COMETa 2022

6th INTERNATIONAL SCIENTIFIC CONFERENCE

17th - 19th November 2022

Jahorina, B&H, Republic of Srpska

University of East Sarajevo

Faculty of Mechanical Engineering

Conference on Mechanical Engineering Technologies and Applications

# CONFERENCE PROGRAM COMETa 2022

17th – 19th November 2022.

East Sarajevo – Jahorina, B&H, RS

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**November 17, 2022 (Thursday)**

09:00 – 10:30 - Registration
10:30 – 11:30 - Opening Conference
11:30 – 12:00 - Welcome Cocktail
12:00 – 14:00 - Plenary Session
14:30 – 16:00 - Lunch
16:30 – 18:00 - Technical Session I-1 (Conference Room No. 1)
Manufacturing technologies and advanced materials
16:30 – 18:00 - Technical Session II (Conference Room No. 3)
Applied mechanics and mechatronics
16:30 – 18:00 - Technical Session III-1 (Conference Room No. 2)
Product development and mechanical systems
20:00 - Dinner

**November 18, 2022 (Friday)**

09:00 – 10:00 - Registration
10:00 – 11:30 - Technical Session I-2 (Conference Room No. 1)
Manufacturing technologies and advanced materials
10:00 – 11:30 - Technical Session III-2 (Conference Room No. 2)
Product development and mechanical systems
10:00 – 11:30 - Technical Session IV (Conference Room No. 3)
Renewable energy and environmental protection
11:30 – 11:45 - Coffee Break
11:45 – 12:25 - Presentation of company - TRB - Technical Overhaul Bratunac (Conference Room No. 1)
12:30 – 14:00 - Technical Session V (Conference Room No. 1)
Quality, management, organization and maintenance
12:30 – 14:00 Technical Session VI (Conference Room No. 2)
Student section
12:30 – 14:00 - Technical Session VII
Poster Session (Conference Room No. 3)
14:30 – 16:00 - Lunch
15:30 - Free activities
20:00 - Gala Dinner

**November 19, 2022 (Saturday)**

10:00 - Free activities – Visit to Sarajevo

**November 17, 2022 (Thursday) (Conference Room No.1, 12:00 – 14:00)**

**PLENARY LECTURES**

1. **Alkiviadis Tsamis**, University of Western Macedonia, Kozani, Greece
   **MICROSTRUCTURE-BASED ENGINEERING OF SOFT BIOLOGICAL MATERIALS**

2. **Milan Zdravković**, University of Niš, Faculty of Mechanical Engineering, Niš, Serbia
   **AI-ENABLED ENTERPRISE INFORMATION SYSTEMS FOR MANUFACTURING**

3. **Tomaž Vuherer**, University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
   **DIFFERENT WAYS FOR HAZ MICROSTRUCTURE PREPARATIONAND TESTING ON HIGH ALLOY STEEL**

4. **Sanjin Troha**, University of Rijeka, Faculty of Engineering, Rijeka, Croatia
   **Željko Vrcan**, University of Rijeka, Faculty of Engineering, Rijeka, Croatia
   **Milan Tica**, University of Banja Luka, Faculty of Mechanical Engineering, Banja Luka, Bosnia and Herzegovina
   **Miroslav Milutinović**, University of East Sarajevo, Faculty of Mechanical Engineering, Banja Luka, Bosnia and Herzegovina
   **POSSIBILITIES FOR THE APPLICATION OF REVERSIBLE PLANETARY TWO-SPEED GEARBOXES**

**November 17, 2022 (Thursday) (Conference Room No.1, 16:30 – 18:00)**

**Session I-1: MANUFACTURING TECHNOLOGIES AND ADVANCED MATERIALS**
Chairpersons: Milan Zeljković, Mladomir Milutinović, Saša Živanović

1. **Panagiotis Chatzisavvas, Stefanos Gerardis, Alkiviadis Tsamis**
   INVESTIGATING MECHANICAL RESPONSE AND COLLAGEN STRUCTURE IN THE INTESTINAL WALL
2. **Saša Živanović, Goran Vasilić, Branko Kokotović, Nikola Vorkapić, Zoran Dimić, Nikola Savković**
   CONFIGURING AND VERIFICATION OF A RECONFIGURABLE MACHINE WITH HYBRID KINEMATICS MOMA V3
3. **Slobodan Tabaković, Saša Živanović**
   COLLABORATIVE ROBOTS IN MACHINING TASKS APPLICATION AND PROGRAMMING
4. **Nemanja Dačević, Marko Vilotić, Mladomir Milutinović, Luka Sevšek, Ljiljana Stefanović, Dragiša Vilotić**
   NUMERICAL ANALYSIS OF PLANE STRAIN MULTI-DIRECTIONAL UPSETTING OF PRISMATIC SAMPLES
5. **Elisaveta Doncheva, Aleksandra Krstevska**
   AN OVERVIEW OF ADVANCED JOINING TECHNIQUES FOR POLYMER AND COMPOSITE MATERIALS
6. **Aleksandar Vencl, Blaža Stojanović, Slavica Miladinović, Damjan Klobčar**
   PREDICTION OF THE WEAR CHARACTERISTICS OF ZA-27/SiC NANOCOMPOSITES USING THE ARTIFICIAL NEURAL NETWORK

