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DESIGN AND TESTING OF PIN ON DISC TRIBOMETER: FINK-POD2025

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Abstract: *In the mechanical industry, friction is a significant parameter of mechanical systems as it greatly affects their service life, efficiency, and safety. Understanding friction force and their effects enables the optimization of materials, machine elements and systems, leading to improved performance and reduced energy losses. This paper describes the design and manufacturing of a tribometer named FINK-POD2025, an experimental device for measuring friction forces between different or same materials. A system has been designed in which friction is tested at the contact between the so-called disc and pin. The pin, with a diameter of 5 mm, and the rotating disc are interchangeable, allowing for testing various material combinations, while the entire system is designed for their easy replacement. The coefficient of friction is determined indirectly through the frictional force resulting from the rotational motion of the disk in contact with the pin. The paper also describes the measurement of the pressure exerted by the pin on the disc, followed by a calculation for determining the the coefficient of friction at the contact surface. To ensure the relevance of the experimental friction force determination, the system is balanced with a fixed joint on one side and a weight on the other. A lever mechanism is used to double the force acting on the pin compared to the applied weight. The paper describes the design, principle of operation, and manufacturing methods of the Pin on Disk type tribometer. The results of this testing are applicable in the design of testing devices for wide range of materials, as they can be used to enhance their characteristics*

Keywords: *Friction, tribometer, material testing, Pin on Disk, frictional force.*

1. INTRODUCTION

The science that studies friction, wear, and lubrication is tribology. Understanding friction and the behavior of materials under its influence is crucial for designing reliable mechanical systems. Friction directly affects wear, efficiency, and the service life of components, which is why it is essential to precisely determine its characteristics under different operating conditions. Understanding these processes allows for the optimization of design and the selection of materials, which results in a longer service life. To understand friction and material behavior, it is of great importance to examine materials through practical examples and experiments. This type of research facilitates the collection of accurate data on the properties of different surfaces under various testing conditions.

Research in the field of tribology includes, among other things, the analysis of different types of tribometers and their application in material testing. The Pin on Disc type tribometer is commonly used in tribology research. During testing, the coefficient of friction and abrasion level, as well as the temperature of the surfaces in contact, are most often measured [1,2]. Scientist Korcan Kucukcoskun, along with his team, designed and optimized a tribometer of this type. The research showed that it is possible to construct a tribometer with a cost of about 200 euros, which provides results comparable to those of professional devices significantly higher in price [3].

The design of the Pin on Disc type tribometer must be developed to comply with a variety of requirements, securing safety and optimal performance during testing. It is essential for the tribometer design to conform to standards while also meeting durability and reliability conditions [4].

A Pin on Disc type tribometer has also been developed at Yıldız Technical University in Turkey. This tribometer has a modular design that allows testing of different tribological combinations and complies with global standard for precision and reliability in testing [5]. This type of tribometer is also used for testing films that reduce friction and influence the wear resistance of materials [6,7].

The development of technology and the growing interest in this field have contributed to the construction of different versions of the Pin on Disc tribometer, customized to specific testing conditions and materials. In 2021, improved data recording from the tribometer enabled accurate tracking of the system's dynamic behavior and the detection of localized changes in tribological conditions [8].

The Pin on Disc tribometer is often used in different industries to test friction, wear, and particle emission. It is used in the automotive industry to analyze wear in braking systems [9], in metallurgy to test superalloys like Inconel-718 [10], and in the train industry to measure wear between wheels and tracks [11]. This method is also used in biomedicine to test ceramic materials such as silicon nitrides [12] and aluminum composites reinforced with nanoparticles [13].

Due to its precision, Pin-on-Disc testing allows for a better understanding of wear mechanisms and extends the service life of materials. Considering the wide application of the Pin on Disc tribometer in the analysis of friction and wear of materials, the aim of this paper is to present the process of designing and manufacturing such a tribometer. This paper analyzes the design characteristics of the tribometer and its potential applications in testing different materials. Although existing Pin on Disc tribometers are widely used in tribology, their high cost and limited adaptability to different testing conditions present challenges. The development of a new and more economical tribometer would enable reliable testing of friction and wear, optimizing costs while meeting functional requirements. The purpose of this paper is to design and manufacture a tribometer that complies with international standards. Future research will focus on further optimization of testing processes, as well as the testing of materials that can improve performance in industrial applications.

2. MAIN DESIGN REQUIREMENTS OF THE PIN ON DISC TRIBOMETER

The designed tribometer is characterized by a simple design. Figure 1 shows the 3D model of the designed tribometer.

Figure 1. Pin on Disc Tribometer

The main idea behind its design was to enable easy usage and testing of a wide range of different materials.

During the design of the tribometer, it was necessary to meet the functionality requirements of the tribometer, while also securing a simple and more economical solution. A motor reducer is used for the rotational movement of the disc, and its characteristics are: rated power *P=1.5* kW, rotational speed *n*=140 min^{-1}, and power shaft diameter *d=25* mm.

