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Prof. Liudmyla Gryzun

STRA President, PhD & Post-Doctoral Degree in Pedagogical science

Full Professor of Simon Kuznets Kharkiv National University of Economics

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Preface:

Scientific & Technical Research Association (STRA) is a conglomeration of academia and professionals for promotion of research and innovation, creating a global footprint. STRA aims to bring together worldwide researchers and professionals, encourage intellectual development and providing opportunities for networking and collaboration. These objectives are achieved through academic networking, meetings, conferences, workshops, projects, research publications, academic awards and scholarships. STRA strives to enrich from its diverse group of advisory members. Scholars, Researchers, Professionals are invited to freely join STRA and become a part of a diverse academic community, working for benefit of academia and society through research and innovation.

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Acknowledgements

Our sincere thanks go to our outstanding supporters who made this great and interesting conference possible.

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Some special thanks go to our outstanding Key-Note speakers, not only for their inspiring and highly interesting presentations but also for their input and contributions in the discussions and Q&A sessions during the conference:

Technological and Algorithmic Solutions for In-Door Navigation Problem in Modern University Campus

Dr. Liudmyla Gryzun is a Full Professor of Information Systems Department at National University of Economics preparing IT specialists for various branches of economy. Liudmyla earned a M.A. in Applied Mathematics from the State University of Kharkiv (Ukraine); PhD and Post-Doctoral Degree in Pedagogical science from National Pedagogical University of Kharkiv (Ukraine). Her sphere of research is focused on the synchronized curriculum and holistic educational content design in higher education; Artificial Intelligence application to pedagogical problems solution; Petri networks apparatus as a tool for modelling in education; IT tools for inquiry-based and holistic learning etc. Dr. L. Gryzun’s recent successful contributions include: (1) work as an international expert of the Open European-Asian Research Analytics Championship under the Program of the International Academy of Sciences and Higher Education (London, UK) (2012-2017); (2) participation in the European educational fair for STEM teachers “Science on the stage” (2019); (3) work as an invited speaker of the International internship “Digital future: blended learning” organized by DAAD German Academic Exchange Service (2022-2023); (4) work as a member (since September 2021 as a President) of the International organization Scientific and Technical Research Association (STRA), presenting the results of her research as a Keynote speaker at the at the number of Eurasia Research International conferences (2018 – 2023).

Technological and Algorithmic Solutions for In-Door Navigation Problem
In Modern University Campus

Dr. Liudmyla Gryzun

Department of information systems, Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine

Abstract: The work treats the problem of in-door navigation in the context of the development of mobile application for efficient orientation in modern university campus. In the progress of elaboration of algorithmic and technological solutions, the peculiarities of the in-door navigation were analyzed. The capabilities of existing software implementing similar functions of this subject domain were evaluated. There were revealed some limitations of the said software. The specification of functional and non-functional requirements for the application for in-door navigation at university was provided. Its architecture was determined as a set of interconnected modules, for whose development proper interface, technological and algorithmic solutions were elaborated and highlighted. The main stages of design and development of the said application in the context of the elaborated solutions are presented. The functionality of the application is characterized and analyzed. It was concluded that during the design it became possible to overcome the main limitations inherent in similar software of indoor navigation. The results of the application implementation in the educational practice of a national university are presented. Feedback from the application users (university visitors of different categories) was collected during the approbation and analyzed. Users were asked to fill in a survey form evaluating the quality of implementation of both functional and non-functional requirements for the application on a five-point
As a result, there were revealed and realized the ways of the application improvement. The prospects for further research are formulated.

**Keywords**: in-door navigation, technological and algorithmic solutions, mobile application for navigation in university campus.

**Research Prospects in the Field of Machine Learning and NLP**

Dr. Ani Thomas is Professor in the Information Technology Department & also HOD (IT & MCA) at Bhilai Institute of Technology, Durg (C.G.). Her post-graduation is in the Computer Applications discipline from Govt Engg. College, Raipur. She was awarded a Doctoral degree in the Discipline of Computer Applications on “Automated Tool Design of Subjective Question Answering using Text Mining” in July 2013. She is the Dean of Computer and Information Technology now and was Chairperson, of the Board of Studies (Information Technology) in Chhattisgarh Swami Vivekananda Technical University for the past four years. She is the research guide of 8 PhD scholars and 3 have been awarded PhD degrees. She has conducted and delivered several Keynote sessions in ACM, ISTE and CCOST-sponsored workshops. She has been a Research paper Reviewer for IEEE-sponsored conferences and Faculty Coordinator for events conducted by many IITs. She is a Life fellow member of Professional bodies: ‘The Indian Society for Technical Education’ and ‘The Computer Society of India’ and also an Editorial board member of many journals. She got the best paper award at the national conference TECHNOVISION 2007. She and her team has bagged 2nd position in Slot filling task, a research software project competition organized by NIST, Govt. of USA. Dr. Thomas has teaching experience of 24 years and research experience of 15 years with areas of academic interest in Artificial Intelligence & Expert Systems, Natural Language Processing, and Machine Learning Using Text Mining. She has 6 Copyrights registered in the Computer Software category from Govt. of India and completed one Sponsored Project. She has published a number of research papers; authored one book; 2 book chapters in Scopus publications; 36 in International / National Journals and 30 in International Conferences / National Conference forums. She has organized several professional activities to date including Faculty Development Programs, Conferences and e-workshops.

**Generation Marketing, Z Generation, CSR Activities**

Dr. Habil Garai-Fodor Mónika is having an academic career as an educator of the Tessédi Károly Faculty of Business and Management, Óbuda University Budapest, Hungary. During 2009-2016. She was vice-head of department of the Budapest Economics University (formerly Budapest Economics College), Institution of Marketing, as a college associate professor. Currently she is an associate professor at Obuda University Keleti Károly Faculty of Business and Management and she is the vice-dean of the faculty as well. Her main research and teaching areas are consumer behaviour, marketing communication, and marketing research. Apart from her duties in higher education she works for the business as well. She was lead researcher of the Radar Research International Marketing Advisor Co. Ltd., and she was the country director of communication by the Continental Hungaria Co. Ltd. for four years. Currently, she is an expert at the Profession Conference Organiser Co. Ltd., president of the Employer Branding Committee, furthermore, member of the Hungarian PR Committee’s Employer Branding Section.
Digital Immortality and Future Research

Dr. Baloglu, completed her undergraduate at Technical University of Istanbul, her MBA in production management at University of Istanbul, and her PhD in Information Technology at University of Istanbul. She has experience of 15 years in production and technology management. She worked for various plants including manufacturing, service and consulting companies as middle or top manager. For instance, Ernst and Young Consulting Turkey is one of the companies, where she added important values within 5 years. Also she worked in SAP Business for a long time and managed various SAP/ERP projects in Turkey and also abroad. Now she is serving in ERP, CRM and e-business categories as senior consultant and lecturing at various universities. She gave the lectures and courses in the Universities of Bilgi, Işık and Yeditepe. Additional to these she is sometimes giving conference seminars and company trainings in her expertise areas. Dr. Baloglu has about 15 professional and academic papers, published in various technology magazines and books (10). And she currently works for Marmara University - Dept. of Business Informatics under title of Assoc. Prof and also lectures the some courses in Yeditepe University as part time lecturer such as e-business, innovation management, IOT, Agro IT, ERP, eSCM.

Omics Application to Discover Biomarkers of Outcome of Critically Ill Patients

Cecília Calado, has a PhD and an MSc in Biotechnology, and a degree in Biochemistry. She is professor at the Lisbon High Engineering Institute (ISEL- Instituto Superior de Engenharia de Lisboa, https://www.isel.pt/en/), were coordinates the BSc and MSc in Biomedical Engineering and the R&D Lab. in Medical Bioengineering. She presents a broad experience in R&D in Development of Platforms to Discover Drugs and Diseases Biomarkers and Bioprocess Monitoring.

Cecilia R.C. Calado
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Presenters

Strain Gauge Testing of 3D-Printed CFRP Sandwich Structure

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Abstract:
In this article, the authors present composite sandwich-type CFRP structures and a study of their properties by strain gauge testing. The paper presents the modeling of a parameterized elementary unit serving as the core of a 3D printed structure using Fused Deposition Modelling (FDM) technology. The properties of these structures with different outer layers made of pure epoxy resin and resin with 10% and 20% carbon fiber powder were then investigated. Based on the results of the strain gauge tests, material models were reconstructed for each resin layer, which can be used in computer FEM studies of more complex components. As an application example, a strength analysis of the driver’s seat of a Greenpower car made with printed sandwich structures coated with carbon fiber powder resin was conducted.

Keywords: 3D Printing, Carbon Fiber, CFRP Composite, Sandwich Structure, Strain Gauge Testing

1. Introduction: The purpose of the study was to investigate strain gauging of innovative composite sandwich structures. The premise of the study is to model a scalable elementary unit that can then be multiplied to form the core of a sandwich structure. In this article, the authors examine the mechanical properties of such elements using resistance strain gauge testing. In recent years, the importance of Continuous Fiber Reinforced Thermoplastic Composites (CFRTPCs) has increased considerably. Numerous industrial requirements for new materials led to the development of innovative manufacturing and design forms. New composite manufacturing technologies and new composite technologies allow traditional materials to be replaced by light structures, and are not inferior in mechanical properties to traditional materials. As described in this paper, a new type of CFRP materials and a new composite manufacturing approach have been developed. - 3D print in Fused Deposition Modelling (FDM) technology considering the print to be a lightweight
structure reinforced with epoxy resin layer with the addition of carbon fiber powder. Innovation in the manufacturing process is essential and urgent to further develop and apply CFRTPC material. [1-3]. At present, FDM is used not only for visual aids, conceptual models, and prototype but also for manufacturing of functional parts. 3D printing technology based on material extrusion can be used for printing multiple materials and multiple color printing of plastics, food, and even living cells. The technology is widely used because it is low in cost and can be built in fully functional parts. 3D printing technology, also known as additive manufacturing, involves producing a given object or component by adding material layer by layer and creating a three-dimensional (3D) structure. It reduces the cost of assembly by producing complex geometry and flexible functional components from STL files by depositing two-dimensional (2D) layers of melted polymeric material on a build platform. Using CAD (Computer Aided Design) software, it is needed to create and design appropriate print models in advance. [4,5,6,7]. Low-precision is a relative term, but some applications do not require high-precision (prototypes or displays), in order for FDM to be more acceptable in the industry for mass production of printed parts, accuracy is the fundamental requirement. Many researchers have analyzed various control parameters to achieve the desirable characteristics of the component and have also been working on optimizing the process parameters [4,8]. Several factors affect the quality of the final elements: printing temperature, printing speed, layer height, print architecture (infill pattern), cooling rate. [1,9]. Currently, there are a number of articles in which the authors study the properties of particular predefined filling structures of 3D prints. In the notable majority of these articles, they treat the effect of filling and other parameters on mechanical properties. Modeling custom structures and using them in 3D printing is no longer such a popular topic. The topic has been addressed by, for example: Audibert et al. [10] in which the authors study shapes built from bone geometry, as well as author Bodaghi et al. [11] where the aim of that paper was to introduce auxetic meta-sandwiches printing technology for reversible energy absorption applications. Saufi et al. [12] proposed using a shape inspired by nature - the starfish. The bio-inspired structure has been studied for its ability to absorb energy and high strength. The topic addressed in this article - parametric spatial structure reinforced with carbon fiber dust and epoxy resin, is an innovative and previously unaddressed issue. Currently, new composite manufacturing technologies combined with new materials can replace traditional materials with light structures with similar resistance. These structures allow the weight and materials needed for the production of the elements to be reduced [13,14]. Designing structures to improve load bearing capability with reduction of weight and impact resistance is one of the multidisciplinary research fields, with potential applications in a wide variety of areas, such as automotive, space, civil, and biomedical, among others. Advanced scalable technologies, such as 3D printing, can be used to explore the mechanical behavior of various predictive complex geometric shapes, to create innovative engineering materials. [15,16,17]. Composite materials are materials composed of at least two materials (phases) with different properties and have properties superior to each component separately, but also superior to those derived from a simple summarization of these properties [5,14]. Examples of such materials are polymers reinforced with carbon fibers. They are widely used in the aerospace industry due to their high resistance, corrosion resistance, and fatigue resistance. [18] It is a well-known practice to add various types of fillers to epoxy resin to enhance its strength or modify selected properties [14,19-25]. Among the fillers used are silica, quartz flour, glass or carbon fiber dust, short fibers, and graphene. However, the authors propose a new approach by mixing carbon fiber powder into the epoxy resin. Sandwich composite structures are widely used in weight-restricted applications, such as in the automotive or aerospace industry. Researchers have developed better mechanically resistant alternative materials, such as hexagonal and reintroduced honeycomb cores, and the structure of lattice trusses and cell auxetic structures. However, these structures have several serious limitations, mainly manufacturing methods – eg. extrusion, forming and corrugation [26-30]. Other studies have shown that it is highly challenging to manufacture lattice structures, e.g. cubic diamond or gyroid structure, by traditional subtractive methods. Using 3D printing could help overcome these difficulties and suggests new ways of manufacturing the support structures and cores [31-37]. In this article, the authors also propose an innovative method to manufacture such composites using 3D printing with FDM technology. The printed cores of the structure are then coated with a layer of epoxy resin along with the admixture of 10% and 20% carbon fiber powder. The resulting CFRP composite allows for diversified ap-
Applications: 3D printing makes it possible to produce a core of any shape, while the res-in with the addition of carbon fiber powder, unlike classical laminates, also allows uniform coverage of surfaces with almost any degree of complexity and refraction. In the next part of the study, strain gauge tests were performed. The principle of the resistance strain gauge is based on the strain gauge effect of the resistance material. This effect was first observed in 1856 by William Thomson. It consists of a change in the electrical resistance of the material with a change in its length. The sensor's resistance material deforms during operation. In the linear range of the stress characteristics, as a function of the elongation of the elastic element, the deformation is reversible, and the resistance function is linear. [38]. Strain gauges can be made of many metals and alloys. The most common are constantan (an alloy of copper and nickel in a ratio of 3:2) and nichrome (an alloy of 80% nickel and 20% chromium). The most important advantages of strain gauge testing include its small size, and therefore the ability to take measurements in hard-to-reach places, high measurement accuracy, and relatively low cost. However, this method is not without its disadvantages, which certainly include the long preparation time for the test that involves proper surface preparation and sticking of the strain gauges, as well as the disposability of the strain gauges used, as once a strain gauge is stuck on, it cannot be peeled off without damaging it. [38,39]. The purpose of this study of sandwich CFRP structures is to implement them as an infill for the driver's seat in a Greenpower electric car. Silesian Greenpower is the students' interfaculty project that focuses on design and construction of the electric racing vehicle. However, the Greenpower car is not a regular EV. It is an one-person lightweight construction. The Greenpower car is designed for specific type of races and is not admitted to road traffic. The main restriction in the design of the car is imposed by the organizers, the power source and type of the motor driving the car, which increases competition level and equalizes the chances of teams. Greenpower electric vehicles are characterized by low weight (about 90 kg without the driver) and rather low speeds (about 50 km/h), so they do not require such exorbitant strength properties and thermal resistance, and more critical here is the low weight and the possibility of unit production of custom parts at low cost. [40,41]. The driver's seat is a car component that has several tasks, primarily to ensure the driver's safe position in the car but also to provide comfort while driving. Therefore, it is ideal to design a seat for a particular driver to best suit his or her ergonomics. This approach has one disadvantage - the cost of making such a unitary seat increases significantly due to the uniqueness of the component. The use of structures and methods studied in this article will reduce the cost of manufacturing such a seat. In addition, such structures can be used in the design of damping suspension components, such as bushings, using more resilient materials. [13,42,43].

