sciendo

DOI: 10.2478/rjti-2024-0011

ROMANIAN JOURNAL
OF TRANSPORT INFRASTRUCTURE

STAND WITH A HIGH DEGREE OF UNIVERSALITY FOR PREDICTION OF RELIABILITY AND TRIBOLOGICAL BEHAVIOR STUDIES FOR MATERIALS USED IN TRANSPORT INDUSTRY

Anca Ruxandra Sasu, Ph.D Student Eng**.** Assistant Professor, Technical University of Civil Engineering, Bucharest, Romania, e-mail: anca-ruxandra.sasu@utcb.ro
Cristian Pavel, Ph.D. Eng. Associate Professor, Technical University of Civil Engineering, Bucharest, Romania, e-mail: cristian.pavel@utcb.ro
Dragoș-Bogdan Vida, Ph.D. Student Eng., Technical University of Civil Engineering Bucharest, e-mail: dragos-bogdan.vida@phd.utcb.ro
Cristian Ștefan Dumitriu*, Ph.D. Eng. Associate Professor Habil., Technical University of Civil Engineering, Bucharest, Romania, e-mail: cristian.dumitriu@utcb.ro (author for correspondence)

Rezumat

In contextul apariției unor noi materiale utilizate în fabricarea elementelor ce compun sistemele de direcție ale mijloacelor de transport, atât în etapa de proiectare cât și în cea de prototipare, încercările privind comportamentul tribologic al acestora reprezintă o etapă importantă în dezvoltarea unui produs. In general, standurile sunt dedicate unei anume configurații privind contactul ș/sau dinamica mișcărilor pe care le poate realiza produsul. Această lucrare prezintă un stand universal pentru astfel de încercări, care poate fi adaptat unor cercetări mai ample.

Cuvinte cheie: stand experimental, configurație, mișcare, Metoda Elementului Finit

Abstract

In the context of the apparition of new materials used in manufacturing the elements that form the vehicles' steering systems, both in the design and prototyping stages, the tests regarding their behavior from the tribology viewpoint represent an essential stage in the development of a product. The stands are generally dedicated to a specific configuration regarding the contact and/or the dynamics of the movements that the product can achieve. This paper presents a universal stand for such trials, which can be adapted to more extensive research.

Keywords: experimental setup, configuration, movement, Finite Element Analysis

1. INTRODUCTION

Individuals' mobility is the engine of human society. Over the last decades, the need for movement has increased both in quantity and quality. The development of road transport plays an active role in this phenomenon. The regulations in the field, the quality of the infrastructure, and the drivers' reactions must corroborate this.

This article focuses on the safety of motor vehicle operation, particularly through the lens of the steering system. This system, which includes elements with moving surfaces, is prone to significant wear (spherical joints, damping systems, mobile support elements, etc.). As materials in this field become more complex, such as metal/plastic, metal/composite, and composite/composite, the need for a comprehensive understanding of their behavior becomes paramount.

Thus, both in the design and prototyping stages, the need for experimental stands to help in prediction of the behavior of such material couples appears[1-3]. These tribometers must simulate both the loads and movement parameters that appear for such a friction couple.

Our proposed stand, with its high degree of generalization, is not limited to the automotive industry. It can be extended to the fields of manufacturing technology and biomechanics [4-7]. For instance, considering that orthopedic implants are essentially mechanical systems with programmed failure [8-12], the stand opens up new possibilities for research and development in this area.

2. DESCRIPTION OF THE EXPERIMENTAL STAND

Most of the stands used in tribology studies are dedicated to a specific ball/plane, pin/disc, roller/roller – Timken, etc. friction coupling. Given that currently, from the point of view of material, geometry, and/or the dynamics of the constructive elements of the components from the automotive industry, a complex approach to their wear and reliability studies is necessary.

The present experimental stand allows the tribological study of material couplings for a complex dynamic, with movements on two perpendicular axes, one of which may have variable frequency and amplitude, including random, under continuous monitoring of the load and the friction force.

The stand was ingeniously designed with a modular construction, a feature that significantly enhances its versatility. This means that it can be easily adapted and modified to suit a wide range of tribology studies.

