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**PROCEEDINGS**

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**Conference Topics:**

Plenary Lectures  
Quality Engineering  
Reliability Engineering  
Industrial Engineering  
Systems Engineering  
Military Engineering  
Energy Efficiency  
Lean Production

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## DQM-POLYTECH-2023: PROCEEDINGS CONTENTS

### *Conference Topic*

#### 01 Plenary Lectures

1.01	STANDARDIZING THE IMPLEMENTATION OF CEV CONTROL CHART WITH INTENTIONAL STATISTICAL CENSORING FOR ENHANCED PROCESS CONTROL IN HIGH-PERFORMANCE ENVIRONMENTS <b>Javier Neira Rueda, Andres Carrión Gardía</b> Universitat Politècnica de València, Department of Applied Statistics, Operations Research and Quality, Valencia, Spain	3
1.02	THE ROLE AND IMPORTANCE OF MAINTENANCE INFRASTRUCTURE IN INDUSTRIAL SYSTEMS <b>Dejan Brankovic, Zdravko Milovanovic</b> University of Banja Luka, Faculty of Mechanical Engineering, Banja Luka, Republic of Srpska, Bosnia and Herzegovina	17
1.03	THE POSITION OF THE REPUBLIC OF SERBIA IN EUROPE AT THE BEGINNING OF THE 21ST CENTURY AS A CAUSE OF NATIONAL POVERTY <b>Hajradin Radončić</b> University in Novi Pazar, Department of Legal Sciences, Novi Pazar, Serbia	24
1.04	MAIN FACTORS AFFECTING THE TIME TO ACHIEVE CONSENSUS IN A SOCIAL GROUP <b>Olga Maksimova</b> Yu. A. Izrael Institute of Global Climate and Ecology, Russia University of Science and Technology MISIS, Russia <b>Iosif Aronov</b> Moscow State Institute of International Relations (MGIMO), Russia University of the Ministry of Foreign Affairs of the Russian Federation, Russia	35
1.05	РАЗВИТИЕ МАШИНОСТРОЕНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ <b>Анатолий М. Костин</b> Национальная технологическая палата, Москва, Россия	41
1.06	PRINCIPLES OF AUTOMATIC PROCESS MANAGEMENT <b>Branko Popovic</b> University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia	62
1.07	FDI AND ISO 14001 MANAGEMENT SYSTEMS: THE CASE OF SERBIA <b>Zeljko Zeljkovic</b> University of Novi Sad, Faculty of Technical Sciences, Department for Graphic Engineering and Design, Novi Sad, Serbia <b>Aleksandra Pavlovic</b> The Academy of Applied Technical Studies, Belgrade, Serbia	75

**Andrea Ivanisevic**

University of Novi Sad, Faculty of Technical Sciences, Department of Industrial Engineering and Engineering Management, Novi Sad, Serbia

**Nemanja Kasikovic**

University of Novi Sad, Faculty of Technical Sciences, Department for Graphic Engineering and Design, Novi Sad, Serbia

**Conference Topic**

**02 Quality Engineering**

- 2.01 ПРИМЕНЕНИЯ КРІ В СИСТЕМЕ УПРАВЛЕНИЯ  
УНИВЕРСИТЕТОМ

**Алсу Т. Козлова**

Федеральное государственное бюджетное образовательное учреждение высшего образования Казанский национальный исследовательский технический университет им. А. Н. Туполева - КАИ, Казань, Россия

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87

- 2.02 MANAGEMENT IN THE DIVISION OF LABOR OF MEDICAL  
STAFF FROM THE POINT OF VIEW OF LAW

**Dejan Resetar**

University of Novi Sad, Faculty of Law, Novi Sad, Serbia

**Ognjen Dopudj**

European Affairs Fund of Autonomous Province of Vojvodina , Novi Sad, Serbia

91

**Conference Topic**

**03 Reliability Engineering**

- 3.01 MINING MACHINERY DOWN TIMES AND OPERATORS'  
ATTITUDES ON SAFETY AND HEALTH AT WORK: EXAMPLE  
OF WHEEL LOADER

**Mirjana Misita, Vesna Spasojevic Brkic**

University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia

**Aleksandar Brkic**

University of Belgrade, Innovation Center of Faculty of Mechanical Engineering, Belgrade, Serbia