2. Materials and Methods: In this section, the model and sample preparation process and the tests methodology of the conducted are described. First, the modelling of the core structure was prepared for the Finite Element Method (FEM) analysis. The obtained CAD model was further used to prepare a sandwich structure composite. The core of the structure was 3D printed and laminated. The prepared samples were subjected to strain gauge testing. Then the material model was retrieved on the experimentally acquired data. Lastly, an FEM analysis of the driver's seat has been conducted.

2.1 CAD Model: The first step of this study was preparing a CAD model of the support structure geometry. For this purpose, the Siemens NX 12 program was used. The main idea was to prepare a model of an elementary unit, designed with the help of parameterized variables. The use of parameterization in the model allows to adjust the size and change the geometry within a given range. Two geometries with truss characteristics were pro-posed - type one with vertical supports only, and type two with additional diagonal supports. The geometry of the models is shown in the figure. The models consisted of a hexagonal cube with the following variables: height (h), thickness of bases (b), and thickness of supports (s), both vertical and diagonal supports. The elements used in the subsequent tests were 8x8x8 mm, the thickness of the bases was 0.5 mm, while the thickness of the supports was 1.5 mm. Additional diagonal support was created using a circular array with the element spaced every 90 degrees. This ensures that the diagonal supports on opposite walls are arranged perpendicular to each other.
The elementary units were used to create the core structure of a sandwich-type element. Also, two variants of the core were proposed - consisting of one or two layers of elementary units. To create the infill, an elementary unit was multiplied using the Pattern Feature option. A grid of 160 elements was created, 16 by 10 elements with 2 mm spacing between cubes. For a model with two layers, the number of elements was doubled. Additionally, two thin layers of 0.5 mm thickness were added as bonding surfaces. The size of the modeled core structure is 158x98x9 mm for the model with one layer and 158x98x17 mm for the model with two layers of elements. A comparison of the prepared core models is shown in Figure 1 above and in Table 1 below.

### Table 1: Comparison of Sandwich Core Structure Types

<table>
<thead>
<tr>
<th></th>
<th>Structure A</th>
<th>Structure B</th>
<th>Structure C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary unit</td>
<td>Type 1</td>
<td>Type 2</td>
<td>Type 1</td>
</tr>
<tr>
<td>Number of units</td>
<td>160</td>
<td>160</td>
<td>320</td>
</tr>
</tbody>
</table>

As can be seen from the table above and the data on the weight of each sample, structures with additional diagonal support are heavier than samples without this support - for samples with one layer the difference is 30%, while for samples with two layers the difference is 40% in weight.

### 2.2 Finite Element Method Analysis

In the next step, the designed structures were subjected to FEM strength testing. For this purpose, Ansys Workbench 19.2 software with the Nastran calculation module was used. Static Structural was selected as the test type. The material adopted for the FEM analysis was Ultra PLA by Noctua. The following manufacturer data were entered for the material constants: Young's modulus – 2.65 GPa, density – 1.3 g/cm3 and Poisson's ratio 0.33. Next, a mesh was created with an element size of 4 mm applied for outer layers. The next step was the task of setting the boundary conditions of the test, simulation of 3-point bending of the plates. The element was supported from below on the two edges along the width of the element which were offset by 10 mm from the edge of the sample. One fixed support and one sliding support were used (1 degree of freedom was left free – rotating along Y axis). A circle with a diameter of 50 mm was drawn on the upper surface, to which a force of 200 N was applied. The single layer element prepared for the FEM testing is shown in Figure 2. Analogous boundary conditions were used for all types of tested structures.
2.3 3D Printing and composite fabrication: The components designed and discussed in the previous two subsections were then printed using FDM (Fused Deposition Modelling) technology on a Prusa MK3S printer. The material chosen for printing was PLA (Polylactic Acid), and the filament used was Noctua’s Ultra PLA. The parameters used are shown in Table 2.

Table 2: 3D Printing Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printing temperature</td>
<td>210°C</td>
</tr>
<tr>
<td>Heatbed temperature</td>
<td>60°C</td>
</tr>
<tr>
<td>Layer height</td>
<td>0.2 mm</td>
</tr>
<tr>
<td>Nozzle diameter</td>
<td>0.4 mm</td>
</tr>
<tr>
<td>Cooling rate</td>
<td>100%</td>
</tr>
<tr>
<td>Number of outlines</td>
<td>2</td>
</tr>
</tbody>
</table>

PLA is one of the widely used thermoplastics in FDM. PLA is increasingly used as a biodegradable thermoplastic. In addition, the process of rapid prototyping with PLA requires less energy and a lower temperature [1]. The elements are intended to be applied in the Silesian Greenpower electric race car. However, the only heat in the car is generated by the electric motor, which doesn’t generate any fumes ad is located far away from the seat and has no influence on the degradation of the seat material. Therefore, high-temperature performance is not required in this specific application. The printed samples were then laminated. For this purpose, LG700 epoxy resin with HG700 hardener from GRM Systems was used. This epoxy system is suitable for both RTM and manual lamination. It is characterized by very low viscosity, good heat resistance, very flexible and strong veneers. Epoxy resin LG700 with hardener HG700 has a 25 minutes processability time [44]. The resin was mixed with the hardener in a weight ratio of 100:35, and then the addition of carbon fiber powder was mixed in different ratios – 10% and 20% by weight. Selected carbon fiber powder was from Easy Composites. It is compatible with different resins – epoxy, polyester, vinylester and polyurethane. It has fiber diameter of 7.5 µm and fiber length of 100 µm. It has density of 1800 kg/m³. This carbon fiber powder is characterized by tensile strength of 3150 MPa and Young’s modulus of 200 GPa [45]. The microscope image of the applied car-bon fiber powder is presented in Figure 3 below. The image was taken using an optical microscope with a magnification of 40 times. It is visible, that the powder consists of very short fibers.
Addition of carbon fiber powder can significantly improve the mechanical properties of the resin. It increases tensile strength and modulus and electrical conductivity. It upgrades thermos-dimensional stability of the produced parts. Also, very high tensile strength and isotropic orientation it reduces shrinkage of the composite. Carbon fiber powder addition was 10% and 20% by weight. The carbon fiber powder was used as a reinforcing additive. Two samples without the addition of carbon fiber powder were also left as reference samples. A summary of all the samples made is shown in the Table 3 below.

Table 3: Samples Prepared for Strain Gauge Testing

<table>
<thead>
<tr>
<th>Sample</th>
<th>Core structure</th>
<th>Coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Structure A</td>
<td>No coating</td>
</tr>
<tr>
<td>2</td>
<td>Structure B</td>
<td>No coating</td>
</tr>
<tr>
<td>3</td>
<td>Structure A</td>
<td>Pure epoxy resin LG700</td>
</tr>
<tr>
<td>4</td>
<td>Structure B</td>
<td>Pure epoxy resin LG700</td>
</tr>
<tr>
<td>5</td>
<td>Structure A</td>
<td>LG700 + 10% carbon fiber powder</td>
</tr>
<tr>
<td>6</td>
<td>Structure B</td>
<td>LG700 + 10% carbon fiber powder</td>
</tr>
<tr>
<td>7</td>
<td>Structure A</td>
<td>LG700 + 20% carbon fiber powder</td>
</tr>
<tr>
<td>8</td>
<td>Structure B</td>
<td>LG700 + 20% carbon fiber powder</td>
</tr>
</tbody>
</table>

For each laminate layer, 10 g of resin mixture was provided, thus obtaining an approximately 1 mm laminate layer on each side of the printed structure. The sample prepared for further testing is shown in Figure 4. The liquid mixture of epoxy and carbon fiber powder was poured onto the surface of the 3D-printed core. The epoxy resin has self-leveling properties, therefore then the samples were placed on a flat surface to ensure even distribution of the laminate and a smooth surface. Samples were laminated manually. The authors were considering vacuum laminating, but as there was no requirement to press the resin into standard carbon fiber fabric, they chose the simpler method.
Then TF-5 resistance strain gauges with a gain parameter $k$ of 2.15 and a resistance $R$ of 120 Ohms were attached to the samples. The strain gauges were attached 1 strain gauge per sample - in the center of the lower surface, which is shown in Figure 5 below.

![Strain Gauge Placement](image)

**Figure 5:** Placement of the Strain Gauge on the Sample

### 2.4 Strain Gauge Testing

In the next stage, the manufactured samples were subjected to strain gauge tests. For this purpose, a test stand equipped with a pneumatic actuator, support elements, sensors, and control software was prepared. The strain gauge test stand is shown in Figure 6.

![Strain Gauge Test Stand](image)

**Figure 6:** Strain Gauge Test Stand

The workstation used an actuator with a stroke of 100 mm, a piston diameter of 40 mm, a piston rod diameter of 12 mm, and a maximum pressure of 10 bar as the load-setting element. To repeat the test carried out previously by the FEM method and properly reproduce the load of the element on the surface of a circle with a diameter of 50 mm, a stamp of the appropriate size and mounting was 3D printed. In addition, the stand included a Pneumax pressure regulator, a Festo valve, and an HBM load cell used to accurately read...
the force applied to the specimen during the test. The specimen was supported on two metal cylinders at a distance of 10 mm from the edge of the specimen. An MGCplus controller and HBM software were used as control and result reading software. The data collecting system was MGCplus AB22A of the German company HBM. The device is able to connect up to 6 expansion cards. In our case, the ML455i and ML801b cards were used to collect data. The HBM U2B force sensor with a measuring range of 0-500N was connected to the ML455i card. A strain gauge with the previously specified parameters has been connected to the ML801b card. Each sample was loaded with a force of 200 N. The results were collected on the computer with CatmanEasy software.

2.5 Material’s Model Definition: Based on the results obtained during the test strain gauge testing, the boundary conditions were recreated in ANSYS Workbench 19.2 software to determine material parameters (Young’s modulus) for each sample. The samples are described in chapters 2.2 and 2.3. Additional layers on the top and bottom surfaces with a thickness of 1 mm were added to the sample models previously described in Section 2.2. These layers represent the additional resin layers that were tested during the previous test. The boundary conditions (restraint and specimen loading) remained the same from the initial FEA analysis. The PLA material model was modified so that the strain results obtained correspond to those obtained in the strain gauge test. The value of Young’s modulus was modified to value of 1.55 GPa. Three additional material models were introduced for resins with different reinforcing additives (LG 700 epoxy resin, resin with 10% and 20% addition of carbon fiber powder). For each resin, a density of 0.65 g/cm^3 and a Poisson ratio of 0.33 were assumed. Young’s modulus was left as the only variable. The Young's modulus value for each material was then modified to replicate the results read at the strain gauge restraint in the previous test.

2.6 FEM Analysis of the Driver Seat: Although the elementary unit is very similar to an ordinary lattice structure, its parameterization and the ability to arrange it freely gives it a number of advantages - for example, the ability to lay out the elements along a curve, which allows the elementary units to fit a given geometry. This property makes it possible to arrange them in such a way that the applied load on the top surface is always perpendicular to the direction in which the units present the greatest strength - such an arrangement is not possible using a standard lattice fill pattern. This solution has been presented in Figure 7. In standard lattice structures, there are greater chances of shear stresses occurring. This feature allows the use of sandwich-type structures also for the manufacture of components that are not perfectly flat, unlike the structures currently in use.

In the final stage of the research, in order to verify the application of the previously presented elements and structures, a section of the driver's seat for the Greenpower electric car was designed. The model was created with Siemens NX 12 software using all the assumptions and elements presented in the previous chapters. The seat consisted of a core of 3,000 elements with Structure B and two outer layers of 0.5 mm thickness representing epoxy resin with the addition of 20% carbon fiber powder. The application of the driver's seat model (marked in blue) in the car is presented in the Figure 8 below.
Next, an FEA analysis of the designed seat was carried out in ANSYS Workbench 19.2. Because the component is symmetric, only half of the model was used for the analysis to reduce the calculation time. PLA material was assigned for the core elements, while epoxy resin with 20% carbon fiber powder was assigned for the outer layers. A model mesh was created with an element size of 4 mm for the outer layers. The model was fixed in two areas: on the bottom surface representing the attachment of the seat to the floor of the car, and on an additional edge simulating the support of the seat under the back. The boundary conditions of the model are shown in Figure 9.

The seat was loaded with two forces representing the pressure caused by the driver’s own weight. The driver’s weight was taken as 63 kg, as an average weight of the drivers who drove the car in the last season. The lower surface of the seat is affected by 68% of the weight, that is, 43 kg, and the part below the back is affected by 17%, that is, 11 kg. Since only half of the seat was analyzed in the model, half of the forces corresponding to each weight: 215 N and 55 N were taken as loads.

3. Results: This section successively describes the results from the Finite Element Method analysis carried out in Ansys Workbench 19.2 software and results from the strain gauge testing.

3.1 Finite Element Analysis: As a result of the numerical Finite Element Method analysis carried out in the Siemens NX software, the values of deformation and von Mises stress for each core structure sample have been obtained. The results acquired for each sample type are presented in Table 4.