7. **Miloš Pjević, Mihajlo Popović, Mladomir Milutinović, Dejan Movrin, Ljiljana Stefanović**
   EXPERIMENTAL EXAMINATION OF THE APPLICABILITY OF ADDITIVE TECHNOLOGIES IN THE FIELD OF RAPID TOOLING - INJECTION MOLDING
8. **Miloš Pjević, Mihajlo Popović, Radovan Puzović**
   CORRELATION BETWEEN MICRO-CUTTING AND STATIC INDENTATION
9. **Uros Zuperl, Miha Kovačič**
   AN INTELLIGENT ROBOTIC CELLS WITH TRANSPORT SYSTEM FOR FULLY AUTOMATED CUTTING TOOL ASSEMBLY
10. **Uros Zuperl, Goran Munđar**
    PLATFORM FOR TOOL WEAR MONITORING VIA CUTTING FORCE CONTROL
11. **Goran Munđar, Uroš Župerl**
    DEVELOPMENT AND CONTROL OF A VIRTUAL INDUSTRIAL SORTING PROCESS

**November 17, 2022 (Thursday) (Conference Room No.3, 16:30 – 18:00)**

**Session II: APPLIED MECHANICS AND MECHATRONICS**
Chairpersons: Branimir Krstić, Novak Nedić, Nebojša Radić

1. **Goran Šiniković, Nenad Gubeljak, Emil Veg, Ivan Milanković, Mladen Regodić**
   DESIGN OF THE MECHATRONIC SYSTEM FOR ACCESS CONTROL TO PROTECTED AREAS OF PRODUCTION LINES
2. **Isak Karabegović, Raul Turmanidže, Predrag Dašić**
   ANALYSIS OF PATENT TRENDS FROM INDUSTRY 4.0 AND THE IMPLEMENTATION OF ROBOT TECHNOLOGY IN THE COUNTRIES OF CHINA, USA, JAPAN, REPUBLIC OF KOREA AND GERMANY
3. **Branimir Krstić, Lamine Rebhi, Younes Djemaoune, Mirko Dinulović**
   FINITE ELEMENT ANALYSIS OF HELICOPTER AEROSPATIALE GAZELLE SA 341H SKID LANDING GEAR DURING NORMAL LANDING USING STATIC LOAD APPROXIMATION
4. **Dragan Rakić, Miroslav Živković, Milan Bojović, Slobodan Radovanović, Aleksandar Bodić, Nikola Milivojević, Dejan Divac**
   STABILITY ANALYSIS OF CONCRETE ARCH DAM USING FINITE ELEMENT METHOD
5. **Jelena Erić Obućina, Stevan Stankovski, Gordana Ostojić**
   SPEED CONTROL OF AC MOTOR IN HYDRAULIC SYSTEM BY USING U/f CONTROL METHOD IN MATLAB SIMULINK
6. **Vule Reljić, Đorđe Dostanić, Slobodan Dudić, Jovan Šulc, Ivana Milenković, Vladimir Jurošević**
   REMOTELY-CONTROLLED ONE-WAY FLOW CONTROL VALVE – THE FINAL VERSION OF THE PROTOTYPE
7. **Janani Rajaraman, Saša Prodanović, Ljubiša Dubonjić**
   DESIGN OF FRACTIONAL - ORDER PI CONTROLLER FOR MULTIVARIABLE PROCESS
8. **Nikola Vučetić, Gordana Jovičić, Ranko Antunović, Vladimir Milovanović, Branimir Krstić, Dejan Jeremić**
   TESTING OF THE FATIGUE PROPERTIES OF ALUMINUM ALLOY 242.0 WITH THE PURPOSE OF THE INTEGRITY ASSESSMENT OF AN AIRCRAFT CYLINDER ASSEMBLY WITH A CRACK