The modules proposed for the current configuration are (Fig.1):

1. The main actuation module,
2. The transducer module,
3. The pill-holder module with the transversal disturbance (excitation) module,
4. The loading module,
5. Drive motor for continuous loading,

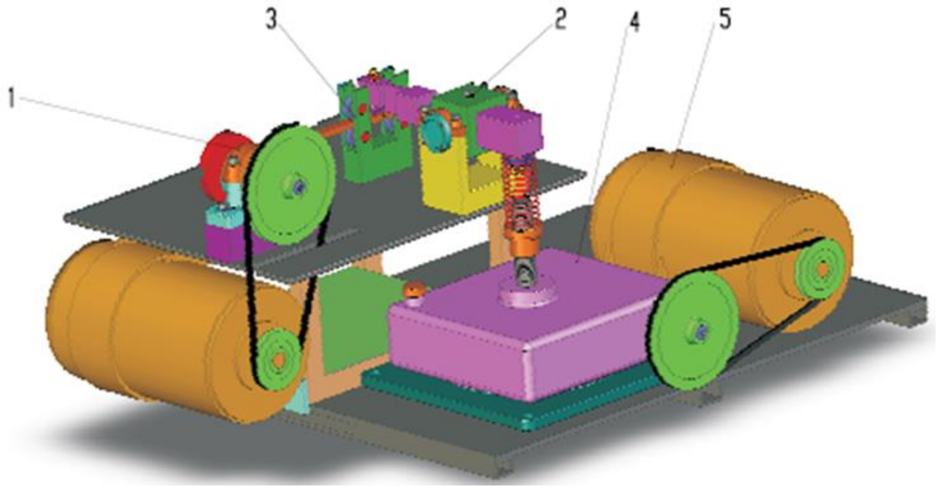

Figure 1. The experimental stand

The main drive module consists of a DC motor with speed variator on which a three-speed belt transmission is mounted, increasing the range of speed adjustment. It transmits the motion to the pill-holder module through a crank mechanism with variable eccentricity, hence allowing the stroke of the tablet-holder platform to be modified (Fig. 2).

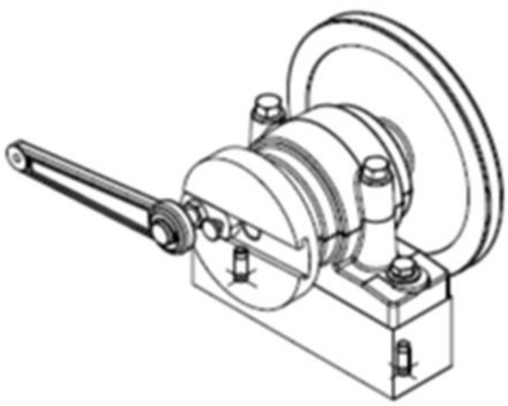

Figure 2. The actuation System

The pill holder module consists of a platform on which the sample made of the material to be tested is mounted. To ensure the rigidity of the system, this platform slides between 4 bearings whose pressure on the platform guide is also adjusted by means of eccentric shafts, simultaneously ensuring the direction of movement (Fig. 3).

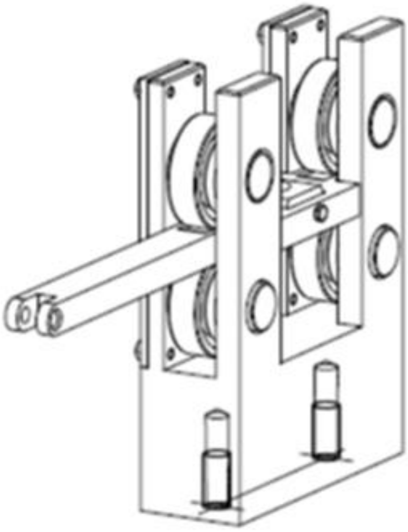

Figure 3. The pill-holder module

The transversal excitation module is located on the pill holder platform, which has as its main actuation element a stepper motor that is controlled through an Arduino board. The transverse disturbance system is a module that allows one of the friction coupling elements to also move transversely to the main test direction. It consists of a support on which a block - on which the studied sample is mounted- slides (Fig. 4)

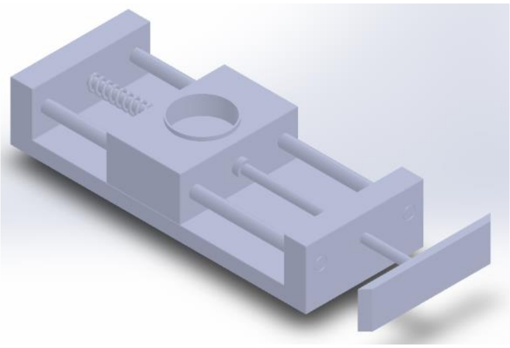

Figure 4. The disturbance system

It is mounted on the same guide as the fixed version.

The movement is generated by a bed acting on a slide integral with the pill-holder block. The bed is mounted on the spindle of a stepper motor, which excites the transverse motion system. The bed touches a yoke, which acts as a latch and is returned by a spring.