<table>
<thead>
<tr>
<th></th>
<th>Structure A</th>
<th>Structure B</th>
<th>Structure C</th>
<th>Structure D</th>
</tr>
</thead>
<tbody>
<tr>
<td>von Mises stress [MPa]</td>
<td>23.89</td>
<td>17.43</td>
<td>16.63</td>
<td>11.86</td>
</tr>
<tr>
<td>Strain [mm/mm]</td>
<td>9.05·10⁻³</td>
<td>6.71·10⁻³</td>
<td>6.30·10⁻³</td>
<td>4.55·10⁻3</td>
</tr>
<tr>
<td>Deformation [mm]</td>
<td>1.76</td>
<td>1.06</td>
<td>0.91</td>
<td>0.36</td>
</tr>
</tbody>
</table>
It can be noted that both factors – the diagonal support and layering of elementary units had significant influence on the results. The stresses in Structure A with one layer of elementary units without diagonal support were 23.89 MPa, while the strain value was 9.05•10^{-3} mm/mm and deformation was 1.76 mm. For Structure B with one layer and diagonal support, the values were 17.43 MPa, 6.71•10^{-3} mm/mm and 1.06 mm, respectively. The stresses in Structure B compared to Structure A are 27% lower, while the strain is 26% lower and deformation is 40% lower. The results for Structure B are shown in Figure 10. For Structure C with two layers of elementary units without diagonal support, the stress was 16.63 MPa, strain 6.30•10^{-3} mm/mm and the deformation was 0.91 mm. Stress in Structure C is 30% less than in Structure A, but only 5% greater than in Structure B. Strain value is 30% lower than for Structure A and only 6% lower than for Structure B. Deformation, on the other hand, is 48% less than in Structure A and 14% less than in Structure B. For Structure D with two layers of reinforced units, the stress was 11.86 MPa, so 27% less than in Structure C and 32% less than in Structure B. Strain value was 4.55•10^{-3} mm/mm, so 32% lower than for Structure B and 28% lower than for Structure C. The deformation in Structure D was 0.36 mm, so 60% less than in Structure C and 66% less than in Structure B.

**Figure 10:** FEM Results For Structure C – Above: Strain Results, Middle: Von Mises Stress Results, Be-Low: Deformation Results

From the information above, it can be concluded that it is more advantageous to use a core with one layer, but with an additional diagonal support than two layers without this support; then we obtain only 5% greater stresses and 6% greater strain values, while maintaining 19% less element weight. An additional layer of reinforced elements reduced stress and strain values by 32%, while deformation was reduced by more than 60%.

**3.2 Strain Gauge Testing:** When the samples were loaded with a force of 200 N, readings were obtained from strain gauges attached to the bottom of the samples. The readings for each sample are shown in Table 5 below.
Table 5: Strain Readings [mm/mm] of Strain Gauge Test for Each Sample

<table>
<thead>
<tr>
<th></th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 N</td>
<td>1.9·10⁻³</td>
<td>1.63·10⁻³</td>
<td>1.45·10⁻³</td>
<td>9.2·10⁻⁴</td>
</tr>
<tr>
<td>150 N</td>
<td>-</td>
<td>2.46·10⁻³</td>
<td>2.17·10⁻³</td>
<td>1.31·10⁻³</td>
</tr>
<tr>
<td>200 N</td>
<td>-</td>
<td>3.55·10⁻³</td>
<td>-</td>
<td>1.79·10⁻³</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Sample 5</th>
<th>Sample 6</th>
<th>Sample 7</th>
<th>Sample 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 N</td>
<td>9.3·10⁻⁴</td>
<td>6.47·10⁻⁴</td>
<td>7.25·10⁻⁴</td>
<td>4.96·10⁻⁴</td>
</tr>
<tr>
<td>150 N</td>
<td>1.24·10⁻³</td>
<td>9.29·10⁻⁴</td>
<td>1.08·10⁻³</td>
<td>8.11·10⁻⁴</td>
</tr>
<tr>
<td>200 N</td>
<td>-</td>
<td>1.22·10⁻³</td>
<td>-</td>
<td>1.16·10⁻³</td>
</tr>
</tbody>
</table>

From the table above, it can be seen that none of the samples with Structure A core (Samples 1, 3, 5 and 7) reached a force of 200 N - the failure of the samples occurred earlier. Sample 1 without reinforcement of any resin layer did not even reach 150 N. The diagonal support gives a noticeable strengthening of the entire structure - all samples reached a force of 200 N, even Sample 2 without resin layers. From the reading for a force of 200 N, it can be seen that a layer of pure epoxy resin gives a stiffening of the structure, and thus less deformation by 50% compared to PLA alone. It can also be noted that the 10% addition of carbon fiber powder reduces deformation relative to pure epoxy resin by 32% and relative to PLA alone by up to 66%. The addition of 20% powder reduced strain relative to the 10% addition by only 5%. Based on the results, the stiffness of each sample was calculated using Equation (1), \( k = \frac{F}{\delta} \) (1) where: \( F \) [N] – force acting on the body, \( \delta \) [mm] – the displacement produced by the force in the same direction. A graph was then drawn to show the change in stiffness of the specimen depending on the type of structure as well as the addition of the laminate layer. The results are shown in Figure 11.

![Figure 11: Stiffness to Weight Ratio of Each Sample](image)

In the graph, it can be seen that samples having Structure A are characterized by lower weight, but also lower stiffness reaching an average value of 117 N/mm (points on the left side of the graph). Samples having Structure B are characterized by a higher weight, but also significantly higher stiffness reaching an average value of 258 N/mm (points on the right side of the graph). The average stiffness of samples with Structure B is as much as 120% higher than those with Structure A.

3.3 Material’s Model Definition: Based on the reproduction of the results and readings from the strain gauges described in Section 3.2, the material properties for layers of epoxy resin and resin with carbon fiber powder additives were defined. The value of Young’s modulus was adjusted to obtain the strain values previously read from the strain gauges. The Figure 12 shows the results obtained for Sample 8. Result probes
were placed around the place where the strain gauge was mounted on the sample. The 4 probes indicated a result of about 1.16•10^{-3} \text{ mm/mm}, which was the target value for this sample.

![Figure 12: Strain Results for Sample 8](image)

The density of the defined resin was calculated at 0.65 g/gm3, while the Poisson ratio was 0.33. The Young's modulus for each additive layer material is presented in Table 6.

<table>
<thead>
<tr>
<th>Material</th>
<th>Young's Modulus [GPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>No coating PLA</td>
<td>1.55</td>
</tr>
<tr>
<td>Pure epoxy resin LG700</td>
<td>1.20</td>
</tr>
<tr>
<td>LG700 + 10% carbon fiber powder</td>
<td>2.00</td>
</tr>
<tr>
<td>LG700 + 20% carbon fiber powder</td>
<td>2.25</td>
</tr>
</tbody>
</table>

From the above, it can be seen that the addition of carbon fiber powder to epoxy resin has a significant effect on raising the Young's modulus of the resulting material. The Young's modulus of the resin with 10% addition of carbon fiber powder is 67% higher than that of pure epoxy resin. On the other hand, the Young's modulus of the resin with 20% addition is 12.5% greater than that of the resin with 10% powder addition.

3.4 FEM Analysis of the Driver's Seat: FEA analysis resulted in von Mises-reduced stresses and deformation in the model. The results are shown in Figure 13 below.

![Figure 13: FEM Results For Driver’s Seat – Top: Von Mises Stress, Bottom: Deformation](image)

The maximum stress was 7.28 MPa and occurred in the core structure in the back support area. The stresses did not exceed the permissible values. The maximum de-formation was 7.24 mm. The obtained results imply, that they do not exceed safe values for these materials that is tensile strength, and can be adopted as a seat material. It should be noted that the seat designed in this way reduces the weight of the component by 172 g, a reduction of about 25% compared to a seat made entirely of PLA. Covering the driver's seat with a layer of epoxy resin laminate with the addition of carbon fiber powder provides sufficient strength to the component, while the ability to 3D print makes it possible to produce a personalized part for Greenpower's small electric car.
4. Discussion: In the above article, the authors presented novel CFRP sandwich structures using FDM 3D printing. The design of a scalable elementary unit used in an FDM printed core is presented. Two concepts of the elemental unit in a truss concept were presented - a simple one and one with an additional diagonal support. During further testing - both FEA and experimental by strain gauging, it was observed that the diagonal support significantly increases the strength of the elementary unit as well as the entire structure in which it is used. During the initial FEA analysis, the properties of the structures were verified, and the possible benefits of successive layers of elementary units in the core were examined. In the following section, a method for manufacturing such structures is presented - 3D printing in FDM technology of a core of thermoplastic material, and then coating its outer layers with resin. Three different coating materials were tested - pure epoxy resin, resin with the addition of 10% and 20% carbon fiber powder. In an experimental study on a resistance strain gauge bench, the behavior of the structures under a force of 200 N was checked, as well as what deformations occur on the bottom surface of the component. From the results collected for a force of 200 N, it can be seen that a layer of pure epoxy resin gives a stiffening of the structure and thus less deformation by 50% compared to PLA alone. It was noted that 10% addition of carbon fiber powder reduces deformation relative to pure epoxy resin by 32%, and relative to PLA alone by as much as 66%. The addition of 20% powder reduced strain relative to the 10% addition by only 5%. The average stiffness of samples with Structure B is as much as 120% higher than those with Structure A. With the results collected, material parameters were reconstructed for individual layers of resin with additives, allowing these material models to be used in computerized strength testing of more complex geometries and components. As an example of the use of both the 3D printed CFRP sandwich structure fabrication technology with carbon fiber powder and the top layer material model, an FEM strength analysis of the Greenpower electric car driver’s seat was conducted. In future studies, the authors plan to test other designed core structures produced using the technology described above and to test yet more coating materials.


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Automated Dimension Measurement and Surface Defect Detection of Cast Metal Parts Using Computer Vision and Deep Learning

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Abstract: This paper presents a comprehensive method for detecting the centers of mounting holes in cast metal parts using computer vision and surface defects using deep learning. The proposed approach involves camera calibration, hole detection algorithm, and deep learning model for defect detection. The camera calibration is performed using a checkerboard image to correct projection effects and radial distortion. The hole detection algorithm accurately detects the centers of mounting holes in sub-pixel level accuracy by comparing the generated graph with a reference graph. The deep learning model, based on fine-tuned DETR architecture, successfully detects surface defects in metal parts. Experimental results demonstrate the effectiveness of the proposed method in accurately detecting mounting holes and surface defects.

Keywords: Quality Control, Deep Learning, Computer Vision, Defect Detection

1. Introduction: In this paper, we propose a method consisting of a computer vision algorithm for detecting the centers of mounting holes in metal parts and measuring their distances, as well as a deep learning model for detecting surface defects. The proposed method combines camera calibration, hole detection algorithms, and deep learning techniques to achieve accurate and efficient detection and measurement.

1.1 Background: In the field of manufacturing, automated quality control has gained significant attention due to its potential for cost reduction, high accuracy in defect detection, and system stability over time. Traditional methods for defect detection, such as computer vision, have limitations when it comes to detecting surface defects on metallic parts due to the surface texture and curvature (Çerezci et al., 2020). Deep learning techniques have emerged as a promising approach for defect detection, as they can learn complex patterns and features from large datasets (Martin et al., 2022). However, the accurate detection of mounting holes in metal parts using computer vision algorithms remains a challenge.

1.2 Motivation: The accurate detection of mounting holes in metal parts is crucial for various industrial applications, such as automotive manufacturing and electronics assembly. Traditional methods for hole detection rely on manual inspection, which is time-consuming and prone to errors. Therefore, there is a need for an automated and efficient method that can accurately detect the centers of mounting holes in metal parts.

1.3 Objectives: The main objective of this research is to develop a method that utilizes computer vision algorithms to detect the centers of mounting holes in metal parts and measure their distances accurately. Additionally, the research aims to develop a deep learning model for detecting surface defects on the metal surfaces. The proposed method will provide a comprehensive solution for quality control in manufacturing processes, enabling faster and more accurate detection of mounting holes and surface defects. To achieve these objectives, the proposed method incorporates camera calibration techniques to ensure accurate image acquisition (Jiang et al., 2011). The hole detection algorithm utilizes sub-pixel level accuracy to detect the centers of mounting holes (Lv et al., 2020). The deep learning model is trained using annotated datasets of surface defects to accurately identify and classify defects on metal surfaces (Çerezci et al., 2020; Martin et al., 2022). The combination of computer vision algorithms and deep learning techniques will provide a robust and efficient solution for detecting mounting holes and surface defects in metal parts. In the following sections, we will discuss the methodology, experimental results, and implications of the proposed method, highlight limitations, and suggest future research directions.
2. Related Work:

2.1 Computer Vision for Hole Detection: Computer vision techniques have been widely explored for hole detection in various applications. Traditional methods often rely on handcrafted features and image processing algorithms to identify and locate holes. However, these methods may struggle with accuracy and robustness when dealing with complex surfaces and varying lighting conditions (Feng et al., 2020). Recent advancements in computer vision have shown promising results in hole detection tasks. For instance, (Feng et al., 2020) proposed a subpixel computer vision detection method based on wavelet transform, which improved the accuracy of hole detection.

2.2 Deep Learning for Surface Defect Detection: Deep learning has emerged as a powerful approach for surface defect detection, surpassing traditional machine vision methods in terms of accuracy and performance (Tabernik et al., 2019). Deep learning models, such as convolutional neural networks (CNNs), have been successfully applied to detect and classify surface defects in various industries, including steel manufacturing and semiconductor inspection (Dey et al., 2022; Ye et al., 2018). These models can automatically learn discriminative features from large datasets, enabling them to detect subtle defects and generalize well to different defect types (Tabernik et al., 2019). For example, (Dey et al., 2022) demonstrated the application of Mask-RCNN, a deep-learning algorithm, to semiconductor defect inspection, achieving improved defect detection and classification.

3. Methodology:

3.1 Camera Calibration: Camera calibration is a critical step in ensuring accurate image acquisition for subsequent analysis. In this study, we employed a checkerboard image acquisition technique to calibrate the camera. The checkerboard pattern provides a known reference that allows for the calibration of the camera. By capturing images of the checkerboard pattern displayed on a retina monitor, we obtained a set of images that were used for subsequent calibration steps.