9. **Jelena Živković, Vladimir Dunić, Vladimir Milovanović, Miroslav Živković**
   PHASE-FIELD MODELING OF DAMAGE IN ALUMINUM ALLOY
10. **Rade Vasiljević**
    CONTROL AND AUTOMATION OF THE LIFTS: BASIC TECHNOLOGY AND NEW ACHIEVEMENTS
11. **Zorana Mandić, Slobodan Lubura, Nikola Kukrić**
    MODULAR MECHATRONIC SYSTEMS WITH AN INDUSTRIAL-ORIENTED APPROACH
12. **Milan Simović, Slobodan Lubura**
    PROGRAMMING THE OPERATOR PANEL FOR CONTROL AND MONITORING THE OPERATION OF PUMPING STATIONS USING THE WINCC (TIA PORTAL) SOFTWARE PACKAGE

**November 17, 2022 (Thursday) (Conference Room No.2, 16:30 – 18:00)**

**Session III-1: PRODUCT DEVELOPMENT AND MECHANICAL SYSTEMS**
Chairpersons: Biljana Marković, Fuad Hadžikadunić, Nenad Marjanović

1. **Nikola Korunović, Jovan Aranđelović**
   STRUCTURAL ANALYSIS AND OPTIMIZATION OF IMPLANTS USED IN TREATMENT OF LONG BONES FRACTURES
2. **Goran Pavlović, Mile Savković, Nebojša B. Zdravković, Goran Marković**
   ANALYSIS AND OPTIMIZATION OF GEOMETRIC PROPERTIES OF A CRANE END TRUCK OF A TOP RUNNING DOUBLE-GIRDER OVERHEAD CRANE
3. **Mirjana Bojanić Šejat, Ivan Knežević, Aleksandar Živković, Milan Rackov, Imre Kiss**
   ANALYSIS OF THE CLEARANCE INFLUENCE ON THE FOUR POINT CONTACT BALL BEARING DYNAMIC BEHAVIOR
4. **Blaža Stojanović, Aleksandar Vencl, Aleksandar Skulic, Slavica Miladinović, Sandra Veličković**
   INFLUENCE OF MATERIALS ON THE DEGREE OF EFFICIENCY OF WORM GEAR TRANSMISSION
5. **Milan Tica, Tihomir Mačkić, Nenad Marjanović, Sanjin Troha, Miroslav Milutinović**
   ANALYSIS OF GEAR RATIOS OF TWO DIFFERENT TYPES OF CYCLOID DRIVE TRAIN
6. **Sara Jerkić, Fuad Hadžikadunić, Mirza Oruč, Kenan Varda**
   DESIGNING OF A SOCKET MODEL OF A LOWER LIMB PROSTHESIS USING 3D SCAN/CAD TECHNOLOGIES
7. **Pavle Ljubojevic, Ivan Simonovic, Tatjana Lazovic**
   COMPARATIVE ANALYSIS OF LOAD CARRYING CAPACITY OF SHEAR-LOADED BOLTED JOINTS
8. **Biljana Markovic, Aleksija Đurić**
   EDUCATION FOR INDUSTRY 4.0, SITUATION AND CHALLENGES – STUDY OF THE STATE OF SECONDARY SCHOOL LEVEL
9. **Milos Knezev, Aleksandar Zivkovic, Hasan Smajic, Aleksandar Stekolschik, Clemens Feller, Cvijetin Mladjenovic, Dejan Marinković**
   THERMAL MODEL OF HIGH SPEED MOTORIZED SPINDLE
10. **Miroslav Milutinović, Madina Isametova, Spasoje Trifković, Sanjin Troha, Milan Tica, Kulwant Singh**
    IDENTIFICATION DESIGN PARAMETERS OR LOAD CAPACITY IN MANUAL GEARBOX FOR DIFFERENCE WORKING CONDITIONS

11. **Anita Vasileva, Elena Angeleska, Kristina Jakimovska, Sofija Sidorenko**
APPROPRIATE ERGONOMIC DESIGNS TO IMPROVE THE SAFETY OF THE CRANE CABIN

**November 18, 2022 (FRIDAY) (Conference Room No.1, 10:00 – 11:30)**

**Session I-2: MANUFACTURING TECHNOLOGIES AND ADVANCED MATERIALS**
Chairpersons: Slobodan Tabaković, Saša Živanović, Edin Šunje