**Martina Perisic, Neda Papic**

University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia

97

3.02	FACTORS OF THE OCCURRENCE OF TRAFFIC ACCIDENTS AND THEIR CONSEQUENCES <b>Dragana Jaksic</b> University of Pristina, Faculty of Technical Sciences, Kosovska Mitrovica, Serbia <b>Dragan Jovanovic</b> University of Novi Sad , Faculty of Technical Sciences, Novi Sad, Serbia	107
3.03	THERMOVISION FILMING OF POWER PREMISES WITHIN HIGH- VOLTAGE FACILITIES <b>Nenad Markovic</b> Kosovo and Metohija Academy of Applied Studies, Department Uroševac - Leposavić, Serbia <b>Uros Jaksic</b> Kosovo and Metohija Academy of Applied Studies, Department Zvečan, Serbia <b>Sasa Ilic</b> EMS Transmission Directorate, Regional Maintenance Center Krusevac, Service for Maintenance of HV Lines, Bor, Serbia	115
3.04	INDUSTRY 5.0: TECHNOLOGICAL ADVANCEMENT AND CHALLENGES AND APPLICATION IN LOGISTICS <b>Milena Ninovic</b> University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia	123

#### *Conference Topic*

### **04 Industrial Engineering**

4.01	KNOWLEDGE MANAGEMENT IN TRANSPORT COMPANIES <b>Milica Milicic, Tatjana Kovacevic, Milica Majstorovic, Pavle Pitka</b> University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia	133
4.02	ECONOMIC GROWTH MODEL AND TRAVEL AND TOURISM TOTAL CONTRIBUTION TO GDP GROWTH <b>Vesna D. Jablanovic</b> University of Belgrade, Faculty of Agriculture, Belgrade, Serbia	139
4.03	INVESTIGATION OF SUSTAINABLE DEVELOPMENT AND QUALITY AT THE LEVEL OF ORGANIZATION <b>Aleksandra Kokic Arsic</b> KiM Academy of Applied Studies, Zvečan, Serbia <b>Mladen Radojkovic</b> Faculty of Technical Sciences, Kosovska Mitrovica, Serbia <b>Aleksandar Djordjevic</b> Univeraity of Kragujevac, Faculty of Engineering, Kragujevac, Serbia <b>Tamara Gvozdenovic</b> Hydroelectric power plant on the Trebišnjica, Trebinje, Bosnia and Herzegovina	144

- 4.04 THE IMPORTANCE OF HUMAN RESOURCES IN THE APPLICATION OF MODERN CONCEPTS  
**Sanja Stanisavljev, Dejan Kovacevic, Zlatko Kosut, Mila Kavalic, Mihalj Bakatori**  
 University of Novi Sad, Technical Faculty Mihajlo Pupin, Zrenjanin, Serbia 150

*Conference Topic*

**05 Systems Engineering**

- 5.01 APPLICATION OF THE FINITE ELEMENT METHOD FOR DETERMINING THE TRAJECTORY OF MAIN STRESSES  
**Mladen Radojkovic, Zivce Sarkocecic, Ivica Camagic**  
 University of Pristina, Faculty of Technical Sciences, Kosovska Mitrovica, Serbia  
**Aleksandra Kokic Arsic**  
 Kosovo and Metohija Academy of Applied Studies, Department Zvecan, Zvecan, Serbia  
**Snezana Joksic**  
 University of Pristina, Faculty of Technical Sciences, Kosovska Mitrovica, Serbia 159
- 5.02 DEFORMATION ANALYSIS OF GEAR SHIFT FORK WITH MASS OPTIMIZATION  
**Snezana Joksic, Mladen Radojkovic, Zivce Sakorcevic**  
 University of Pristina, Faculty of Technical Sciences, Kosovska Mitrovica, Serbia  
**Sasa Milojevic, Blaza Stojanovic**  
 University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia 165
- 5.03 SELECTION OF INDUCTION MOTOR FOR CRANE DRIVE WITH COMPUTER SUPPORT  
**Zorica Bogicevic, Milan Tomovic**  
 Academy of Applied Studies Kosovo and Metohija, Department Zvecan, Serbia 172