3.1.1 Checkerboard Image Acquisition: To acquire the checkerboard images, we carefully positioned the camera to capture the entire checkerboard pattern (Figure 1). Multiple images were captured from different angles and positions to ensure comprehensive coverage of the pattern. The acquired images were then used for camera calibration.

3.1.2 Projection Effect Correction: Projection effects can introduce distortions in the acquired images, affecting the accuracy of subsequent measurements. To correct for projection effects, we applied correction techniques to the acquired images. This correction step involved compensating for the perspective distortion caused by the camera’s position and angle relative to the object being imaged. By applying appropriate correction algorithms, we were able to rectify the acquired images and minimize the impact of projection effects on subsequent analyses.

3.1.3 Radial Distortion Correction: Radial distortion is another common type of distortion that can affect the accuracy of measurements. It occurs due to the non-linear mapping of light rays passing through the
camera lens. To correct for radial distortion, we employed algorithms that estimate the distortion parameters and apply the necessary corrections. By compensating for radial distortion, we were able to improve the accuracy of subsequent measurements and ensure more precise detection of mounting holes and surface defects.

3.1.4 Camera Calibration using discorpy: To achieve accurate camera calibration, we utilized the discorpy Python library. Discorpy provides a comprehensive set of tools and functions for camera calibration, including intrinsic and extrinsic parameter estimation. By utilizing discorpy, we were able to calibrate the camera using the acquired checkerboard images (Figure 2). The calibration process involved estimating the intrinsic parameters (e.g., focal length, principal point) and extrinsic parameters (e.g., camera position and orientation) of the camera. This calibration step ensured that subsequent measurements and analyses were performed with a properly calibrated camera, enhancing the accuracy and reliability of the results.

![Figure 2: Calibrated checkerboard image](image)

3.2 Mounting Hole Detection Algorithm: The mounting hole detection algorithm aims to accurately detect the centers of mounting holes in the cast metal parts. The algorithm consists of several steps, as described below.

3.2.1 Image Acquisition of Cast Metal Parts: Images of the cast metal parts, specifically passive coolers for automotive hifi systems, were acquired using the calibrated camera. These images served as input for the mounting hole detection algorithm. After the images are corrected for distortion and projection errors, their contrast is increased to make the detection of mounting holes easier (Figure 3).

![Figure 3: Original (left) and high contrast (right) image](image)

3.2.2 Outer Hole Detection and Reprojection: The algorithm first focuses on detecting the outer mounting holes, which are located at the outermost corners of the square part. By analyzing the acquired images, the algorithm identifies the outer holes and reprojects the square defined by their centers (Figure 4). This reprojection step allows for more accurate measurement of the distances between the inner holes.
3.2.3 Inner Hole Distance Measurement: Once the outer holes are detected and reprojected, the algorithm measures the distances between the inner holes. This is achieved by analyzing the reprojected square and calculating the distances between the centers of the inner holes. The algorithm considers the known dimensions of the mounting holes and uses geometric calculations to determine the distances accurately. To achieve high accuracy in hole center detection, the algorithm utilizes sub-pixel level accuracy techniques. Traditional image processing techniques often provide pixel-level accuracy, which may not be sufficient for precise hole detection. By employing advanced image processing and feature extraction methods, such as edge detection and sub-pixel interpolation, the algorithm can precisely locate the centers of the mounting holes in the acquired images. This sub-pixel level accuracy ensures more accurate measurements and enhances the overall performance of the mounting hole detection algorithm.

To determine whether a part is defective or not, the algorithm compares the generated graph, where each node represents a detected hole center, with a reference graph. The reference graph contains ideal x and y coordinates for each hole center. By comparing the detected hole centers with the reference graph, the algorithm can assess the accuracy of the hole detection and flag any deviations as potential defects. Assuming that the dimensions of the detected holes are within a certain tolerance of the nominal values, the part is flagged as non-defective. This graph comparison approach provides a reliable and objective criterion for defect flagging, ensuring the accuracy and consistency of the defect detection process (Figure 5).

3.3 Deep Learning Model for Surface Defect Detection: In addition to mounting hole detection, a deep learning model was developed for surface defect detection on the metal parts. The methodology for developing the deep learning model is as follows:

3.3.1 Dataset Preparation and Annotation: A dataset of images of the metal parts with surface defects was prepared. The dataset included various types of defects, such as wrinkles and stains, to ensure the model's ability to detect a wide range of surface anomalies. The images were carefully selected to cover different defect severities and orientations. Each image in the dataset was annotated to indicate the presence and
location of surface defects using VGG Image Annotator. The annotations provided ground truth information for training and evaluating the deep learning model.

3.3.2 Fine-tuning DETR Model: To detect surface defects, the DETR (Detection Transformer, Figure 6) model was chosen as the base architecture (Carion et al., 2020). The DETR model has shown promising performance in object detection tasks and is well-suited for our surface defect detection task. The pre-trained DETR model was fine-tuned using the annotated dataset of metal part images with surface defects. Fine-tuning allows the model to adapt to the specific defect detection task and learn to detect and classify surface defects accurately. By leveraging the pre-trained weights and fine-tuning on our dataset, we were able to expedite the training process and improve the model's performance.

3.3.3 Training Set Augmentation: To improve the generalization and robustness of the deep learning model, data augmentation techniques were applied to the training set. Augmentation involves applying various transformations to the training images, such as horizontal and vertical flipping, rotation, and scaling. These transformations help the model learn to detect defects from different perspectives and orientations, making it more robust to variations in the appearance of surface defects. By augmenting the training set, we were able to increase the diversity of the data and improve the model's ability to generalize to unseen samples.

3.3.4 Model Training and Optimization: The fine-tuned DETR model was trained using the augmented dataset. The training process involved optimizing the model's parameters to minimize the detection loss and maximize the accuracy of defect detection. The AdamW optimizer was employed (Loshchilov & Hutter, 2017), which combines the benefits of adaptive learning rates and weight decay regularization to improve the convergence and generalization of the model. The model was trained for a total of 4000 epochs, with a batch size of 4, to ensure sufficient exposure to the training data and convergence to an optimal solution.

3.3.5 Model Evaluation: To evaluate the performance of the deep learning model, mean average precision with 50% overlap (mAP-50) was used as the evaluation metric. mAP-50 measures the precision and recall of the model's predictions, considering the overlap between the predicted bounding boxes and the ground truth annotations. A higher mAP-50 score indicates better performance in detecting surface defects with high precision and recall. By evaluating the model using mAP-50, we were able to assess its ability to accurately detect and classify surface defects and compare its performance against other state-of-the-art models.

4. Experimental Results:

4.1 Camera Calibration Results: The camera calibration process was conducted using the checkerboard image acquisition technique and the discorpy library (Vo et al., 2015). The acquired checkerboard images were used to estimate the intrinsic and extrinsic camera parameters. The calibration results demonstrated the effectiveness of the calibration process in correcting projection effects and radial distortion. The calibrated camera exhibited improved accuracy and reduced distortions, ensuring more precise measurements in subsequent analyses.

4.2 Mounting Hole Detection Results: The mounting hole detection algorithm was applied to the acquired images of cast metal parts. The algorithm successfully detected the centers of the mounting holes with sub-pixel level accuracy. The distances between the inner holes were accurately measured, and the algorithm
compared the generated graph with a reference graph to flag any potential defects. The experimental results showed that the algorithm achieved high accuracy in detecting the mounting holes and effectively flagged defective parts.

4.3 Surface Defect Detection Results: The deep learning model for surface defect detection was trained and evaluated using the annotated dataset of metal part images with surface defects. The model achieved promising results in detecting the various types of surface defects, such as wrinkles and stains. The evaluation metric, mAP-50, indicated the model’s ability to accurately detect and classify surface defects with high precision (95.5%) and recall (96%) with an mAP-50 score of 20. The experimental results demonstrated the effectiveness of the deep learning model in detecting surface defects and its potential for industrial applications.

Figure 7: Three instances of defect detection. Note that under certain angles the model is not able to consistently detect all defects

5. Limitations and Future Work: While the proposed method showed promising results, there are some limitations that should be addressed in future work. One limitation is the reliance on annotated datasets for training the deep learning model. Acquiring and annotating large-scale datasets can be time-consuming and
resource intensive. Additionally, the proposed method may have limitations in detecting certain types of surface defects under certain angles that exhibit low contrast or complex textures. Further research could focus on improving the robustness of the deep learning model and expanding the dataset to include a wider range of defect types and variations.

6. Conclusion:

6.1 Summary of Contributions: In this study, we presented a comprehensive method for detecting mounting holes in metal parts using computer vision algorithms and surface defects using a deep learning model. The camera calibration process ensured accurate image acquisition, and the mounting hole detection algorithm achieved sub-pixel level accuracy in detecting the centers of mounting holes. The deep learning model demonstrated high accuracy in detecting various surface defects. The proposed method contributes to the field of automated quality control in manufacturing processes, providing a robust and efficient solution for detecting mounting holes and surface defects.

6.2 Implications and Applications: The proposed method has significant implications for various industries, including automotive manufacturing, electronics assembly, and quality control. Accurate detection of mounting holes and surface defects is crucial for ensuring product quality and reliability. The integration of computer vision algorithms and deep learning techniques in the proposed method offers a reliable and efficient solution for automated quality control processes. The method can be applied in real-time inspection systems, improving productivity, and reducing manual inspection efforts. Furthermore, the methodology can be extended to other domains that require precise detection and measurement of features in complex surfaces.

7. Acknowledgements: This work has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call “RESEARCH – CREATE – INNOVATE” (project code: T2EDK-04162)

8. References:


Casale Monferrato Remediation: Asbestos Pollution and Safety Measures to Protect Workers and Environment

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Abstract: Asbestos is a natural hazardous substance, which cause an environmental pollution creating a significant impact on human health. Asbestos has long been produced and marketed worldwide for its insulating, fireproof, chemical, and sound-absorbing and tensile strength. Because of its excellent and numerous characteristics it has been widely used, and in some Countries it still is, leaving behind serious health problems as well as complex remediation and management of asbestos containing waste (ACW). Asbestos is considered one of the most harmful occupational carcinogens causing more than 100,000 deaths per year and exposure to airborne asbestos fibers is held responsible for half of the deaths from occupational cancer (caused by mesothelioma, asbestos-related cancer and asbestosis). Because of this, this substance is now banned in 52 Countries, including Italy, which prohibited the extraction, and marketing of asbestos in 1992. Many areas have therefore been identified in this European Country as highly contaminated by asbestos. Among them also the area of Monferrato, which includes the Municipality of Casale Monferrato and 46 neighboring municipalities. The Eternit asbestos cement plant, located in the municipality of Casale, caused the contamination. The aim of this paper is to describe the complex remediation activities conducted in this wide area, located in northern Italy, highlighting the main phases and the most important issues during the remediation execution; moreover the purpose is to recall the appropriate prevention and protection measures to adopt to prevent new asbestos exposures and to emphasize their importance. This study can serve as an important reference for the academic participants involved in this field at European or international level.

Keywords: Asbestos, Remediation, Pollution, Safety measures

1. Introduction: In recent years, the media has brought to the forefront worldwide the issue of asbestos, highlighting various health and environmental concerns. The term "asbestos" refers to a group of minerals (Chrysotile, Crocidolite, Amosite, Tremolite, Anthophyllite, and Actinolite) whose commercial success has been determined by their unique technical characteristics, which are considered "unparalleled." These minerals are capable of withstanding fire, heat, chemical and biological agents, abrasion, and wear. They are also easily woven, possess sound-absorbing and thermal insulating properties, and readily bond with other substances such as lime, plaster, cement, and certain polymers like rubber and PVC. Due to their technical characteristics and low cost, various mixtures incorporating asbestos, primarily with cement, plastics, bitumen, and paints, were developed, leading to the production of over three thousand types of asbestos-containing products (ACPs), with asbestos content ranging from 10% to 99% by weight. These materials were mainly used in sectors such as shipbuilding, railway rolling stock, metallurgy, steelmaking, metalworking, automotive industry, military industry, asbestos-cement industry, construction, sugar refineries, agriculture, oil refineries, textiles, and the glass industry. The Industrial activity had a notable boost in the post-war era, during which asbestos was considered a strategic material. Estimated global consumption of asbestos minerals is currently around 1 million tonnes, mainly for asbestos-cement products. Chrysotile accounted in the past for more than 85% of all asbestos extracted and is at present mined and used predominantly in Asia and Eastern Europe. In recent years, the world leaders in the production of asbestos have been Russia, China, Brazil, Kazakhstan and India, while China is the first world consumer, with 570,000 tons used in 2015. The
asbestos extraction by these countries has been declining sharply, although the natural reserves remain enormous. The extraction of the mineral by these mentioned countries has been sharply declining, while the natural reserves of the mineral still remain enormous.

**Table 1: Global Production and Mineral Reserves in Tonnes (U.S. Geological Survey, Mineral Commodity Summaries, January 2022)**

<table>
<thead>
<tr>
<th></th>
<th>Mine production</th>
<th>Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2020</td>
<td>2021</td>
</tr>
<tr>
<td><strong>United States</strong></td>
<td>71,200</td>
<td>110,000</td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td>120,000</td>
<td>120,000</td>
</tr>
<tr>
<td><strong>China</strong></td>
<td>227,000</td>
<td>250,000</td>
</tr>
<tr>
<td><strong>Kazakhstan</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Russia</strong></td>
<td>720,000</td>
<td>700,000</td>
</tr>
<tr>
<td><strong>Zimbabwe</strong></td>
<td>8,000</td>
<td>10,000</td>
</tr>
<tr>
<td><strong>World total (rounded)</strong></td>
<td>1,100,000</td>
<td>1,200,000</td>
</tr>
</tbody>
</table>

Many epidemiological studies have demonstrated the carcinogenicity of these fibers, and as a result, it has been classified by European legislation (Regulation EC 1272/2008 concerning the "Classification, Labeling, and Packaging of Substances and Mixtures" - Table 1) into:

- **Hazard Category 1A** - known to be carcinogenic to humans, classification largely supported by human evidence:
- **Hazard Category STOT RE 1** - specific target organ toxicity, upon repeated exposure.

The hazard statements are:
- **H350**: may cause cancer;
- **H372**: causes damage to organs through prolonged or repeated exposure.

As a consequence, asbestos has left behind numerous problems related not only to health aspects but also concerning the remediation activities and disposal of Asbestos-Containing Waste (ACW).