1. **Milan Zeljković, Slobodan Tabaković**
ABOUT ACCURACY OF MACHINE TOOL – ACCURACY OF POSITIONING
2. **Tomasz Węgrzyn, Bożena Szczucka-Lasota, Wojciech Tarasiuk, Piotr Cybulko, Adam Jurek, Adam Doring, Aleksandar Kosarac**
MAG WELDING OF DUPLEX STEEL FOR THE CONSTRUCTION OF ANTENNA MOUNTS
3. **Wojciech Tarasiuk, Aleksandar Kosarac, Tomasz Węgrzyn, Bożena Szczucka-Lasota, Piotr Cybulko, Jan Piwnik**
INFLUENCE OF THE SLIDING VELOCITY ON THE INTENSITY OF GENERATION OF AIRBORNE WEAR PARTICLES OF POLYMERIC MATERIALS
4. **Cvijetin Mlađenović, Aleksandar Košarac, Aleksandar Živković, Miloš Knežev, Dejan Marinković, Robert Čep**
ANALYSIS OF MACHINE TOOLS DYNAMIC STABILITY BY APPLICATION OF VIBRATION TIME SIGNAL DECOMPOSITION
5. **Goran Vasilić, Saša Živanović, Milan Milutinović, Zoran Dimić**
MACHINE TOOL WITH PARALLEL MECHANISMS INTENDED FOR CUTTING FOAM MATERIALS WITH HOT WIRE
6. **Strahinja Dašić, Suzana Savić Petrović, Bogdan Nedić**
COMPARATIVE ANALYSIS OF THE MACHINING TIME SIMULATION RESULTS FOR 3+2-AXIS AND 5-AXIS MILLING OF THE SHAPER
7. **Milos Milovancevic, Dalibor Petković**
EVALUATION OF CHIP-TOOL INTERFACE TEMPERATURE BY ADAPTIVE NEURO FUZZY INFERENCE SYSTEM
8. **Nikola Kostić, Saša Ranđelović, Sandra Stanković**
FEM ANALIZA NAPONSKO DEFORMACIONOG STANJA PRI TOPLOM KOVANJU ČELIČNOG NEROTACIONOG OBLIKA
9. **Edin Šunje, Edin Džiho**
EXPERIMENTAL AND NUMERICAL DETERMINATION OF WARPAGE INTENSITY IN ELECTRIC BRAKER PANEL BOX MADE OF UV STABILISED ABS
10. **Jovica Ilić, Mladomir Milutinović, Milija Kraišnik, Dejan Movrin**
SHEET METAL FORMING USING VACUUM CAST POLYMER TOOL
11. **Igor Babić, Aleksandar Košarac**
INFLUENCES OF THE MILLING DIRECTION ON SURFACE QUALITY ON MILLING X155CRVMO12-1 STEEL

**November 18, 2022 (FRIDAY) (Conference Room No.2, 10:00 – 11:30)**

**Session III-2: PRODUCT DEVELOPMENT AND MECHANICAL SYSTEMS**
Chairpersons: Mirko Blagojević, Milan Tica, Milan Rackov

1. **Snežana Vulović, Miroslav Živković, Rodoljub Vujanac, Ana Pavlović, Marko Topalović**
   DETERMINING THE NUMERICAL VALUES OF THE POTENTIAL AT THE MEASURING POINTS
2. **Vojislav Miltenovic, Biljana Markovic, Milan Tica**
   BAUKASTEN PLANETARY TRANSMISSION CONSTRUCTION SYSTEM
3. **Marija Matejić, Miloš Matejić, Jovana Zivic, Lozica Ivanovic**
   DESIGN AND TESTING OF ABRASIVE BELT GRINDER
4. **Miloš Matejić, Marija Matejić, Ljubica Mudrić-Staniškovski, Ivan Miletić**
   IMPLEMENTATION OF MATHEMATICS MODELS IN DESIGN AUTOMATION
5. **Nenad Kostić, Nenad Petrovic, Nenad Marjanović, Jelena Petrovic**
   TRANSPORTATION OPTIMIZATION WITH EXCEL SOLVER
6. **Rodoljub Vujanac, Nenad Miloradovic, Snezana Vulovic**
   MEZZANINE FLOORS AS A PART OF RACKING SYSTEM
7. **Milan Vasić, Mirko Blagojević, Miloš Matejić**
   EFFICENCY OF NON-PIN WHEEL CYCLOID REDUCER CONCEPT
8. **Dejan Marinković, Aleksandar Živković, Cvijetin Mlađenović, Miloš Knežev, Dejan Lukić, Nicolae Ungureanu**
   MODELING OF THE MACHINE TOOL SLIDERS MOVEMENT USING ARTIFICIAL INTELLIGENCE
9. **Nedeljko Vukojević, Amna Bajtarević-Jeleč**
   STRUCTURAL INTEGRITY ASSESSMENT OF THICK-WALLED PRESSURE VESSEL
10. **Svetomir Simonović**
    ON DESIGN AND CALCULATION OF LEVER TYPE LIFTING MECHANISM MULTIPLIERS

**November 18, 2022 (FRIDAY) (Conference Room No.3, 10:00 – 11:30)**

**Session IV: RENEWABLE ENERGY AND ENVIRONMENTAL PROTECTION**
Chairpersons: Dušan Golubović, Mirko Dobrnjac, Vlatko Cingoski