*Conference Topic*

**06 Military Engineering**

- 6.01 СОЗДАНИЕ АВТОМАТИЗИРОВАННОЙ ИНФОРМАЦИОННО-АНАЛИТИЧЕСКОЙ СИСТЕМЫ ВОИНСКОГО УЧЁТА  
**Владимир А. Лисичкин**  
 Федеральный Научно-Исследовательский Социологический Центр РАН, Москва, Россия 183

	<b>Андрей Ю. Мананков</b> Автономная некоммерческая организация «Экспертный совет по актуальным социально-экономическими научно-техническим проблемам», Москва, Россия	
	<b>Анатолий М. Костин</b> Национальная технологическая палата, Москва, Россия	
6.02	NEGOTIATION AS A MEANS OF RESOLVING INTERNATIONAL DISPUTES <b>Hajradin Radoncic</b> University of Novi Pazar, Department of Legal Sciences, Novi Pazar, Serbia	194
6.03	EVALUATION OF THE RESILIENCE OF DEFENSE SYSTEMS BASED ON THE CONCEPT OF TOTAL DEFENSE <b>Andjelija Djukic</b> University of Defense in Belgrade, Strategic Research Institute, Belgrade, Serbia	206
6.04	COMPARATIVE ANALYSIS OF COMBAT EFFICIENCY OF MORTAR UNITS AND COMBAT DRONES UNITS <b>Marko Radovanovic</b> University of Defence in Belgrade, Military Academy, Belgrade, Serbia <b>Aleksandar Petrovski</b> University Goce Delchev, Shtip, Military Academy General Mihailo Apostolski, Skopje, North Macedonia <b>Zeljko Jokic</b> University of Defence in Belgrade, Military Academy, Belgrade, Serbia Bojan Lakanovic 1 <sup>st</sup> Army Brigade, Novi Sad, Serbia	213
6.05	THE SUSTAINABILITY OF SERBIA'S MILITARY NEUTRALITY IN THE STRATEGIC ENVIRONMENT <b>Hatidza Berisa</b> University of Defence in Belgrade, Military Academy, Belgrade, Serbia <b>Goran Korsev, Dragan Stevanovic</b> University of Defence in Belgrade, Military Academy, Belgrade, Serbia	221

### *Conference Topic*

#### **07 Energy Efficiency**

7.01	ANALYSIS OF INFLUENTIAL FACTORS IN STRATEGIC PLANNING OF RELIABLE WATER SUPPLY <b>Ana Stojanovic, Dejan Vasovic</b> University of Nis, Faculty of Occupational Safety, Nis, Serbia	239
------	--	-----

## *Conference Topic*

### **08 Lean Production**

- 8.01 ПРЕДКОНТРОЛЬ – НА ШАГ ВПЕРЁД И НЕ ОСТУПИТЬСЯ  
**Владимир Ю. Смелов, Владимир Л. Шпер, Елена И. Хунузиди**  
Национальный исследовательский технологический университет  
МИСиС, Москва, Россия 249
- 8.02 INDUSTRY 4.0 AND ROBOTICS IN PRODUCTION  
**Sanja Stanisavljev, Zlatko Kosut, Mila Kavalic, Dejan Kovacevic**  
University of Novi Sad, Technical Faculty Mihajlo Pupin, Zrenjanin,  
Serbia  
**Branko Markoski**  
University of Novi Sad, Faculty of Technical Sciences, Serbia 268

### **About the Editor**

LJUBISA PAPIĆ 277



## DEFORMATION ANALYSIS OF GEAR SHIFT FORK WITH MASS OPTIMIZATION

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**Summary:** *In this work, the mass optimization and static analysis of the gear shift fork, which shows the deformations of the model, is performed. The first step is to create a 3D model in the Autodesk Inventor 2023 software package, then a finite element mesh is created and a static deformation analysis is performed. After that, the model is optimized with a 23% mass reduction. For optimization, the Shape Generator option is used. On the optimized model, deformation analysis is performed under the same loads and constraints as for the old model. By comparing the results from both models, it can be concluded that in the version of the model with reduced mass, the deformation displacements increase.*