2. **Context:**

2.1. **International legislation:**

Many countries have already banned the extraction and commercialization of asbestos (European Union, Japan, etc.) and are now engaged in remediation actions and management of Asbestos-Containing Waste (ACW). Historically, Europe has heavily utilized this substance, to the extent that between 1920 and 2000, it used over 50% of the asbestos commercially traded worldwide. Currently, it bears the largest global burden of asbestos-related diseases as a consequence of its extensive use and asbestos is the major cause of work-related cancer, with as much as 78% of occupational cancers recognised in the Member States. Within the European Union, which represents only 13% of the world population, the majority of asbestos-related deaths have been recorded, accounting for approximately 56% of global mesothelioma deaths and 41% of asbestosis deaths. In this context, the European Commission has banned the commercialization and use of products or substances containing asbestos since 2005. Currently, the final discussion is taking place in Brussels regarding the future Directive of the European Parliament and of the Council amending Directive 2009/148/EC on the protection of workers from the risks related to exposure to asbestos at work. At present, it is still being optimized. The current text briefly states that, after a two-year implementation period, the new Occupational Exposure Limit (OEL) of 0.01 asbestos fibers per cm³ will come into effect. After a transition period of six years, Member States will be required to use only electron microscopy, excluding phase-contrast optical microscopy, which is currently allowed. Later this six years, two options will be possible:
- reducing the asbestos limit value in air to 0.002 f/cm³, excluding the counting of thin fibers (<0.2 μm),
- setting it at 0.01 f/cm³ counting thin fibers (<0.2 μm). The regulation always emphasizes the importance of risk assessment, considering removal as the preferred option.

2.2. **Italian legislation:** In regards to Italy, it is important to note that in the past, approximately 3.7 million tonnes of raw asbestos produced between 1945 and 1992 were used, along with around 1.9 million tonnes
of imported raw asbestos during the same period, considering it as a strategic material. However, exports declined due to competition from Canada, and production levels gradually decreased, ultimately ceasing in 1992 with the ban on the substance. Most of Italy’s raw asbestos fibers were extracted from the Balangero site in Turin, which was the largest asbestos mine in Europe, and the Emarese site in the Aosta Valley. Today, many asbestos-contaminated sites still remain, requiring significant remediation and disposal of ACW. Many facilities that produced asbestos were left highly contaminated by companies, and the Italian government had to undertake their remediation to protect the surrounding urban residential areas. Among them, the most emblematic and internationally renowned case is the Casale Monferrato production plant in Piedmont. The safe management of this remediation involved the collaboration of multiple public administrations (Ministry of Environment, Region, Municipalities, Local Health Authorities, Regional Environmental Protection Agencies, etc.) with the technical and scientific support of national scientific institutions. It represents a significant case study that has led to the redevelopment of the territory, including land use recovery, resulting in positive health, environmental, and economic outcomes.

2.3. Casale Monferrato case of study: In 1998, the Casale Monferrato site was declared a Superfund Site (SS) to remediate, encompassing the territory of 48 municipalities with a total area of 739 km². It housed the Eternit and Fibronit plants, which accounted for over 40% of the national production of asbestos-cement products. This led to both occupational and environmental exposure: workers were exposed to pollution within the production facilities or from the dispersion of fibers from the open-air storage of production waste materials. Further dispersion of fibers occurred during the transportation of raw asbestos from the station to the plant or finished products from the plant to general warehouses located on the other side of the city, using uncovered vehicles. Reuse of jute sacks, originally containing crocidolite, for mail or agricultural purposes also contributed to additional airborne exposure. Further improper exposures were generated by the transportation and laundering of work overalls at home, the cultivation of gardens or other recreational activities along the contaminated riverbank, the reuse of non-intact and unsellable waste materials, and the use of "polverino" (a waste powder derived from asbestos processing) received for free from the plant and reused as insulating material for attics or paving courtyards. Moreover, the degradation of asbestos-cement roofs, which were widely spread across the area, also posed an additional risk.

3. Research aim: Casale Monferrato remediation: The remediation of the SS site involved the removal of both friable and compact asbestos-containing materials. The main activities carried out were:

1. The remediation of the Eternit plant and surrounding areas;
2. The remediation of the "Polverino" (asbestos waste powder);
3. The remediation of the asbestos-cement roofing in public and private buildings.

4 Methodology: Inail scientific consultancy activity: INAIL, together with the Local Health Agency and Local Environmental Agency, has conducted several inspections in the Casale National Superfund Site, which have identified the main risk situations and also developed "unusual" remediation procedures specific to the environmental context; in fact the wide area extension and high level contamination required site specific evaluation and remediation actions not defined by law. INAIL has also produced technical-scientific advices following applied for this site and then endorsed by the Ministry of the Environment as general Guidelines for all asbestos Superfund remediations. Inail produced more than 20 specific advices, realized more than 20 on-site surveys and participate more than 50 administrative meeting with regional, local and Ministerial administration to define the best strategy to renovate the entire area. Considering the high amount of indication prescribed, here are reported synthetically only the main precautionary and safety indications provided for the remediation of Ex Piemontese area and to identify and quantify the “polverino” still in place.

4.1. Ex Piemontese Data collection and analysis procedures: The remediation concerned an area of approximately 16,000 square meters with the presence of residential and school urban settlements frequented by young people. The asbestos-containing material was found both in friable matrix and in highly fragmented compact matrix, at depths of up to 1.40 meters, with a quantity of approximately 14,000 cubic meters. Below are the main prescribed measures:
• Operate with static and dynamic enclosures, not exceeding 10,000 cubic meters, in order to allow sufficient air exchange.
• Access to the entire "Ex Piemontese" area must only be through the Personnel Decontamination Unit (PDU) located at the site entrance, following the correct entry/exit procedures.
• Appropriate PDUs and Material Decontamination Units (MDUs) must also be set up at the entrance of each individual confined area (work lot).
• After the remediation of each lot, the concentration of asbestos in the soil must always be verified to be < 1000 mg/kg through sampling and analysis at the bottom and walls of the excavation.
• In confined areas, a certification of reusability of the areas must be carried out if the asbestos concentration in the air does not exceed 0.002 f/cm³. Ambient air sampling should be performed using high-flow pumps at a rate of 8-10 liters per minute, with a minimum of 3000 liters sampled, using polycarbonate or mixed cellulose ester filters and analysis using a scanning electron microscope (SEM).
• The ACW (asbestos-containing waste), properly packaged in big bags, must be deposited, categorized and separated by E.E.R. codes, in a statically and dynamically confined temporary storage area.
• After the removal of contaminated material and certification of reusability of the remediated area, the excavation must be covered with a layer of clean soil of at least 20 cm before any potential reuse of the area.
• Wastewater from the PDU must undergo purification using filtering systems capable of retaining particles equal to or larger than 3 microns. Regarding wastewater discharge into the sewer system, the limit to be adopted is 100 f/cm³.
• Workers must wear personal protective equipment (PPE) during their entire stay within the work area and during all work phases, ensuring that the PPE is kept in full working condition or promptly replaced, even during visual inspections or preliminary activities.
• A specific vehicle washing platform must be provided and installed in the immediate vicinity of the site entrance. For the aforementioned platform, if water reuse is intended, a treatment unit must be included that, at the final stage, retains fibers larger than 3 microns. It is necessary to conduct periodic sampling to monitor the clogging state of these filters, followed by SEM analysis on a bi-weekly or monthly basis.
• Before leaving the "Ex Piemontese" area, all vehicles, especially those used for the handling of excavated soil, must undergo thorough cabin vacuuming using a vacuum cleaner with HEPA absolute filters and complete washing (not just the wheels) at the designated platform at the entrance.
• Proper decontamination procedures must be followed for all PPE, equipment, and vehicles that will be used outside the work area after completion of the work.

4.2. “Polverino”: detection procedure in attics: The peculiarity of the Casale Monferrato Superfund Site lies precisely in the use of asbestos dust as residual of factory production in out-door area paving or as insulation in the attics of private residences. This latter case has led to the contamination of high amount of buildings included in the mentioned 48 municipalities. Most of the “polverino” used in in-door areas has already been removed using static and dynamic confined area or permanently secured (where it was too much complicated to remove). However, numerous situations still remain to be verified if still contaminated or not; so, they pose a potential source of environmental contamination and risks for the local health agency surveyors involved in the controls. To this end, a safety procedure has been agreed upon for inspecting the attics of residential buildings by technicians from the regulatory authorities, aimed at detecting any remaining asbestos dust in place. The procedure includes, among other things:
• Using personal protective equipment (PPE) such as a category III coverall (with a non-woven fabric of class 3 o 4 o 5), gloves, and a full-face mask with a P3 filter.
• Using a portable vacuum cleaner with absolute filters to vacuum the specific coverall.
• Spraying water on the outside of the coverall when exiting the contaminated area.
• Operators wearing a double coverall that should be removed at the end of the sampling process, ensuring that it is rolled down and outwards to contain the contaminated part inside. The used coverall should be immediately packaged in a dedicated sealed bag for disposal on the ground as asbestos-contaminated waste. All exhausted PPE must be classified with the EER code 15.02.02* - Absorbents, filter materials, rags, and protective clothing contaminated with hazardous substances.
• Removing the plastic sheet protecting the platform at the end of the inspection and packaging it in a double bag and subsequent big bags as soon as it reaches the ground.
• Closing and sealing the access point used for sampling to prevent the dispersion of friable materials in outdoor environments after completion of the operations. All materials used to seal the opening must be brought at the working height before the opening procedure.
• Managing and classifying the waste materials separately from the exhausted PPE. This procedure has been adopted by all local advisors assuring a higher safety level.

5. Findings: The remediation activities that involved both the Eternit and Fibronit plants and the surrounding areas, as well as various municipalities in the district, resulted in the remediation of a large part of the area. Specifically, the following asbestos-related materials were removed from the former industrial plants:
• Approximately 1,500 cubic meters of friable asbestos piles within the plants.
• 54,000 square meters of asbestos-cement roof, including 15,000 cubic meters of sheets that were disposed of in underground production and decantation basins, later buried and secured.
• 160,000 square meters of demolished surfaces.
• 12,000 cubic meters of friable asbestos from the right bank of the Po River, where an actual "asbestos beach" had formed due to the discharge channel of water from the nearby former industrial plants.
• 700,000 square meters of asbestos-cement roof coverings in public and private buildings. Furthermore, the remediation of the SS included approximately 25,000 square meters of insulated courtyards and attics containing "polverino," a material that contained about 10-15% asbestos. This material was present in more than 150 spots spread across all 48 municipalities. For the remediation activities at this site, approximately 47 million euros have been allocated to date, with funding provided by the Ministry of Environment and the Piedmont Region.
6. Conclusion: This Paper describes the complexity of the Environmental Remediation and Restoration activities carried out at the Superfund site of Casale Monferrato where the former asbestos cement factories Eternit and Fibronit were located. This so complex remediation started in the early ‘90, is still in progress, but the major source of fibre’s dispersion are eliminated and the asbestos concentration level in the town is now much lower than the european threshold limit value. This result has been achieved thanks to the cooperation among the Environmental Ministry which funded the remediation, and the regional and local agencies, coordinated by Inail-Dit to guaranty a maximum level of workers safety. This paper also show some technical procedures that could be reused in similar situations often encountered in other Countries, like the removal of “polverino” from buildings or how to prevent exposition of health local agencies workers, uncharged to check if asbestos is still present in the buildings. These procedures, applied in hundreds situations, can be considered strongly accurate and feasibly reproducible in other places. They could be considered useful not only for friable asbestos but also for the safe asbestos cement removal, guarantying the respect of the higher prevention and protection measures established by the new European Directive. This Directive will be soon approved and will require immediately lower asbestos threshold limits and new analytical technics for asbestos sampling and analysis using after the next six years only the electron microscopy.

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Resolution EU - P7_TA (2013) 0093 on asbestos related occupational health threats and prospects for abolishing all existing asbestos.
The Difference in Fitting a Surface with a Standard Topology and a Surface with a Matrix Topology

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Abstract. This paper presents the impact of the surface topology of the scanned 3D object on parametric fitting. Whether it is a simple NURBS (Non-uniform rational B-spline) or a more complex hierarchical spline version, it is important to apply the fitting procedure. Here we describe the differences between fitting a surface with a given topology as a result of a 3D scanning system and a matrix topology of the surface, where the original surface is replaced by the result of a preset number of sections of the original geometry.

Keywords. Topology, NURBS, hierarchical spline.

1. Introduction: Surface topology affects the results of many numerical methods. In this paper we describe the implications for fitting a parametric model to a scanned 3D model with different surface topologies. A brief introduction to the creation of a parametric NURBS model is given in this paper, while detailed information can be found in [1–3]. The work shows that the fit of the parametric model in the case of a free-form surface topology (original triangulation) depends on the density of the triangulation mesh and, also on the distribution of vertices in the surface mesh. As a result, the control points of the parametric model are grouped in areas with a higher density of grid points. In the case of a uniform distribution of vertices in the surface mesh, a uniform distribution of control points of the parametric model is to be expected. Using the matrix distribution of the vertices of the model surface in the fitting process leads to a more uniform distribution of the control points of the parametric model, independent of the density of the triangulated mesh.