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**Presentation of company - TRB - Technical Overhaul Bratunac**

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   Theoretical foundations of photovoltaic systems
3. **Srđan Samardžić**
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4. **Nemanja Vuković**
   LUBRICATION OF STEAM TURBINES

5. **Borislav Jović**
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2. **Eleonora Desnica, Jasmina Pekez, Dalibor Dobrilović, Ljiljana Radovanović, Dragica Radosav, Luka Đorđević, Milica Mazalica, Siniša Mihajlović**
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**CONCLUSIONS AND CLOSING CEREMONY OF COMETa2022**

**President of the Organizing Committee**
**PhD Milija Kraišnik**

**NOTES**

COMETa 2022
6th INTERNATIONAL SCIENTIFIC CONFERENCE
17th - 19th November 2022
Jahorina, B&H, Republic of Srpska
University of East Sarajevo
Faculty of Mechanical Engineering
Conference on Mechanical Engineering Technologies and Applications

# APPROPRIATE ERGONOMIC DESIGNS TO IMPROVE THE SAFETY OF THE CRANE CABIN

**Anita Vasileva[1], Elena Angeleska[2], Kristina Jakimovska[3], Sofija Sidorenko[4]**

*Abstract: Cranes are an essential part of the load handling equipment in industrial workplaces but they are high risk machines that can cause a great deal of material damage or injury which commonly occurs due to human error. In response to new design challenges, growing trend of focusing on user needs, such as body positions of the operator, unintuitive interactions in the work stations, disturbed field of view, and other issues that affect the operator's well-being and productivity, this research suggests principles, guidelines, and methods for designing and evaluating crane cabins with improved comfort and safety for the operator. In that aim firstly, the main ergonomic issues that exist of existing crane cabins are identified using correlating of data from ergonomics, design, construction and safety aspects, and a survey for collecting the user's opinions and experiences. After that, the research highlights a list of relevant anthropometric data need for designing crane cabins and existing standards regarding: the minimum operator envelope, zones of comfort and reach of controls, as well as requirements related with the operator's seat. Based on all collected and systematized data, in the end a design approach for developing crane cabins is suggested and solution is proposed. The generated concept is examined using software tools for virtual ergonomics. Finally, the issue of this paper is to provide baseline information that helps to upgrade the crane cabin ergonomics and avoid crane related fatalities and injuries.*

*Key words: crane cabin, ergonomic, human-centric design, safety*

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## 1. INTRODUCTION

Cranes are one of the most widely used equipments, but followed by a high accident rate. A large number of studies about accident causes exist [1-3], which analyse the construction and the components of a crane safety system, but in most of the research the body positions of the operator, disturbed field of view, the operator's well-being and productivity are almost neglected. To bride the current "gap" in the field, this research conducts both a literature review and applied research.

The research is supported by a review of previous surveys in the field of the crane's safety, and the analyzed need for reducing errors in the operator-machine interactions which can consequently reduce possible damages or injuries. Moreover, in order to fully understand the problematic, an additional survey was conducted among crane operators in North Macedonia aiming to withdraw additional information about their specific requirements. This was done with the goal of finding a way to improve the process of designing crane cabins using a human-centric approach that has the potential to reduce the risk of operator discomfort or distraction. The human-centric design strategy is one segment of the product ergonomics methodology that involves fitting the equipment to the users. This means that the user is analyzed as a part of the system which is being designed that is consisted of the human, the product or equipment and the environment. Despite the growing trend of focusing on user needs and applying these human-centric strategies when developing industrial machines and equipment, ergonomic issues continue to exist in crane cabins resulting with unnatural body positions of the operator, unintuitive interactions in the work stations, disturbed field of view, and other issues that affect the operator's well-being and productivity such as: poor insulation, inappropriate heating/cooling, ventilation, vibrations, noise, etc.

According to reference [4] crane operators have the most direct consequence on how safely cranes are handled. An operator must never menage a crane in conditions that could compromise proper operation or mechanical integrity of the crane. As stated in reference [5], where crane cabin types are examined regarding characteristic divided in three groups: (1) operator-control devices interaction, (2) safety and (3) anthropometric adjustment, results show that all examined crane cabins only 52.5% of operator-control devices interaction, 75% of safety and 60% of anthropometric adjustment issues are satisfied in current designs.