The motor is driven by a controller controlled by an Arduino board, allowing controlled movement. This allows the user to choose the duration and direction of movement and to fragment the speed. The board allows for adopting a "random" program that generates a random movement in terms of direction and speed. It permits the movements simulation according to the real operating situation, including that of a human joint.

The loading module has as central element a worm gear - worm wheel transmission continued with a movement screw which has a spring mounted on the driving sprocket with the role of maintaining the preset load constant (Fig. 5).

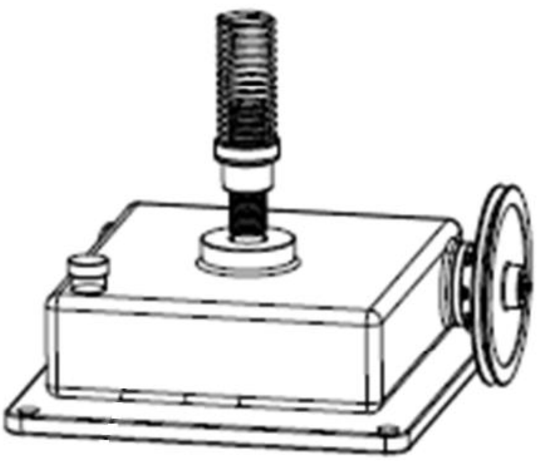

Figure 5. The loading module

The port-transducer module is actually a lever with a loading area at one end and a tweezer at the other that allows the attachment of the second component of the friction coupling. Two weakened sections in which tensiometric resistive transducers are mounted allow the control of both the friction force and the pressing force over time (Fig. 6).

To increase the sensitivity, four resistive transducers (two on one side and two on the opposite side) are mounted in each weakened section and connected in a complete bridge.

The configuration of friction couplings that can be obtained are sphere/plane, cylinder on plane, and pin on disk type.

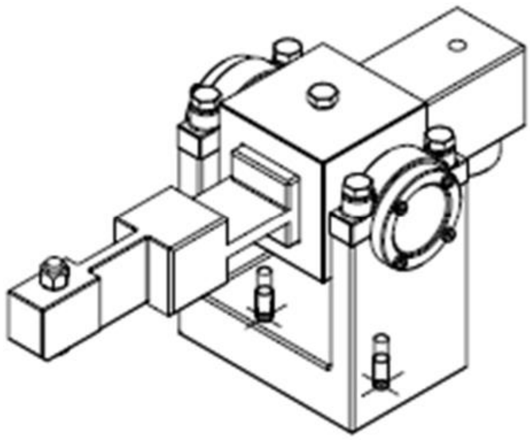

Figure 6. The port-transducer module

One notable feature of the disc in the tablet holder plate is its unique geometry. This design allows for the creation of a small retention tube, which is particularly useful in maintaining the lubricant during experiments that necessitate it.

3. RESULTS AND DISCUSSIONS

The present experimental stand has allowed the testing of various material couplings used in the manufacture of ball joints in motor vehicle steering systems (steel/Teflon or steel/polyethylene). It also permits assessing the suppleness of biocompatible metal alloys and high-density polyethylene, providing a comprehensive understanding of their performance.

The main movement is alternative, whose amplitude is given by the eccentricity of the crank mechanism, with a maximum value of 10 mm (20 mm/revolution). Speeds up to 1 m/s have been achieved.

The loads applied are adaptable, depending on the material and dimensions of the weakened section. The load bearing bar can be easily replaced with another one, featuring a different geometry and therefore a different load range, showcasing the versatility of our testing equipment.

The load limits for the current configuration are shown in Fig. 7, which shows a finite element analysis performed.

A tensile tester was employed to visualize and record the values of the pressing force and the friction force. To verify the stand's versatility, the dynamics of the human step were simulated for a friction coupling made of biocompatible titanium alloy/high-density polyethylene UHMPW (Fig. 8)