The main components of the tribometer are a pin with a diameter of 5 mm, which is fixed on tribometer arm. On the other side is a disc with a diameter of 120 mm and a central hole with a diameter of 20 mm, which can rotate around its axis. A single disc can be used for multiple tests, as the tribometer is designed so that the pin can be positioned at a distance ranging from 25 mm to 60 mm from the center of the disc. The sensor used for determining the frictional force can measure forces up to a maximum of 100 N.

For the construction of the tribometer, the ASTM G99 standard was used, which requires the motor to be able to control and keep a constant speed, while also making sure the angular tolerance between the disc and the pin is ± 1° [14].

3. DESIGN AND WORKING PRINCIPLE

The main mechanism of the constructed tribometer includes several important parts for its operation (Figure 2). The disc is connected to the motor shaft with a round connector and rotates.

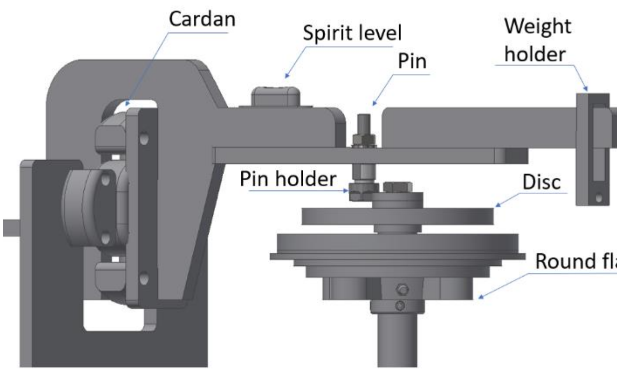

Figure 2. Main components of the tribometer

On one side of the pin, there is a weight holder. By adding the weight, a normal force is generated, which causes contact between the pin and the disc.

With the appearance of the normal force from the weight, the system loses necessary balance. For this reason, on the other side of the pin, there is a universal joint. This joint has two Cardan forks, one of which is fixed to the so-called Plate 1. Plate 1 is then connected to a handle that enables the horizontal movement of the Cardan joint and the pin that is attached on the same support.

The design of the universal joint, shown in Figure 3, allows the second Cardan fork to rotate around the universal joint cross-axis, in order to establish balance. A spirit level, placed on the second Cardan fork, provides a very simple solution for determining the balance of the system.

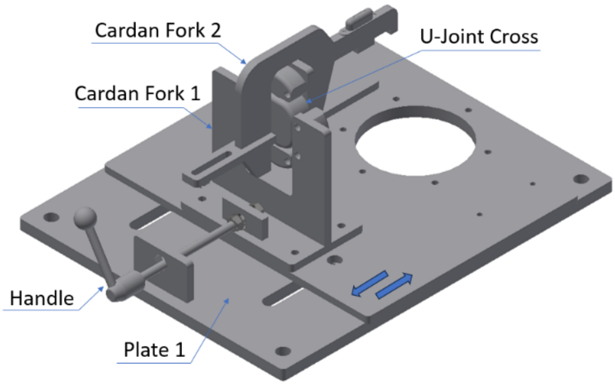

Figure 3 Construction of the Cardan joint with Plate 1 and the handle

After positioning the weight in the correct position and establishing balance, the forces generated by the weight lead to contact between the pin and the disc. The disc rotates thanks to the motor, and during this process, the pin leaves a trace as it moves along the rotating disc.

4. CALCULATION OF THE COEFFICIENT OF FRICTION

The determination of the coefficient of friction between the same or different materials is performed using a simple formula (1):

$$\mu = \frac{F_\mu}{F_N} \quad (1)\ [15]$$

Where are:

F_μ - The frictional force that occurs as a result of the movement of the Pin on the Disc,

F_N - The normal force that arises as a result of the weight's effect, and is calculated using equation (2):

$$F_N = 2 \cdot m \cdot g \quad (2)$$

Where are:

m – Mass of the weight,

g - Gravitational acceleration.

As shown in equation (2), the product of the weight's mass and gravitational acceleration needs to be multiplied by two, which is explained by the lever system.

The distance between the weight and the pin is twice the distance between the pin and the joint. This way, a force twice as large as the one applied by the weight is generated in the pin, in order to achieve force balance.

After placing the weight, a force F_N appears, which acts on the pin with twice the intensity. This leads to contact between the pin and the disc, which rotates with angular velocity ω (Figure 4).