There are several similar researches which indicate that contemporary crane cabins still contain significant ergonomic and safety flaws and do not satisfy the operator's needs entirely. The main challenge in designing the crane cabins is to adjust them according to the nature of the work. The crane operator's tasks require a static sedentary position with both hands constantly positioned on controls and frequent head and neck bending and body twisting while under the continuous influence of strong vibrations. Therefore, authors aim to propose some suggestions and guidelines to overcome the design flaws and offer more ergonomic solutions. For instance, in [6] the author's content analysis is to identify the crane operator's biomechanical and visual problems and to present certain design suggestions and changes to existing standards on the path to improved safety of crane cabins. In addition, [7] demonstrates a modification of a crane cabin through ergonomic analysis. Reference [8] on the other hand, gives an overview of strategies how to reduce whole-body vibration exposure on drivers. This paper also aims to analyze and systematize the main crane cabin issues related with ergonomics and propose a human-centric design method which can be applied for constructing safer crane cabins.

## 2. RESEARCH METHODOLOGY

As elaborated in the introduction, the main goal of this paper is to provide a thorough understanding of the crucial ergonomic issues in crane cabins based on background information and suggest principles, guidelines, and methods for designing and evaluating crane cabins with improved comfort and safety for the operator. The study goes through several stages (Figure 1). It is based on data which is extracted chiefly from academic literature and publications through attentive content analysis.

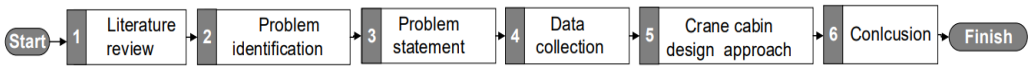


Figure 1. *Research methodology*

## 3. COLLECTION

In order to fully understand the problematic and pinpoint the main aspects and components of crane cabins that require an improved design approach for increasing the ergonomics, the initial step was to collect relevant data through a literature review and a survey. The data collection and analysis helped to understand and rate the main crane cabin interior issues. Once the main problems were established, the data collection process continued with withdrawing anthropometric data, ergonomic recommendations and existing standards which are directly related with the defined crane cabin interior components that cause those main problems.

### 3.1. Main crane cabin ergonomic issues according to a literature review

Based on information from several sources, the most common crane cabin issues are related to the seat, visibility, noise and commands/controls. In the review of cabin problems done in [6] it is stated that the placement of controls poses a great issue, as well as the positioning and visibility of indicators and displays, and the understandability of the signals and symbols. Furthermore, the authors elaborate that among the largest problem-causing factors are the seat and armrests. The issue lies in: the placement of the armrests at appropriate height, the options for adjustability of the armrests, the options for adjustability of the seat positions (horizontal and vertical adjustment), and the positioning and adjustments of the lumbar support of the seat (options for tilting and swiveling). In addition, the challenges of positioning the controls and levers to be within reach zones and easily operated, as well as allowing sufficient overview of the ground zone by removing obstructions from the field of view and distracting reflections are emphasized. According to [5] based on the evaluation of several crane cabin models, even the best-rated crane cabin models still have a 20% room for improvement. The main identified problems in the research are the interactions between the crane operator and controls, requiring a better placement of indica¬tors and regulators and adjustable work posutures. Similarly, in [9], authors pinpoint the following causes of driving discomfort: uncomfortable reach of controls, poor vision and poor seat adjustment (support, suspension, height), and in [10] authors also highlight the statement that the highest inconvenience is caused by armrests and inappropriately designed seat.

### 3.2. User requiremnts

With the goal to withdraw more information directly from crane operators and understand their problems and requirements, a short survey was conducted among 11 crane operators in North Macedonia. The survey questions are presented in Table 1.

Table 1. *List of questions*

| Question | Offered answers |
|---|---|
| Age | 18-25; 26-35; 36-45; 46-55; >56 |
| Average daily hours operating in the crane cabin | |
| Rate the comfort of the work in the crane cabin | 1-Extremely uncomfortable 2-Uncomfortable 3-Not so uncomfortable 4-Comfortable 5-Extremely comfortable |
| Usually in which part of your body do you feel pain at the end of your workday? | Hands; Shoulders; The Neck; The Back; Legs; Feet; Knees; Eyes ;Other |
| What do you consider to be the biggest disadvantage of the crane cabin? | Disturbed field of view; Dimension of the seat; The position of the seat; The position of the armrest; The position of the joysticks; Other |

### 3.3. Anthropometric data, ergonomic recommendations and standards

In order to properly position the operator in the crane cabin, the crucial data that needs to be considered are the physical dimensions of the operator which then define the minimum operator envelope and seat dimensions. In that sense, for designing the crane cabin the key anthropometric dimensions required are the basic body dimensions of a male individual of the 5th and 9th percentile in a seated position which according to an anthropometric chart by [11] are: popliteal height, buttock-popliteal height, elbow rest height, shoulder height, sitting height normal, elbow-to-elbow breadth, hip breadth, shoulder breadth and lumbar height [10].