2. Comparison of fitting with different topologies: In the following, we outline the definition of the standard NURBS parametric model, which is sufficient to demonstrate the effects of different surface topologies when fitting the parametric model to the given model surface. The NURBS surface is defined by its control points,
weight factors, degrees of polynomials and the set of knots,\
\[ C(u, v) = \frac{\sum_{i_0=0}^{n_0} \sum_{i_1=0}^{n_1} N_{i_0,p_u}(u) N_{i_1,p_v}(v) w_{i_0 i_1} Q_{i_0 i_1}}{\sum_{i_0=0}^{n_0} \sum_{i_1=0}^{n_1} N_{i_0,p_u}(u) N_{i_1,p_v}(v) w_{i_0 i_1}} \in \mathbb{R}^3 \] \hspace{1cm} (1)

where \( n_0, n_1 \) are the numbers of the control points, and \( N_{i_0, p_u}(u) \) and \( N_{i_1, p_v}(v) \) are the basic B-spline functions of degrees \( [p_u, p_v] \in \mathbb{N} \) defined by

\[ N_{i_0}(u) = \begin{cases} 1, & \bar{u}_i \leq u \leq \bar{u}_{i+1}, \\ 0, & \text{else} \end{cases} \]

\[ N_{i, p}(u) = \frac{u - \bar{u}_i}{\bar{u}_{i+p} - \bar{u}_i} N_{i, p-1}(u) + \frac{\bar{u}_{i+p+1} - u}{\bar{u}_{i+p+1} - \bar{u}_{i+1}} N_{i+1, p-1}(u). \] \hspace{1cm} (2)

The knots \( \bar{u}_i \in [0, 1] \), as part of the basic B-spline functions, we set as

\[ \bar{u} = \left\{ 0, \ldots, 0, \bar{u}_{p+1}, \ldots, \bar{u}_n, 1, \ldots, 1 \right\}, \quad \left\{ \bar{u}_i = \frac{i}{n} \right\}_{i=p+1} \]

Matrix \( Q \) presents control points.

\[ Q = \begin{bmatrix} Q_{00} & \cdots & Q_{0n_1} \\ \vdots & \ddots & \vdots \\ Q_{n_00} & \cdots & Q_{n_0n_1} \end{bmatrix} \in \mathbb{R}^{3(n_0+1) \times (n_1+1)}. \] \hspace{1cm} (4)

**Figure 1** shows an example of a model with the original surface density provided by the scanner system. It is the first example to which we fitted NURBS parametric model using two different surface topologies.

![Example of a Model with the Original Surface Density Provided By the Scanner System](image)

**Fig. 1:** *Example of a Model with the Original Surface Density Provided By the Scanner System*

The following equation shows the error function when fitting the NURBS model to the surface with the original surface topology, where \( P_j \) represents the vertices of the triangulated mesh.

\[ E_{freeform}(Q) = \frac{1}{2} \sum_{j=0}^{m} \left\| C(u_j, v_j) - P_j \right\|^2 \] \hspace{1cm} (5)

The next equation
\[ E_{\text{matrix}}(Q) = \frac{1}{2} \sum_{j_0=0}^{m_0} \sum_{j_1=0}^{m_1} \| C(u_{j_0j_1}, v_{j_0j_1}) - P_{j_0j_1} \|^2 \]  

Assumes that the model surface is represented in matrix form,

\[
P = \begin{bmatrix} P_{00} & \cdots & P_{0m_1} \\ \vdots & \ddots & \vdots \\ P_{m_00} & \cdots & P_{m_0m_1} \end{bmatrix} \in \mathbb{R}^{3(m_0+1) \times (m_1+1)}
\]  

Where \(m_0\) is the number of sections and \(m_1\) the number of vertices in each section (see figure Fig2).

**Fig. 2:** The Approach to Obtain the Matrix Topology of the Given Surface

The detailed description for the matrix form of the surface can be found in [2, 4]. The next figure below shows the result of fitting NURBS to the model with the original free form surface topology and matrix topology.

**Fig. 3:** The Result of NURBS Fitting To the Model with the Original Surface Topology and Matrix Topology
(a) NURBS with free form surface topology;
(b) NURBS with matrix form surface topology;
(c) Distribution of the distance between (a) and the original surface form Fig1;
(d) Distribution of distance between (b) and the original surface form Fig1.
The above example shows a small difference in the distribution of control points between two NURB models (Fig. 3a and Fig. 3.b), which leads to a small difference in the error distribution (Fig. 3c and Fig. 3.d). The larger difference in the distribution of control points and the corresponding geometry differences arise in the case of a thinner surface triangulation grid, as shown in figure Fig4. This kind of change affects the connection of multiple NURBS surfaces into a more complex hierarchical spline [5,6], the creation of models of displacement surfaces [7], and so on.

Fig. 4: The Result of NURBS Fitting to the Thinned Model with the Original Surface Topology and Matrix Topology
(a) The thinned surface of the surface from Fig.1;
(b) NURBS with free form surface topology;
(c) NURBS with matrix form surface topology;
(d) Distribution of the distance between b) and the original surface form a);
(e) Distribution of distance between c) and the original surface form a).

3. Future work: In the future, we plan to adopt our method of projection into a parametric rectangular domain based on harmonic mapping, so that the redistribution of vertices in 2D depends on whether the vertices belong to geometric features or not. In this way, we can avoid the need for the matrix form of geometry.

Effect of Cryogenic and Natural Aging Process Applied to Al-Zn-Mg-Cu Alloys on Life Time Calculation

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Abstract: In this study, life time calculation of aluminum 7075 alloy with cryogenic and natural aging processes was performed by thermal analysis. The aluminum alloy was quenched after solid solution treatment at 480°C and naturally aged for 10-100 days at room temperature (25°C). Other samples were cryogenically treated at -40°C and -80°C for 2 hours after solid solution treatment at 480°C. After the cryogenic treatment, natural aging was done at room temperature for 10-100 days. At the end of each period determined for the samples, the hardness values were measured. It was observed that there was no significant change in hardness values at the end of 10 and 100 days at -80 °C. Thus, it was determined that the natural aging process does not start after cryogenic treatment at -80 °C. It was observed that the hardness value of naturally aged samples after cryogenic treatment at -40 °C increased more than the natural
aged samples only. This showed that -40 °C improved the mechanism by creating a driving force in the material. Life time calculations between 30 °C and 500 °C also showed that -40 °C cryogenic treatment + natural aging increased life time by approximately 20% compared to natural aging alone.

**Keywords:** Al-Zn-Mg-Cu alloy, Cryogenic treatment, Natural aging, Life time calculation

1. Introduction: Al-Zn-Mg-Cu alloys are also included in the 7xxx series aluminum alloys group. Due to its features such as low density and high strength, it is frequently preferred in structural applications and in the aviation industry. Since this alloy is in the group of aging aluminum alloys, it is often used by applying aging heat treatment (Altuntas et al., 2022). Thanks to this heat treatment, the strength ratio increases and a wide usage area is formed (Chen et al., 2009). The aging heat treatment is divided into two groups as artificial and natural. With natural aging; Depending on the ratio of chemical elements, the solution heat treatment is carried out for 1 or 2 hours at (400-500 °C) in general, and water is given and supersaturated solid solution is formed (Altuntas et al., 2021). The main purpose of the solid solution heat treatment is to increase the solubility of the alloy by heating to high temperature, to dissolve the precipitates in the structure in a single phase and to obtain a supersaturated single-phase solid solution. If the alloy is allowed to cool slowly after solution treatment, coarse precipitates with negative mechanical properties are formed. As a result of rapid quenching, a supersaturated α-phase precipitate is obtained by not allowing the second phase to precipitate in the α solid. The α-phase is unstable due to the effect of flash cooling. The number of atomic cavities in equilibrium in the alloy increases logarithmically with the increase in temperature. The volume fraction of atomic vacancies during the solutioning process is quite high compared to their ratio at low temperatures. In this case, as the equilibrium conditions cannot be achieved as a result of the sudden cooling of the material from high temperatures, the excess of atomic vacancies remains in the structure. Atomic cavities, which are found in large amounts in the structure, are formed as a result of sudden cooling and move away from the structure over time. Atomic cavities that form point defects tend to come together and coalesce, and some of them absorb the atomic cavities and form the basis for the formation of dislocation rings. During quenching, the solid solution becomes unstable and tends to precipitate. It is then left to natural aging by keeping it at room temperature (Mackenzie et al., 2003). It takes about six months to achieve maximum hardness with this process (Mukhopadhyay et al., 2011). Artificial aging heat treatment, on the other hand, is carried out by giving water (80°C-200°C) after the solution heat treatment (holding for 1 or 2 hours between 400-500°C) and keeping the material for 12-24 hours. The aging time varies according to the temperature. By keeping the rapidly cooled alloy at a temperature above room temperature, precipitation takes place in a shorter time due to the increased diffusion rate. With both aging, the same phase occurs, which increases the strength of the material. In practice, artificial aging is frequently used to save time. But during natural aging, not only the size and number density, but also the type of clusters and GP zones can change over time, and this can have a profound effect on the metastable η' phase. It has been observed in different studies that the microstructural evolution and the form of the formed phases during natural aging have a deeper effect (Liu et al., 2015). The precipitation sequences formed during aging of Al-Zn-Mg-Cu alloys have been shown in many studies (Sha et al., 2004). It is well known that Guinier-Preston (GP) zones with hardening effect and metastable η' phase precipitates can form from supersaturated solid solution during aging (SSSS) (Couturier et al., 2017). In general, there are two types of GP zones. These are GPI zones and GPII zones. The sequences shown below are most likely to arise during aging.

SSSS → GPI zones → GP II zones → Metastable η' (MgZn2) → Stable η (MgZn2) consists of sequentially (Lendvai, 1996).

It has been reported that the effect on the highest strength increase is associated with the metastable η' phase (Li et al., 1999). The precipitation kinetics of the formation of this phase has been investigated in different studies (Khalfallah, et al., 2019). Thus, the activation energies, growth and nucleation kinetics of the phases are shown. The precipitate kinetics of the phases after secondary treatments were also investigated in different studies (Leyva-González et al., 2015). However, there are no studies on the precipitate kinetics
and life time calculation of the $\eta'$ phase after natural aging. With this study, information about the degradation time of the material depending on the temperature will be obtained through thermal analysis, especially with life time calculation in all material groups.

2. Experimental Studies: The Al 7075 alloy used in this study was purchased commercially. Solution heat treatment of samples cut in 10*10*10 mm3 dimensions was first performed in high temperature furnace at 480 °C for 2 hours. Then it was quenched and some of the samples were left to natural aging for 10 and 100 days at room temperature. These samples were coded as NA10 and NA100, respectively. Other cut samples were cryogenically treated at -40 °C and -80 °C for 2 hours after solution heat treatment and quenching. Then it was left to natural aging for 10 and 100 days. After each aging period, the mechanical change was controlled by measuring their micro hardness. However, there was no change in the mechanical hardness values of the samples that were cryogenically treated at -80 °C during this period. This showed that the aging mechanism could not start after cryogenic treatment at -80 °C. Therefore, these samples were not coded.

Due to the effective initiation of natural aging after cryogenic treatment at -40 °C, these samples were coded as CNA10 and CNA100, respectively. Hardness measurements were taken in the Qness hardness device according to the ASTM E384 standard. HITACHI DSC 7020 thermal analyzer was used for differential scanning calorimetry (DSC) experiments. The tests were carried out at a temperature range of 30 °C to 320 °C in an argon atmosphere with a heating rate of 5 °C/min, 10 °C/min, 15 °C/min, 20 °C/min. DSC analysis was carried out with samples of 10 mg mass enclosed in aluminum pans. With the data obtained through this analysis, first of all, the activation energies were found and a life time calculation was made.

<table>
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<tr>
<th>Elements (%)</th>
<th>Zn</th>
<th>Mg</th>
<th>Cu</th>
<th>Mn</th>
<th>Cr</th>
<th>Fe</th>
<th>Al</th>
</tr>
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<td>5.9</td>
<td>2.7</td>
<td>1.8</td>
<td>0.3</td>
<td>0.25</td>
<td>0.4</td>
<td>Balance</td>
<td></td>
</tr>
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</table>

3. Result and Discussion: Figure 1 shows the micro hardness values of the samples. The hardness of the NA10 sample was measured as 105 HV0.5, and the hardness of the NA100 sample was measured as 160 HV0.5. It was observed that the hardness value of the material increased as the natural aging time increased. This is an expected result as observed in the literature (Altuntaş et al., 2022). When we look at the hardness value after cryogenic treatment at -80 °C and 10 days of natural aging, the hardness value was measured as 100 HV0.5. After 100 days, the hardness value was measured as 108 HV0.5. It has been observed that the cryogenic process performed at -80 °C has a bad effect on the progression of natural aging. For this reason, life time calculations of the experiments carried out at -80 °C were not performed. After the cryogenic treatment at -40 °C and 10 days of natural aging, the hardness of the CNA10 sample was measured at 126 HV0.5. The hardness value after 100 days of natural aging was found to be 175 HV0.5. The results showed that cryogenic treatment at -40 °C is an effective force accelerating the aging mechanism. It is thought that the probability of formation of more $\eta'$ phases by triggering the formation of new nucleation points will increase the hardness.
As seen in Figure 2, the activation energy graph is shown with the data obtained as a result of the DSC analyzes performed in argon atmosphere with a heating rate of 5 °C / min, 10 °C / min, 15 °C / min, 20 °C / min. Table 2 shows the life time calculation of the NA10 sample between 30 °C and 320 °C. In general, it was observed that the life time value decreased as the temperature increased.

In general, the reaction rate of a sample according to Arrhenius’s law is expressed by the following equation:

\[
\frac{dx}{dt} = A \exp \left( -\frac{\Delta E}{RT} \right) \cdot f(x)
\]

Where

- \( x \) : quantity of reaction
- \( t \) : time
- \( A \) : frequency factor
- \( \Delta E \) : activation energy
- \( R \) : gas constant
- \( T \) : absolute temperature
- \( f(x) \) : function of \( x \)

In thermal analysis, \( T \) (temperature) is a function of \( t \) (time) and usually indicates the relationship \( \frac{dT}{dt} = B \) (constant). Here \( B \) is the heating rate (°C/min). Therefore, if the above expression is reserved for the variables \( x \) and \( t \), the following expression can be obtained:

\[
\int_{x_0}^{x_1} \frac{dx}{f(x)} = \int_{t_0}^{t_1} A \exp \left( -\frac{\Delta E}{RT} \right) dt
\]

\[
= \frac{A}{B} \int_{T_0}^{T_1} \exp \left( p - \frac{\Delta E}{RT} \right) dT
\]

So, if \( F(x) \) is defined as:

\[
F(x) = \int \frac{dx}{f(x)}
\]

and after changing the following variables, integration is performed according to the parts.

\[
\frac{\Delta E}{RT} = y
\]
\[ F(x_1) - F(x_0) = A \frac{\Delta E}{B R} \left[ P \left( \frac{\Delta E}{R T_1} \right) - P \left( \frac{\Delta E}{R T_0} \right) \right] \ldots \ldots \]

\[ P(y) = \frac{e^{-y}}{y} - \int_y^\infty \frac{e^{-y}}{y} \, dy \]

Since the relationship \( T_1 > T_0 \) is generally true, the 2nd term of the equation on the right is usually negligible, while the 1st term cannot be. Hence, the following relationship is obtained:

\[ \frac{A + \Delta E}{B R} P \left( \frac{\Delta E}{R T_1} \right) = F(x_1) - F(x_0) \ldots \ldots \]

If \( x_1 \) is calculated assuming \( x_0 = 0 \), the value of the right-hand member of the above equation will be a constant as follows:

\[ \frac{A + \Delta E}{B R} P \left( \frac{\Delta E}{R T_1} \right) = \text{const}. \]

Therefore, when the heating rate \( B \) is changed, the temperature \( T_1 \) with the reaction rate \( x_1 \) also changes proportionally, and therefore the value on the left side of equation does not change as a whole. Regarding \( P(y) \), the following approximate expression is known:

\[ \log P(y) = 2.315 - 0.467y \quad 20 < y < 60 \]

\[ \text{Const} = \log \frac{A + \Delta E}{B R} P \left( \frac{\Delta E}{R T_1} \right) \]

\[ = \log \frac{A + \Delta E}{B R} + \log P \left( \frac{\Delta E}{R T_1} \right) \]

\[ = \log \frac{A + \Delta E}{B R} - \log B - 2.315 - 0.467 \left( \frac{\Delta E}{R T_1} \right) \]

If we rearrange the above equation for heating rate \( B \) and temperature \( T_1 \), the following equation is obtained:

\[ \log B = -0.467 \frac{\Delta E}{R} + \frac{1}{T_1} + \text{constant} \]

If at least three measurements are made at different heating rates and the relationship between \( 1/T_1 \) and \( \log B \) of each pair of these data is plotted in x-y coordinates, the activation energy of a sample can be obtained from a plotted slope.

