Preliminary Design Review

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Mechanical systems

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This document is the Preliminary Design Review of the technical competence ‘Mechanical Systems’. Its briefly contains the experimental platform analysed in MISCE project, to be designed and standardised for improving the acquisition level of this competence on engineering degrees.

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1 Competence and skills

The conceptual design presented in this document is referred to the technical competence:

C5. Mechanical systems

which related skills are (see Table I):

Table I. Skills of Mechanical Systems

S5.1.	To understand the different energy conversion process to produce movement
S5.2.	To know to design mechanical system
S5.3.	To know the different movement transmissions
S5.4.	To be able to analyse and optimise a mechanical device
S5.5.	To know the force and torque involved in mechanical systems

The different conceptual designs presented in this document have been analysed to ensure that can improve the acquisition level of the aforementioned competence.

2 Experimental proposals

Burnishing process

Burnishing involves local cold plastic deformation of an object as a result of force and kinetic interaction of the tool with the machined surface. The impact of a smooth and practically undeformable tool on the machined surface causes the displacement of irregularities and deformation of the surface, which has a beneficial effect on the properties of the surface layer.

Burnishing is most often used when it is necessary to simultaneously reduce the surface roughness, increase the material share of its profile, strengthen the surface layer of the material and obtain a favorable state of compressive stress in it. (1)

The educational setup for students consists of a ball indenter mechanism (burnishing tool) mounted on a lathe and controlled by advanced servo systems. The mechanism, referred to as the “indenter,” enables students to analyze various scenarios of indentation and material interaction.

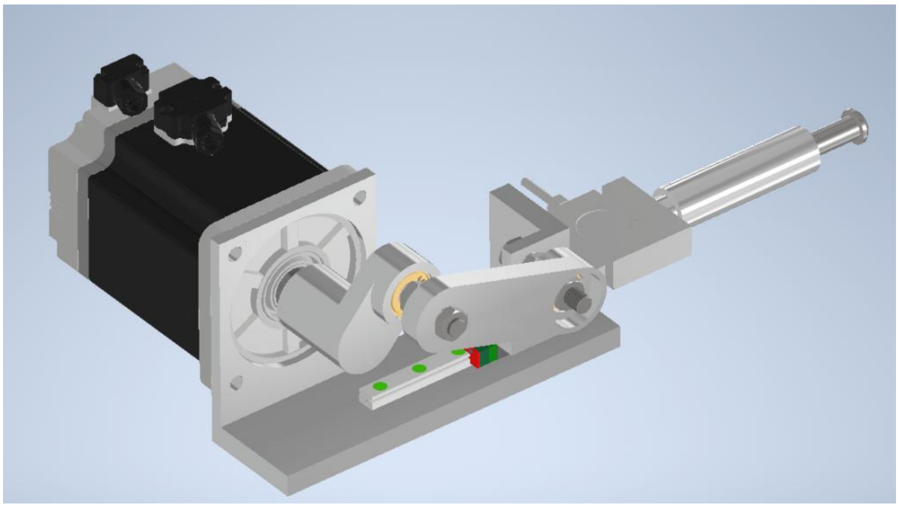

Figure 1. The burnishing tool

2.1 Exercise 1 – Static Burnishing Analysis

The experiment employs a ball burnisher mounted on a crank mechanism driven by a 750W servo motor controlled by a PLC (Siemens S7-1200). The system allows for precise adjustments of the indenter's position and force. The ball head of the indenter, equipped with a force sensor, presses against a rotating aluminum shaft. Students can switch between static and dynamic modes to study different mechanical properties.

The ball burnisher is statically pressed against a rotating aluminum shaft to study indentation depth and surface roughness. This experiment also involves analyzing energy transfer into plastic deformation and validating theoretical force models. Students compare results for different indentation forces (e.g., F1 and F2) and evaluate surface quality.

1. Investigate the impact of different indentation forces on depth and surface quality.
2. Compare theoretical and experimental outcomes using standard formula:
$$\delta = R - \sqrt{R^2 - (d/2)^2}$$
3. Relate energy conservation principles to material deformation.
4. Graphical representation of depth versus force.