**Key words:** *Optimization, analysis, gear shift fork, deformations, mass.*

### 1. INTRODUCTION

Manual transmissions in today's industry need to comply with very high standards and requirements. In addition to efficiency, reliability, and long service life, noise and vibration reduction, it is increasingly required to provide as much comfort as possible for the speed change. In order to meet all the requirements, it is necessary that all the parts function properly and that each part is analyzed and improved separately. In this paper, the analysis and optimization of the transmission fork was performed.

The working principle of the gear shift fork is based on the inclusion and exclusion of a certain gear in operation, which results in different gear ratios. The fork as a part of the gearbox, and therefore of the car, has an important function when it comes to correct operation and human safety. Therefore, it is necessary for the fork to be constructed in such a way as to ensure the longest service life without deformation and damage. On the other hand, it is necessary to construct a fork with as little consumption of material, energy and time as possible. These facts lead to the conclusion that optimization is necessary for the construction of a part, in order to increase the positive characteristics and decrease the negative ones.

The paper [1] deals with the causes that lead to gearbox damage. Finite element methods were applied, mechanical properties of materials and lubrication were analyzed in order to reduce the wear of individual parts. The method of creating an oil film the contact surfaces of the gears and fork of the gearbox, is presented. This method proved to be effective, because the gearbox with this type of lubrication worked continuously for five years.

The publication [2] deals with the static analysis of a special gear shift fork on the ANSYS Workbench platform. Based on the analysis, data were obtained for the concentration and value of stress, deformation and life expectancy. Data on deformations, service life and safety factor of the special fork were obtained through material fatigue analysis.

The publication [3] is based on methods that can reduce the load, that is, the force that acts when changing gears in the gearbox in order to change the speed as quickly and easily as possible. The importance of synchronization and how it can be improved is shown.

Also, in the paper [4], the quality of changing speeds was discussed based on the speed analysis method. Using GSA technology, faults in gear shifting are detected, indicating elements of design improvement, performance and force reduction for gear shifting. In paper [5], the GSA method was used in order to increase the quality of truck gear shifting and low fuel consumption. The importance of giving subjective and objective evaluation of performance, as a basis for design optimization, is presented.

The paper [6] shows the development of a software tool for the analysis of the quality of gearbox operation. The existing gearbox control mechanism and components that affect correct operation and comfort were analyzed, on the basis of which a new method was developed. In this way, force, idle speed and positions of certain components can be measured. The importance of the adaptability of the gearbox to man in today's industry is described.

There are a number of different methods and analyzes that are used to increase the efficiency and quality of gearbox operation. This indicates the need for a detailed analysis of each component, in order for the system to function properly and be competitive in today's market. Within this work, the gear shift fork, which has a key role when changing speeds, is considered. First, a 3D model of the fork was created, then an analysis of the deformations that occur under a certain load was carried out, after which the model was optimized and an analysis of the deformations was performed on the new model in order to compare them with the old model.

## **2. MATERIAL AND METHOD**

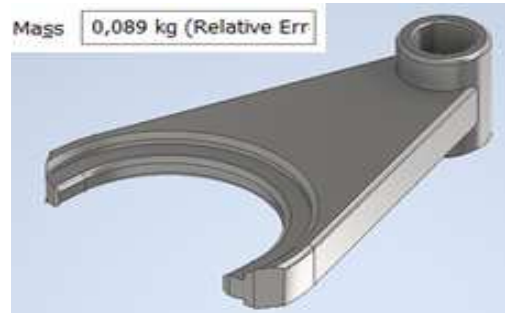
The 3D model of the gear shift fork was created in the Autodesk Inventor 2023 software package [7].

To analyze the deformations on the formed model, the Shape Generator option available in the Autodesk Inventor 2023 software package was used, in

which the data necessary for the static analysis was entered. The material from which the fork is made is carbon steel.