Area and partial area calculations are made by determining the temperature point where the phase transformation starts and ends (a-b). A set \((B_j, Y_i, X_{ij})\) is created for all data to be used in the calculation.

Where,

- j : Data No.
- Bj : Heating rate of j-th data (\( \text{°C/min} \))
- Yi : j number data obtained in step (4)
- Xij : X signal (\( \text{°C} \)) for Yi
- Convert Xij (temp) to the absolute temperature (\( \text{°C} \rightarrow K \))

\( X_{kij} = X_{ij} + 273.15 \)
\( Z_{ij} = \frac{1000}{X_{kiij}} \)

Plot the set \((Z_{ij}, \log B_{j})\) on \(x-y\) coordinates and approximate it linearly to each of \(i=1, 2, 3, \ldots, n-1\). Then, based on the following linear expression, find a value corresponding to \(P_i, q_i\):

\[
\log B = P_i + q_i + Z_{ij} \quad (i = 1, 2, 3, \ldots, n-1)
\]

Calculate the activation energy \((\Delta E)\). Each value of \(\Delta E_i\) for \(i=1, 2, 3, \ldots, n-1\) is calculated with the following expression:

\[
\Delta E_i = -\frac{R}{0.4567} \times q_i \text{ (kJ/mol)} \quad R = 8.31434 \text{ (kJ/mol)}
\]

The constant temperature degradation time \((\tau)\) is calculated as

The temperature to be kept is considered as \(T_c\) (\(^\circ\)C).

\[
B = \sqrt{\max B_j \times \min B_j} \quad \text{(use midpoint of logB)}
\]

\[
T_i = \frac{q_i}{\log B - P_i} \text{ (K)}
\]

Each respective \(\tau_i\) to \(i=1, 2, 3, \ldots\) \(\tau_i\) is calculated by the following expression

\[
\tau_i = \int_{T_0}^{T_i} \exp \left( -\frac{\Delta E_i}{RT} \right) dT \quad \text{Bexp} \left( -\frac{\Delta E_i}{R(T_c + 273.15)} \right)
\]

**Figure 2:** Activation energy graph of NA10 sample

**Table 2:** Life time calculation and activation energy values of NA10 sample in the range of 30-320°C

<table>
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<tr>
<th>R.F %</th>
<th>(\Delta E) kJ/mol</th>
<th>30°C day</th>
<th>40°C day</th>
<th>50°C day</th>
<th>60°C day</th>
<th>70°C day</th>
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<tr>
<td></td>
<td>R.F</td>
<td>ΔE</td>
<td>80 °C</td>
<td>90 °C</td>
<td>100 °C</td>
<td>110 °C</td>
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<td>---</td>
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<td>---------</td>
<td>---------</td>
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</tr>
<tr>
<td>20</td>
<td>97</td>
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<tr>
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<td>1.7E-05</td>
</tr>
<tr>
<td>80</td>
<td>118</td>
<td>1.7E-04</td>
<td>9.6E-05</td>
<td>5.6E-05</td>
<td>3.4E-05</td>
<td>2.1E-05</td>
</tr>
</tbody>
</table>
In Figure 3 and Table 3, activation energy and life time calculation values of the CNA10 sample, which was cryogenically treated and aged for 10 days, are shown. When we look at the values, it has been calculated that natural aging after cryogenic treatment at -40 °C increases the hardness and has a positive effect on life time. Up to 180 °C, the life time value of the CNA10 sample increased compared to the NA10 sample. In other words, the formation of more nucleation points by cryogenic treatment represents the formation of more η' phase, supporting the increase in life time value. It is thought that the degradation time of the η' phase, that is, the decrease in the life time value in the CNA10 sample after 180 °C, may have entered the extreme aging phase after this temperature (Wang et al., 2022). Formation of more η' phases by cryogenic treatment will require further reduction as degradation occurs or as overaging occurs. For this reason, there may be a greater decrease in the life time value compared to the NA10 sample.

### Figure 3: CNA10 numunesinin aktivasyon enerjisi grafiği

### Table 3: CNA10 numunesinin 30-320°C aralığında life time calculation ve aktivasyon enerjisi değerleri

<table>
<thead>
<tr>
<th>R.F</th>
<th>ΔE kJ/mol</th>
<th>280°C day</th>
<th>290°C day</th>
<th>300°C day</th>
<th>310°C day</th>
<th>320°C day</th>
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<tbody>
<tr>
<td>20</td>
<td>97</td>
<td>1.0E-05</td>
<td>6.9E-06</td>
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<tr>
<td>40</td>
<td>105</td>
<td>1.0E-05</td>
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<td>3.1E-06</td>
<td>2.2E-06</td>
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<tr>
<td>60</td>
<td>111</td>
<td>1.1E-05</td>
<td>7.1E-06</td>
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<tr>
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<td>Life Time</td>
<td>R.F</td>
<td>ΔE</td>
<td>kJ/mol</td>
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</tr>
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<tr>
<td>80°C day</td>
<td>20</td>
<td>6.6E+00</td>
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<td>100°C day</td>
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</tr>
<tr>
<td>110°C day</td>
<td>80</td>
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<tr>
<td>120°C day</td>
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<table>
<thead>
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<td>130°C day</td>
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<td>160°C day</td>
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<tbody>
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<tr>
<td>240°C day</td>
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<td>250°C day</td>
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<td>260°C day</td>
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<td>270°C day</td>
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<th>Life Time</th>
<th>R.F</th>
<th>ΔE</th>
<th>kJ/mol</th>
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<tr>
<td>280°C day</td>
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<td>300°C day</td>
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<td>310°C day</td>
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<td>320°C day</td>
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4. Conclusion:

Acknowledgements
This study has been financially supported by the Gazi University Scientific Research Projects Coordination Unit [under Project Number FDK-2023-7620].

5. Conflict of interest
The authors report no potential conflict of interest.

6. References


Comparison of Non-evaporating Spray Characteristics of Gasoline and Methanol for a Swirl Type GDI Injector

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Abstract: During the past decade, gasoline direct injection engines have gained significant traction in the automotive market owing to their advantages over traditional port fuel injection engines. The complex breakup and atomization process in gasoline direct injection engines hold a key role in characterizing the mixture formation (air-fuel mixing) and the ensuing combustion process. Therefore, this study focuses on the nonevaporating spray characteristics of methanol and gasoline for a pressure swirl atomizer. For this, a semi-empirical correlation of Sauter mean diameter suggested by Lefebvre is used under different injection pressures and ambient pressures. Moreover, the main spray tip penetration is calculated using an empirical correlation suggested by Gao et al. for methanol and gasoline. According to the results, with increasing injection pressure, the main spray tip penetration increases at each ambient pressure for gasoline. Sauter mean diameter values of methanol are somewhat higher than gasoline at each injection pressure. The increase in injection pressure decreases Sauter mean diameter for gasoline and methanol. The increase in ambient pressure results in an increase in Sauter mean diameter while a decrease in spray tip penetration for gasoline.

Introduction: Today, people around the world use fossil fuels for generating energy, and consequently, the reserves of fossil fuels are depleting at a swift pace. Increasing worries regarding the future accessibility of fossil fuel reserves along with the imperative to curtail exhaust emissions are driving the escalated adoption of renewable fuels [1]. Alcohols present an attractive alternative fuel for gasoline engines due to their benefits including high octane number over 100, generally less emissions when compared to gasoline, high evaporative cooling effect increasing volumetric efficiency, and low sulfur content. Moreover, alcohols can be obtained from both natural and manufactured sources. However, the low energy content, more aldehydes in the exhaust, and vapor lock in fuel delivery systems are some disadvantages of alcohol fuels [2]. Methanol, ethanol, and 1-propanol are lower alcohols (short-chain alcohols) while 1-butanol and 1-pentanol are higher
alcohols (long-chain alcohols). Gasoline engines are mainly used in passenger cars, small trucks, motorcycles, lawnmowers, and small generators [3]. Gasoline engines employ two distinct fuel injection strategies: Gasoline direct injection (GDI) and port fuel injection (PFI). GDI has gained increasing popularity in recent years due to its benefits over PFI as follows: the lower CO2 emissions, the reduced fuel consumption resulting from lower pumping losses, higher compression ratios, decreased octane number requirements, and improved volumetric efficiency. Moreover, the direct injection enables more precise control of the air-fuel mixture [4].

There are three possible injector categories used in direct injection spark ignition engines: multi-hole nozzle, the outwardly opening nozzle, and the inwardly opening pressure swirl injector. The last two produce a hollow-cone spray. Hollow-cone sprays have small droplet diameters, effective fuel-air mixing, reduced penetration, and thus enhanced atomization efficiencies [5, 6]. At present, the pressure swirl injector is commonly used in direct injection spark ignition engines [5]. Pressure swirl injector finds application in generating a hollow-cone spray. Inside the injector, there are internal swirl vanes responsible for inducing rotational movement in the liquid. The swirling motion compels the liquid towards the injector’s wall. The liquid forms a film along the inner walls of the injector with an air core in the center. This liquid film undergoes a transition into a free cone-shaped liquid sheet and eventually disintegrates into droplets (breakup), leading to the creation of a hollow cone spray [5, 6]. The initial and critical step in the injection of fuel is the breakup of the spray. Therefore, an in-depth understanding of the breakup mechanisms is of significance and necessity to enhance the mixture formation and improve the combustion process for a GDI engine. Moreover, SMD (Sauter mean diameter) is defined as the diameter of the droplet having the same surface-to-volume ratio as that of the overall spray [7]. The reduction in SMD results in greater surface area per unit volume [5]. Increased surface area leads to enhanced evaporation and improved mixture formation [5]. In other words, SMD shows atomization quality [8]. However, SMD does not offer insights into the distribution of droplet sizes within the spray [5]. In the existing literature, although numerical and experimental studies focusing on the diesel spray mechanism have been performed [9-11], relatively little has been reported for GDI engines. However, this study involves the comparative analysis of the atomization quality of methanol and gasoline under different operating conditions using a semi-empirical relation of SMD suggested by Lefebvre [12] for the pressure swirl injectors. Moreover, main spray tip penetration is calculated using an empirical correlation suggested by Gao et al. [13] for methanol and gasoline. This study can serve as essential preliminary research for further analyses that center on the mixture formation into GDI engines, as well as the performance, combustion, and emission characteristics of GDI engines fuelled with alcohol blends.

**Materials and Method:** Calculation of SMD and Main Spray Tip Penetration

In order to measure SMD, special and costly advanced equipment like a phase Doppler particle analyzer and CCD camera are required. However, in this study, SMD of a pressure swirl atomizer is computed by using the following semi-empirical relation suggested by Lefebvre [12]:

$$\text{SMD} = 2.25 \cdot \sigma^{0.25} \cdot \mu_l^{0.25} \cdot \dot{m}_l^{0.25} \cdot \Delta P^{-0.5} \cdot \rho_a^{-0.25}$$

(1)

where $\sigma$, $\mu_l$, $\dot{m}_l$, $\Delta P$, and $\rho_a$ are the surface tension (N/m), dynamic viscosity (Pa.s), mass flow rate of liquid (kg/s), difference between injection pressure and ambient pressure (Pa), and density of ambient gas (kg/m3), respectively [12]. For this study, the values of fuel delivery per injection and injection duration are taken as 56.8 mm3 and 3.86 ms, respectively [6].

In order to calculate the main spray tip penetration, an empirical correlation is used suggested by Gao et al. [13] as follows:

$$L = 0.027 \cdot \left( \frac{\Delta P}{\rho_a} \right)^{0.25} \cdot t^{0.5} \quad 0 < t < 3.5 \text{ ms}$$

(2)

where $L$ is the main spray tip penetration (m) and $t$ is the time after the start of injection (s). Gao et al. [13] suggested the correlation (Eq. (2)) under different injection pressures (2, 3.6, 4.6, and 5 MPa) and ambient pressures (0.1, 0.5, 1.0, 1.5, and 2 MPa) for the nonevaporating free spray of a Mitsubishi pressure swirl injector in a GDI engine fuelled with pure gasoline at 300 K (ambient temperature). Therefore, as will be seen
later in the Operating Conditions section, Eq. (2) is suitable to the conditions studied in this study. Moreover, it should be noted that only the main spray is taken into account as suggested by Gao et al. [13].

**Properties of Test Fuels:** In this study, the atomization quality of methanol is investigated and compared to gasoline by computing SMD. The required fuel properties of fuels in determining atomization quality are listed in Table 1 [13, 14].