Additionally, in ISO 3411:2007, the physical dimensions of small, medium and large operators in a seated position are also provided. The standard refers to earth-moving machinery operators, but is equally applicable in the case of crane cabins due to the similar characteristics of the operators and the cabins. The same ISO standard contains guidelines for dimensioning the minimum operator envelope. Based on the reviewed ISO standard, simple illustrations were prepared to graphically illustrate the required operator space which can be used as a reference for dimensioning the crane cabin (Figure 2). The physical dimensions of the small and large operators were selected since they are to be used for defining the required adjustable elements in the cabin: the horizontal and vertical seat adjustment dimensions, the horizontal and vertical armrest adjustment dimensions, as well as the armrest tilting adjustment angles, and the backrest adjustment angles. The operator envelope dimensions, on the other hand, were also included in the illustration for describing the minimum clearances around the body of the operator in a seated position. Standard ISO 6682:1986 is also relevant, containing information regarding the zones of comfort and reach of controls. A similar approach was used for describing the comfortable reach zones through the same illustration using color marks of the comfortable reach areas around the reference hip point of the operator (yellow for hand reach zone, orange for feet reach zone). This was done to serve as a simple reference for fitting all the equipment in the crane cabin interior according to the user characteristics (Figure 2). The background grid on the illustration helps to identify the dimensions around the operator, one square of the grid represents a 100x100mm area.

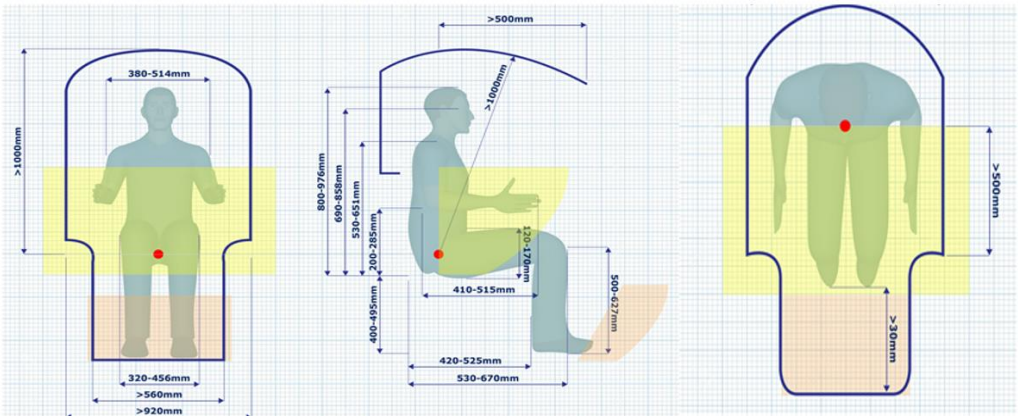


Figure. 2 *Anthropometric dimensions of a small and large male operator in a static seated position and operator envelope, according to ISO 3411:2007; and zones of comfortable reach (marked yellow and orange), according to ISO 6682:1986*

## 4. CRANE CABIN DESIGN APPROACH

### 4.1. Human-centric design method

The qualitative analysis and classification of the weaknesses of crane cabins was aggregated as per literature [4-9]. Finally, the verification of this literature analysis was made through a questionnaire. The goal was to conduct the questionnaire with 10 users and to get their feedback about the problems in crane cabins. Data was collected from October 2022 to November 2022 in Skopje. The questionnaire was completed online, using Google Forms. The Likert scale [12] was used in the questionnaire that converted it into points (1- being the least important, 5- being the most important). Summary, the results of the literature review and survey is shown on Table 2. In Table 2, the main users' health problems and the elements in a crane that contributed to them are indicated.

Table 2 *Data collection by literature review [5-7], [13-17] and survey*

| Problem identification (by literature) | Resulted of |
|---|---|
| Increased force requirements of the joysticks<br>Wrist/hand pain | Arm rest and joystick |
| White fingers when cold<br>Disturbed field of view<br>Neck pain and shoulder pain<br>Shoulder pain<br>Low back pain and lowe back<br>Knee | seat position |
| **Problem identification (by survey)** | **Resulted of** |
| Position of the joysticks<br>Wrist/hand pain | Arm rest and joystick |
| disturbed field of view<br>Neck pain and shoulder pain<br>Low back pain and lowe back | seat position |
| Cleaning of the windows | Cabin design |

### 4.2. Concept generation for improved safety and ergonomics

Based on the inputs from (Table 2) a concept design of crane cabin was developed. The most important cabin issue which needs redesign of the ergonomic aspect is the crane seat. The common crane seats require people to actively fit the waist and back with the backrest when sitting, so that the backrest can provide enough support for the waist. However, due to the long-term attention to the workspace, users tend to subconsciously lean forward due to blurred vision and waist fatigue, and thus form a bad sitting posture, resulting in further waist and back pain. Issues of crane seat that need to be improved are: trunk flexion (>20°) position required to adequately view the workspace and place for knee rest when trunk flexion is more than 20°. According to [17] and [18] the basic concept for improved safety and ergonomics in the crane's cabin is generated. The crane chair consists of the knee-rest and the flexibility seat, whose surface can be tilted by an angle (Figure 3).