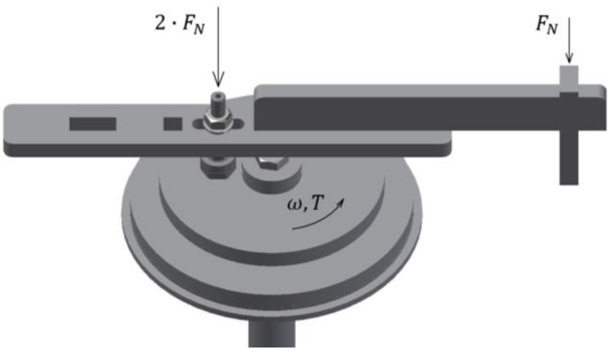

Figure 4. Action of the force F_N

The frictional force that is created as a result of the pin's movement on the disc is measured experimentally using a sensor. After determining the mentioned force, all conditions for determining the coefficient of friction are ensured, i.e., the application of equation (1).

5. MANUFACTURING AND COST

The supporting structure of the tribometer consists of standard square profiles according to EN 10111, with dimensions of 50x50x2 mm. The construction includes table legs, side and front reinforcements, the tribometer support, and finally, the motor mount. The profiles were first cut to the required lengths, then joined by welding, ensuring the strength and stability of the entire structure.

The entire construction is mounted on 4 adjustable feet with dimensions of M16 x 100 mm. Figure 5 shows the tribometer during the manufacturing process.

Figure 5. Tribometer in the manufacturing process

The rotary motion of the disc is driven by a 1.5 kW motor reducer, which includes a through shaft with a diameter of 25 mm. A frequency regulator is used to control the motor speed, while force measurement is performed using the Ems30-100 sensor with a capacity of 100 N.

The EMS-169 signal conditioner is used for processing and modifying the sensor's output signal to obtain a signal able to be used for more processing or analysis. Table 1 shows the prices of machined and laser-cut parts, and Table 2 presents the prices of components needed for the manufacturing of the Pin on Disc tribometer.

Table 1 Prices of Machined and Laser-Cut Parts

Component	Qty.	Total price (€)
Square section □50 x 3 mm	15 m	64.7
Round bar Ø30 x 2 mm	1 m	5.64
Seamless pipe Ø140 / Ø112	0.15 m	5.54
Circular Hollow Section Ø159 / Ø 151	0.5 m	17.14
Laser-cut positions #5 mm, #10 mm, #15 mm	1 piece	159.78

The tables provide an overview of the required quantities of all parts necessary for the tribometer's production, showing the unit price as well as the total cost for the required quantity of each individual part.

The cost of laser-cut components includes both the laser cutting price and the cost of the required material in thicknesses of 5, 10, and 15 mm.

Table 2 Prices of Components Required for Tribometer Manufacturing

Component	Qty.	Price per unit (€)	Total price (€)
Feet for 50x50 mm pipe – M12	4	1.79	7.14
Rubber feet with M12x60 thread	4	0.03	0.12
Motorredaktor 1.5 KW	1	291.67	291.67
Frequency Regulator 1.5 KW	1	175	175
Sensor EMS30-100	1	285.42	285.42
Signal Conditioner EMS-169	1	189.58	189.58
UCFC 205 KYK Bearing	1	6.25	6.25
KK 4C Crosspiece	1	50.85	50.85
DIN 975 8.8 Zinc Threaded Rod	1	1.79	1.79
Small threaded components	60	0.2	≈11

The cost of the tribometer should also include the labor cost of the engineer responsible for the design and preparation of the technical documentation of the structure (Table 3).

Table 3 The labor cost of the engaged engineer

Phase	Time Required (hours)	Hourly Rate (€)	Total Labor Cost (€)
Design	50	25	1250
Technical Documentation	50	25	1250
Automation	40	35	1400
Testing	50	25	1250

The last table provides an overview of the total cost of designing and manufacturing the tribometer, which includes the labor cost of the engineer and the cost of the components purchased for the production of the Pin on Disc tribometer (Table 4).

The manufacturing cost is also provided, which includes the cost of welding and machining of certain components.

Table 4 Total Cost of the Tribometer

Description	Price (€)
Total component costs	2500
Total labor costs	5150
Manufacturing costs	2000
Total:	9650

The total cost of the tribometer analyzed in this paper is approximately 9650 euros.

By using simpler components and an efficient manufacturing process, functionality has been achieved that is largely comparable to more expensive models, making this tribometer suitable for research institutions with limited budgets.

This device allows for a reduction in overall material testing costs.

6. CONCLUSION

The presented analysis of the design and manufacturing of the tribometer revealed several benefits:

- The selected materials and manufacturing method contribute to the device's durability and cost-effectiveness.
- The developed model allows easy adaptability to different measurement needs and quick replacement of parts.
- Simple establishment of the construction's balance, which eliminating mistakes during testing.
- The cost analysis confirms the economic feasibility of the proposed solution.
- The technical documentation of the tribometer helps easy production of the device, providing detailed instructions for manufacturing, assembly, and testing.

The application of this method in the development of the tribometer can be considered a practical and useful solution.

Further research will focus on testing this device in real conditions, with the goal of confirming its accuracy and reliability.

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