<table>
<thead>
<tr>
<th>Properties</th>
<th>Gasoline</th>
<th>Methanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at 300 K (kg/m³)</td>
<td>770</td>
<td>787</td>
</tr>
<tr>
<td>Dynamic viscosity at 300 K (mPa.s)</td>
<td>0.50</td>
<td>0.5330</td>
</tr>
<tr>
<td>Surface tension at 300 K (mN/m)</td>
<td>23</td>
<td>22.51</td>
</tr>
</tbody>
</table>

**Operating Conditions:** In this study, the spray characteristics of methanol and gasoline are investigated at different injection pressures and ambient pressures for GDI pressure swirl injectors. The studied operating conditions are given in Table 2. These values given in Table 2 are selected from the following experimental studies [6, 15-20]. It should be noted that the hole diameter (0.5 mm) is for a Mitsubishi swirl-type GDI injector [16].

<table>
<thead>
<tr>
<th>Injector type</th>
<th>GDI Pressure Swirl Injector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection pressure (MPa)</td>
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</tr>
<tr>
<td>Ambient pressure (MPa)</td>
<td>0.5, 1, 1.5</td>
</tr>
<tr>
<td>Ambient temperature (K)</td>
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<tr>
<td>Hole diameter of the nozzle (mm)</td>
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</tr>
</tbody>
</table>

**Results and Discussion:** The variation of spray tip penetration depending on injection pressures (2, 3, 4, and 5 MPa) and ambient pressures (0.5, 1, and 1.5 MPa) for gasoline is shown in Figure 1. The spray tip penetration is calculated using Eq. (2). The spray tip penetration progressively rises over time following the injection, irrespective of injection pressure and ambient pressure. The spray tip penetration increases with increasing injection pressure under all investigated ambient pressures since the initial speed of the spray rises with rising injection pressure because of the increase in pressure difference [18]. Moreover, the spray tip penetration decreases under higher ambient pressure conditions compared to lower ambient pressures. This phenomenon occurs because elevated ambient pressure leads to a reduced pressure difference which decreases the fuel injection velocity [13]. Additionally, the increase in ambient pressure leads to greater ambient air density and an increased drag force on droplets which prevents penetration of spray into the combustion chamber [13]. For the injection pressure of 2, 3, 4, and 5 MPa, the maximum spray tip penetration is 33.6203 mm, 38.2000 mm, 41.5523 mm, and 44.2467 mm at 0.5 MPa ambient pressure; 25.5459 mm, 30.3793 mm, 33.6203 mm, 36.1273 mm at 1 MPa ambient pressure; and 19.4107 mm, 25.5459 mm, 29.0257 mm, and 31.5729 mm at 1.5 MPa ambient pressure, respectively.
Figure 1: Variation of Spray Tip Penetration Depending On Injection Pressure and Ambient Pressure

Figure 2 shows the comparison of SMD values of gasoline and methanol depending on injection pressures (2, 3, 4, and 5 MPa) at an ambient pressure of 0.5 MPa. SMD values are computed using Eq. (1). Regardless of fuel type, SMD values decrease with increasing injection pressure since the increase in injection pressure (the increase in pressure difference raises the fuel injection velocity) induces more instability factors and adequate energy for break-up process [21]. Moreover, at each injection pressure, SMD values of methanol are somewhat higher than those of gasoline since methanol has higher density and dynamic viscosity preventing break into the spray. The lowest SMD value is determined as 13.0908 µm for gasoline at the injection pressure of 5 MPa. Figure 3 shows SMD values of gasoline at different ambient pressures (0.5, 1, and 1.5 MPa) and a constant injection pressure of 2 MPa. An increase in ambient pressure (i.e. increase in ambient gas resistance) results in an increase in SMD due to a decrease in pressure difference and low spray kinetic energy [21].

Figure 2: Comparison of SMD Values of Gasoline and Methanol under Different Injection Pressures
Conclusions: Understanding spray characteristics is essential for optimizing mixture formation, enhancing combustion, and decreasing exhaust emissions in internal combustion engines. Therefore, this study investigates some spray characteristics of methanol and gasoline for a pressure swirl atomizer under different operating conditions. The main findings from this study include as following:

- **Injection pressure effects**: The spray tip penetration rises with rising injection pressure for gasoline under all ambient pressure conditions. However, for both fuels, SMD values decrease with higher injection pressure due to increased instability and greater energy for the breakup process.

- **Ambient pressure effects**: Higher ambient pressure leads to decreased spray tip penetration for gasoline due to the higher drop drag force. Moreover, higher ambient pressure increases SMD for gasoline.

- **Fuel type**: Methanol exhibits slightly higher SMD values compared to gasoline at each injection pressure, primarily due to the higher density and viscosity of methanol.

The numerical investigations of spray characteristics of alternative fuels for GDI engines using computational fluid dynamics can be studied under various operating conditions in future studies.

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Anomaly Detection on Images

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Abstract: Anomaly detection in images has started to be used frequently in many fields such as agriculture, health and security. Along with the developing technology, much progress has been made in this field in a short time, and many methods have been developed as a result of studies on anomaly detection. In this study, a compilation of current anomaly detection techniques adapted for image data is made. While making an evaluation of the existing methods, Producer Contention Networks were also examined in detail. Anomaly detection can be examined in two main branches as traditional methods and modern approaches. While its traditional methods create techniques such as Statistical Methods and Texture Analysis, modern approaches include Machine Learning, Convolutions Neural Networks and Autoencoders. In this study, modern approaches are included. In addition, Producer Contested Networks, which have developed in recent years and are used in anomaly detection, are given in detail along with their varieties. However, the usage areas, efficiency, advantages and disadvantages of these methods are given together. Finally, some ideas for future work are presented.

Keywords: Anomaly Detection, Generative Adversarial Networks, Image Anomaly

References:
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Facile Synthesis of an Efficient Antimicrobial Agent as a Promising Therapeutic Drug: Preparation, In Vitro Antimicrobial Evaluation, In Silico Molecular Docking, Drug-Likeness, Pharmacokinetics and Toxicology Prediction

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Abstract: Nowadays, antimicrobial resistance in pathogenic bacteria poses a big challenge to discover and design novel antimicrobial agents. The use of transition metals with biologically active ligands is yielding an
unprecedented progress in biological applications. New compounds are developed, with higher biological activity compared to the free ligands. Sorbates are well-known antimicrobial agents, widely used in Food and pharmaceutical landscape. However, metal complexes based on sorbates are far less explored in this regard. This article deals with the coordination behavior of sorbate ligand with copper (II) cation. A variety of techniques were utilized to characterize the Cu(II) sorbate complex. The antimicrobial properties of sorbate and its Cu(II) complex were studied in vitro, the complex showed promising antibacterial activity with a quite low MIC value, compared to the free ligand. The structure of the two compounds were subjects to density functional theory (DFT) optimization to prepare them for molecular docking. The optimized structures of both ligand and Cu(II) complex were docked on the active site of DNA gyrase B (PDB ID: 6KZV), to identify the possible interactions causing the inhibition of the tested bacteria. These results were complemented with in silico prediction of drug-likeness pharmacokinetic and toxicity of the newly compound. The findings presented in this study showed that the designed coordination complex might be used not only as potential antibacterial agent but also as a novel therapeutic drug.

Keywords: Drug discovery, Copper-sorbate complex, Crystal structure, Antibacterial resistance, In silico prediction.

Quantitative Analysis of Microvesicles Storage Stability

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Purpose: Currently, microvesicles of human cells are attracting increased attention of researchers and physicians around the world. Microvesicles (MV) are spherical structures surrounded by a cytoplasmic membrane, released from the cell surface, contain the cytoplasmic content of the parent cell and have a size of 50-2000 nm. The use of MVs from mesenchymal stem cells in medicine as therapeutic agents and drug delivery vectors is of great interest. However, a quantitative assessment of the stability of isolated MVs in solution remain limited investigated. Therefore, the aim of our work is to evaluate the storage stability of MVs-MSCs under various storage conditions within 112 days.

Keywords: Microvesicles, Mesenchymal Stem Cells, Drug Delivery Vectors.

Material & Methods: Microvesicles were obtained by treating MSCs with 10 µg/ml cytochalasin B as described previously. Cytochalasin B is an agent for the cell cytoskeleton disorganization and used in the mass production of MVs. Obtained MVs were resuspended in saline and stored under different conditions at: -20°C, 4°C, 25°C, and 37°C, freeze dried and stored at -20°C. Quantity of MVs was analyzed using flow cytometry with enhanced detector (BD FACS Aria III BD Bioscience, USA).

Results: We found that after 7 days of storage at 37°C only 30% of MVs remained intact. Storage at 25°C for 28 days allowed only 47% of the original amount of MVs to be retained, whilst storage at 4°C kept 59% of the MVs and extended the MVs shelf life to 112 days. Freeze-drying resulted in 49% of the intact MVs been retained. Whereas freezing of MVs suspended in saline at -20°C retained 79.5% MVs after 112 days of storage.

Conclusion: Thus, the storage of MVs-MSCs in saline at -20°C for at least 112 days is the most suitable retention condition for MVs.

Funding: This work was funded by Russian Government Program “Recruitment of the Leading Scientists into
Exosome‐Like Particles Remain in Fetal Bovine Serum after Depletion by Ultracentrifugation

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Introduction: Extracellular vesicles (EVs) are widely studied as carriers of cellular signals involved in many physiological and pathological processes. EVs of cultivated cells are isolated from conditioned medium containing fetal bovine serum (FBS), which is known to contain its own xenobiotic EVs. In order to eliminate EVs of FBS from nutrient medium, FBS was ultracentrifugated 18h at 100,000g, +4°C. The aim of this study was to determine whether 18h of ultracentrifugation completely eliminate EVs from nutrient medium.

Materials and methods: To prepare EVs-depleted FBS, 50 ml of FBS was centrifuged for 18h at 100,000g in an Optimal L-90K ultracentrifuge (Beckman Coulter). Next, the supernatant was taken and full medium DMEM containing 2 mM L-glutamine, 10% FBS, 1x mixture of antibiotics penicillin and streptomycin was prepared. Amount of EVs was assessed using nanoparticle tracking analysis (NTA) using NanoSight LM-10.

Results: We found exosome‐like particles in the medium prepared using EVs-depleted FBS. The amount of exosome‐like particles was 3,2x10¹⁰ particles/ml with 70±45 nm in size. The obtained data indicate that ultracentrifugation of FBS at 100,000g during 18h does not lead to complete elimination of xenobiotic EVs. Thus, the presence of residual exosome‐like particles of FBS in the nutrient medium can introduce a significant inaccuracy in the calculation of yield of EVs derived from cultivated cells.

Funding: This work was funded Russian Government Program “Recruitment of the Leading Scientists into the Russian Institutions of Higher Education” (grant number 075-15-2021-600).

Disclosure: The authors confirm that they have no conflict of interest.

Ultrasound-Mediated Generation of Membrane Vesicles from Human Cells

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Introduction: Extracellular vesicles (EVs) produced by cells are natural carriers of biological molecules. Due to their ability to encapsulate various substances and penetrate physiological barriers, they are widely studied as drug delivery vehicles. However, the introduction of EVs into clinical practice is difficult due to the lack of an industrially adapted production method, which ensures their obtaining in meaningful amounts, integrity, homogeneity, and preservation of biological activity of vesicles. Therefore, the goal of our work was to increase the yield of vesicles by ultrasound-mediated generation of membrane vesicles from human cells.

Materials and methods: We isolated natural EVs from conditioned medium obtained as a result of 48-hour incubation of murine adipose tissue MSCs in exosome-depleted medium by ultracentrifugation at 100,000g for 16 h. Natural EVs were isolated by sequential centrifugation at 1) 150g - 10 min; 2) 150g - 20 min; 3) 2300g - 10 min; 4) 10,000g - 45 min; 5) 100,000g - 90 min. To generate vesicles, a suspension of adipose mesenchymal stem cells was treated by ultrasound (US) using a Sonopuls HD 2200 ultrasound homogenizer with a working frequency of 20 kHz for 1 min at 4°C in the mode: amplitude 20%, cycle 5 (working step - 0.5 sec, idle step - 0.5 sec). The vesicles were precipitated by centrifugation at 10,000 g for 45 min and resuspended in DPBS followed by filtration (pore size 1 μm). The morphology of the US-induced vesicles was examined using a Merlin analytical scanning auto emission electron microscopy system. The concentration and size of US-induced vesicles were analyzed using NanoSight LM10.

Results: We found that the US-induced vesicles were round-shaped membrane structures. The average particle size was found to be (115±52 nm) and the number of vesicles was 54,000 particles/cell. The exit of natural vesicles was 55,400 particles/cell.

Conclusion: The method of US-induced vesicles processing makes it possible to obtain vesicles, in a short period of time and with less labor, which makes it a promising way of mass production of vesicles, stimulating their introduction as a means of drug delivery into clinical practice.

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Combination "Resistant Variety X Botanical Treatment": A Simple Integrated Management Method of Fusarium Wilt of Onion

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Abstract: Onion is one of the major vegetables grown in Burkina Faso with an average production of 362,480T. In field, fungi cause between 10 and 23% annual crop losses, in addition to 10 to 20% post-harvest losses. The use of synthetic fungicides remains the main means of combating these pathogens, however, with multiple consequences: development of resistance and toxicity for humans, the environment and animals. Face to these problems and to boost onion production, the use of control practices that are consistent, sustainable, adapted to small farmers and ensuring healthy protection of the crop is needed. The present study aimed to demonstrate to farmers and agricultural support agents that by combining varietal resistance with an antifungal treatment based on plant extract, it is possible to effectively combat Fusarium wilt and significantly increase production. For this, the reaction of five local cultivars to Fusarium wilt was evaluated with a view to identifying those resistant or tolerant, botanical extracts were evaluated in seed or plant treatment, in order to identify those capable of effectively combating Fusarium wilt, and, finally, different “cultivar-antifungal treatment” combinations were evaluated in order to determine the best combination for integrated management of Fusarium wilt. According to the results obtained, the Zimtanga cultivar was more tolerant to the disease than the Violet de Galmi variety, recognized as a susceptible variety. Treatment with essential oils of L. multiflora and O. americanum contributed to reduce damping offs to 10-15% compared to 50% for the untreated control, with an increase in bulb production of 199.11-204.32 g and 85.31-145.15 g, respectively, compared to the untreated control, with only 30.31-62.73 g of bulbs. Among the combinations, “Zimtanga- L. multiflora essential oil”, significantly reduced damping off and increased bulb production. Thus, the study showed that there is an integrated method to effectively combat Fusarium wilt of onions in Burkina Faso.

Keywords: Onion, Antifungal Treatment, Essential Oils, Fusarium Wilt, Integrated Control
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