be exercised when extrapolating the results to SMEs in different contexts.

While the study examined the mediating role of organisational leadership in the relationship between innovation and organisational performance, it did not thoroughly explore the underlying mechanisms or boundary conditions. Further research could delve into the specific leadership behaviours or strategies that mediate or moderate this relationship, providing a deeper understanding of the dynamics involved.

The study relied on self-developed measurement instruments for assessing innovation, organisational leadership, and organisational performance. While efforts were made to ensure the validity and reliability of these instruments, using established and validated scales would enhance the rigour and comparability of the study's findings.

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Aims and Objectives

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This current Issue mainly consists of selected paper presented on the International Conference on Digital Science (DSIC 2023) that was hold on October 20-22, 2023 in Agia Napa, Cyprus and divided on two equal parts: 1. Engineering scientific view (the first three articles) and 2. Economics scientific view (the last three articles) with multidisciplinary approach on adoption of Digital technology/knowledge in modern reality.

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