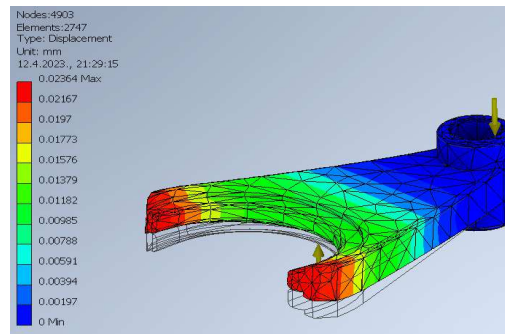
### 3. RESULTS

The designed 3D mass model is shown in Figure 1.

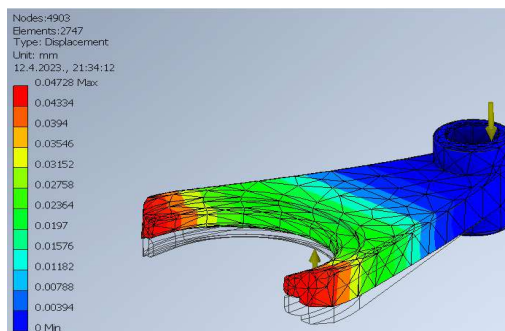


*Figure 1. 3D model of the fork*

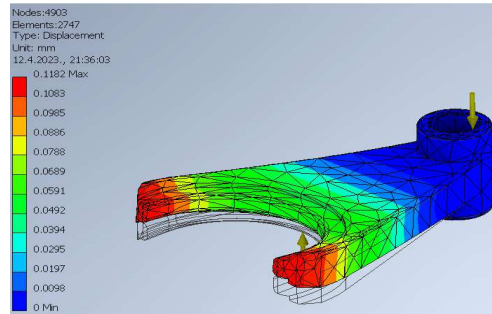
Using the static analysis, the places with the largest deformation movements in the x direction were obtained, under the action of a force of 100, 200 and 500 N. The obtained results are shown in figures 2, 3 and 4.



*Figure 2. Stress distribution under the force of 100 N*



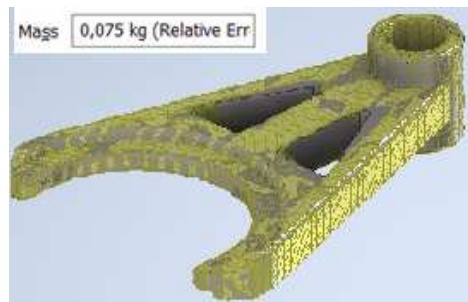
*Figure 3. Stress distribution under the force of 200 N*



*Figure 4. Stress distribution under the force of 500 N*

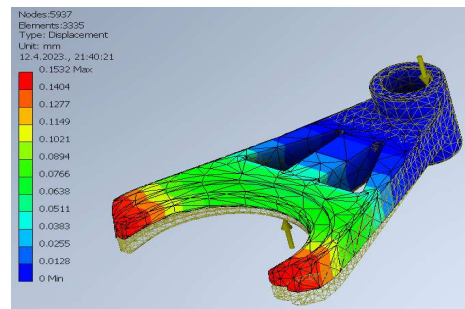
Based on the results, it can be concluded that the maximum deformation displacements occur in the x direction and under the load of 500 N. The value of the deformation displacements under the action of the highest load is 0.118 mm.

After the analysis, optimization was performed using the Shape Generator option, in which the mass was reduced by 23%. By starting the option, it is necessary to first define the constraints and then certain loads, after which the program determines the area where the mass will be reduced, as shown in figure 5.



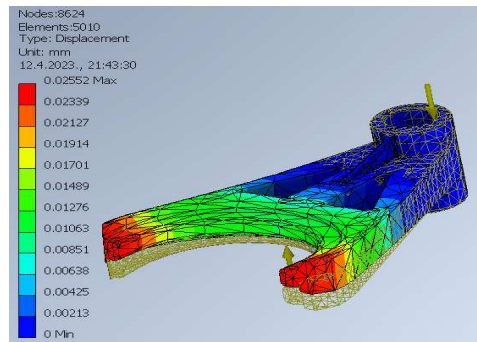
*Figure 5. Optimized model*

The next step is the static analysis of the new model, in order to check the deformations. Figure 6 shows the results obtained when the fork was loaded with a force of 500 N.