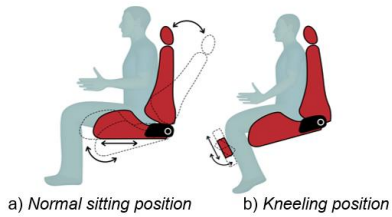


Figure. 3 *Schematic diagram of different use postures*

The arrows shown on Fig. 4 present the concept of fore-aft seat movement, the angle of the backrest, and knee position movement, as well as seat and knee rest lifters. It should be emphasized that the anthropometric data in Figure 2 was analyzed to obtain the height of the knee rests as well as their distance from each other. Additionally, the knee rest removal option or their comfort distancing is possible if the users do not want to use them.

### 4.3. Proposed model

Derived from the schematic diagram (Figure 3) a 3D model in SolidWorks was made of the proposed concept (Figure 4). In the 3D model the main components, such as high back, headrest, mechanical suspension, knee-rest, armrest, including their shape and anthropometric dimensions are defined.

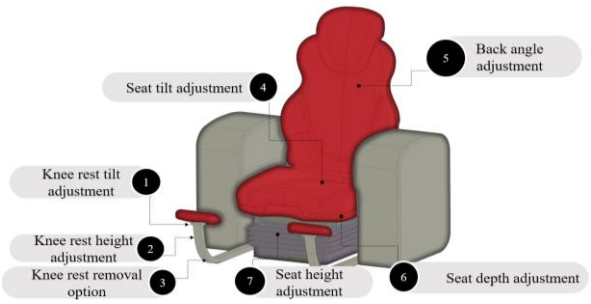


Figure 4. *The proposed model*

On Figure 4 the main tilt mechanisms of the proposed model are illustrated. In this paper, the mechanical elements that will be used are not considered. To verify the proposed model, the Siemens Jack software was used. The virtual mannequin which was used has a stature of nearly 175 cm and weight of 77.7 kg. In this study, the verification is made by positioning the upper-limb, back, shoulderes and joint angles of the down-limbs and knees. The proposed model has appropriate ergonomics according to the results of the simulation. The results by simulation are illustrated on Figure 5.

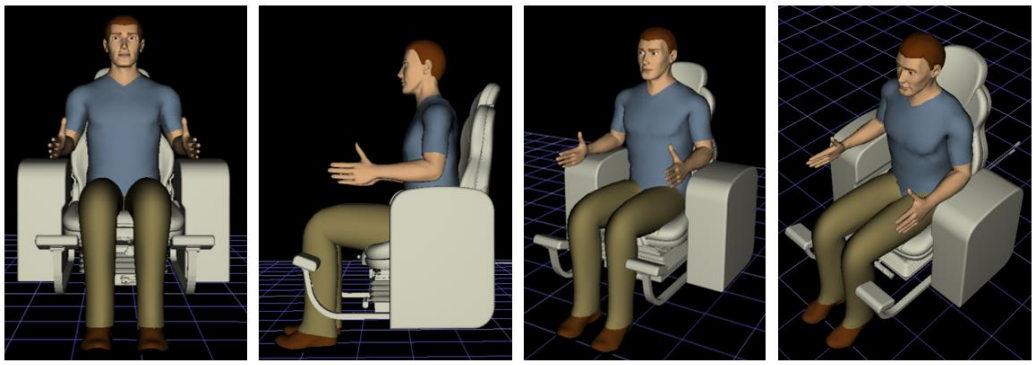

Figure 5 *Simulation for verification*

## 5. CONCLUSION

This research paper examines the ergonomic weaknesses of crane cabins and the ways in which they can be improved. The results of the conducted survey via a tailor-made questionnaire and data collection through literature give guidance on the current state and the desired future state. According to the results of the data analysis, the most important crane cabin issue that needs to be redesigned is the seat. Choosing the right crane cabin seat tilt mechanism can improve the operator's comfort. Hence, the proposed model of the crane seat was composed. The proposed model allows the operator to control exactly how much lumbar support is needed to maintain a healthy sitting posture as well as to improve the visual field. Further, the generated concept is analyzed using software tools for virtual ergonomics. However, the complexity of the issues considered has shortcomings in aspects such as mechanical design, material, the need to incorporate more experts and users, and the need for experimental investigations.

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