Results: Surface quality and uniformity comparisons for different forces. Insights into material properties and energy utilization.

2.2 Exercise 2 – Dynamic Burnishing Analysis

The ball burnisher dynamically impacts a shaft under two patterns: continuous spiral and discrete intervals. This experiment extends to analyze the rotational dynamics and feed rates to optimize surface patterns.

1. Analyze differences in depth and spacing between patterns.
2. Explore relationships between feed rates, shaft rotation speeds, and surface characteristics.
3. Develop understanding of dynamic mechanical behavior using derived relationships for force and energy.
4. Graphs demonstrating relationships between depth, velocity, and force.

Results: Recommendations on optimal patterns for uniform surface characteristics and determination of process parameters for precise control.

3 Competence and skills analyses

Table II summarises the competence and skills analyses of the proposed experimental platform attending to the contribution of acquisition of the technical competence ‘control engineering’ and their corresponding skills in Table I.

Table II. Contribution of each proposed platform to control engineering competence and its corresponding skills

Platform	S5.1	S5.2	S5.3	S5.4	S5.5	Overall competence contribution
mechatronic burnishing tool.	★★★★	★★★★	★★★★	★★★★	★★★☆	★★★★ 4.2
	Multi-stage energy conversion. Electrical energy to kinetic (DC motor), kinetic to potential (screw - spring), potential to kinetic (spring - tool).	Easy-to-construct basic mechanical system, i.e., drive, transmission, end effector.	Conversion of rotary motion to linear motion using a screw gear mechanism.	Ability to select a drive for pre-tensioning the spring. Ability to select the spring and dimensions of the tooltip.	Easily calculable analytically, the motor torque and the impact force of the tool on the material.	

Competencies Acquired by Students During the Burnishing Process Experiment

The burnishing process experiment enables students to acquire various competencies related to mechanics and mechatronic systems. Below is an analysis of how the described experiment allows students to gain the competencies listed in the table:

S5.1. To understand the different energy conversion processes to produce movement

Students will learn how kinetic energy from the moving burnishing tool head is converted into deformation energy as it impacts the aluminum shaft. They will also understand how the servo motor transforms electrical energy into precise mechanical motion to control the indentation depth and dynamic patterns. This knowledge extends to energy efficiency and loss during mechanical operations.

S5.2. To know how to design mechanical systems

Students will gain insights into mechanical system design by analyzing the components of the burnishing tool mechanism, including the ball head, servo motor, and force sensor. They will learn how to select appropriate materials and configure system parameters such as force and velocity to achieve accurate and repeatable results. The design process also covers control systems using PLC programming to manage both static and dynamic indentation modes.

S5.3. To know the different movement transmissions

The experiment provides knowledge about various movement transmission mechanisms, such as the rotational motion of the shaft and the linear motion of the burnishing tool head. Students will analyze how these movements interact to produce specific indentation patterns. They will study the effects of movement synchronization, such as feed rate and shaft speed, on the quality of surface deformations.

S5.4. To be able to analyze and optimize a mechanical device

Students will optimize the burnishing tool system by adjusting experimental parameters such as force, speed, and feed rate. They will analyze the relationship between these parameters and the resulting surface characteristics, identifying optimal configurations for uniformity and precision. Additionally, they will evaluate system performance against theoretical models to improve overall device efficiency.

S5.5. To know the force and torque involved in mechanical systems

Students will measure and analyze the forces applied by the burnishing tool and the torques generated by the servo motor. They will understand how these factors influence indentation depth, surface quality, and material deformation. The experiment emphasizes the importance of balancing force and torque for achieving desired mechanical outcomes in both static and dynamic processes.

The work stand burnishing process experiment provides students with practical knowledge and skills in energy conversion, mechanical system design, movement transmissions, analysis and optimization of mechanical devices, and understanding forces and torques in mechanical systems.

References

1. **Kluz, R., Antosz, K., Trzepieciński, T., & Bucior, M.** Modelling the Influence of Slide Burnishing Parameters on the Surface Roughness of Shafts Made of 42CrMo4 Heat-Treatable Steel. *Materials.* 5 2021, pp. 1175.