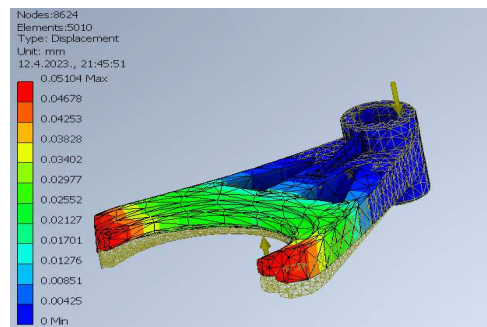


*Figure 6. Stress distribution under the force of 500 N on the optimized model without rib*

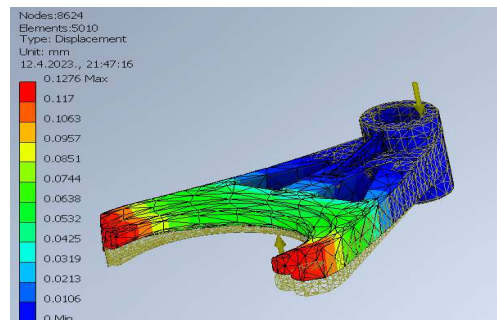
Considering that the mass of the model was reduced, reinforcement in the form of ribs was added and the static analysis was performed again for the optimized model with rib. Results of the static analysis of the optimized fork with rib are shown in figures 7, 8 and 9.



*Figure 7. Stress distribution under the force of 100 N on the optimized model*



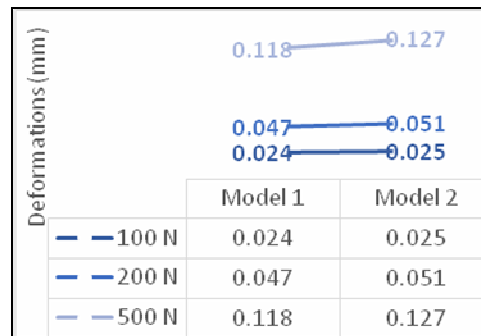
*Figure 8. Stress distribution under the force of 200 N on the optimized model*



*Figure 9. Stress distribution under the force of 500 N on the optimized model*

Based on the previous figures, which show the numerical values of the deformation displacements, it is noted that the maximum deformation value is 0.153 mm on the model without reinforcement. With the addition of the rib, the maximum deformation displacements are 0.127 mm at a force of 500 N.

Figure 10 shows the results of the analysis before and after optimization with the given tabular values.



*Figure 10. Numerical values of deformations before and after optimization*

#### 4. DISCUSSION

After optimization and static analysis, it is concluded that on the constructed model of the fork, deformation movements occur in the x direction, with maximum values at the ends of the fork, that is, on the part that is in contact with the gears. The model before optimization shows smaller deformational movements compared to the new model, because the optimized model is weakened by the reduction in mass. In order to reduce the deformations, reinforcement was added, which reduced the deformations in the x direction. Also, the deformations on both models increase in proportion to the increase in load.

The paper [2] shows the deformations of a special transmission fork under the action of a force of 460 N. Under the effect of the load, the maximum deformations amount to 0.49 mm, which is a higher value compared to the fork in this paper.

#### 5. CONCLUSION

A detailed analysis of the components of a system is the most important factor required by today's market and industry. In this paper, the transmission fork was analyzed in order to reduce the mass, and thus the material used, to improve efficiency and performance.

The aim of this work was to show the importance of optimization on the example of a transmission fork. After creating the model, deformation analysis was performed, then the mass of the part was reduced by 23%. After reducing the mass, it is necessary to check whether it affects the deformation of the part. The results showed that the deformations increased slightly compared to the old model. Future directions of research could be based on how to reduce the deformation of the part on the optimized model, under the same constraints and loads, in order to increase the service life of the part and the reliability of the entire system.

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