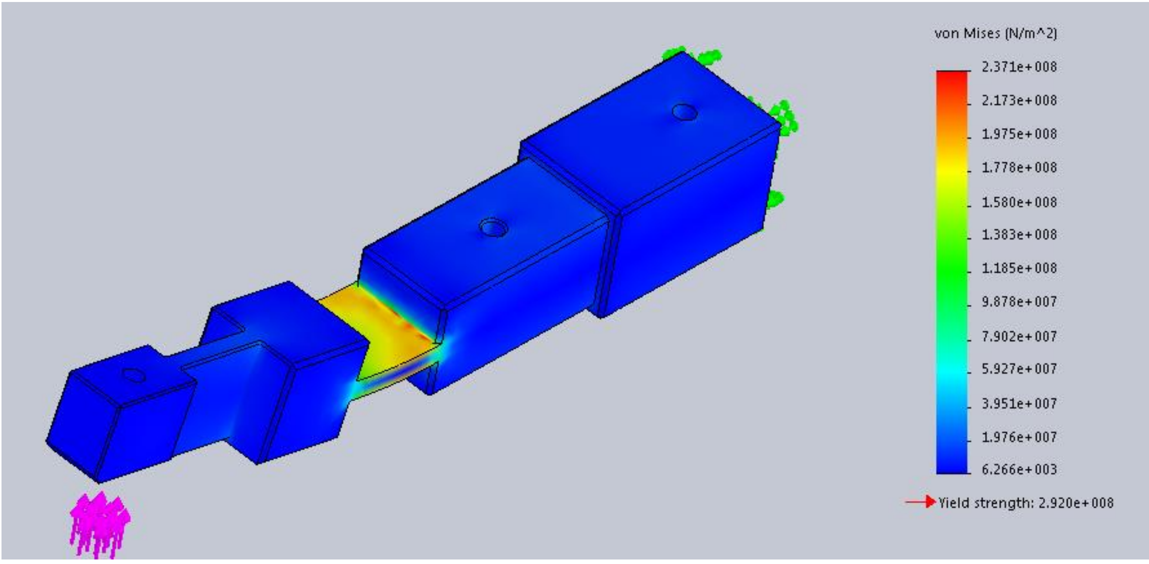

Figure 7. Finite element analysis of the transducer bar for a load of 1000 N

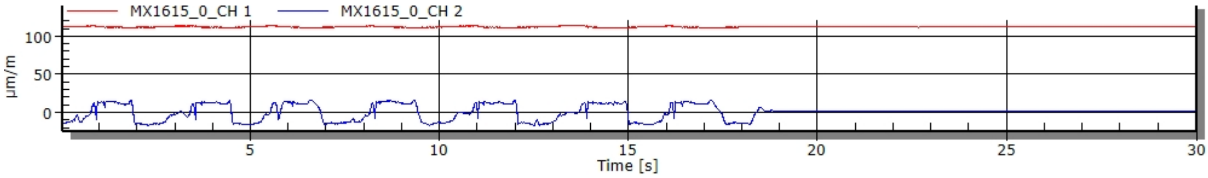

Figure 8. Frictional force recording for a titanium alloy/UHMPW friction coupling

Research was carried out regarding the tribological of a material behavior coupling corresponding to the manufacture of car pivots. Figure 9 shows the state of the metal surfaces before and after the test on the stand. The results of the mentioned study will be extensively reported in another paper.

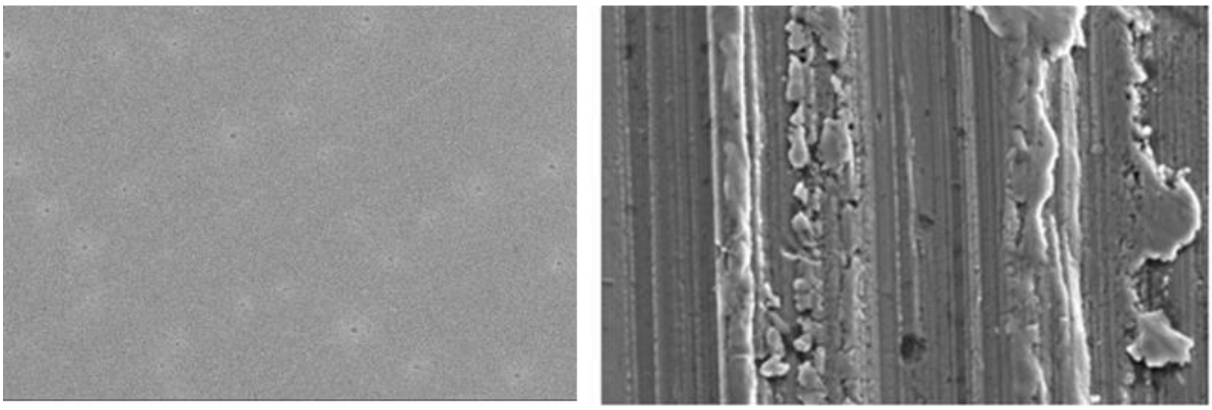

Figure 9. Steel sample spatter before (left) and after (right) the test

3. CONCLUSIONS

The proposed stand is versatile. In its current configuration, it offers a realm of possibilities that can be further expanded by simply altering the geometry of the transducer bar.

It can simulate excitations and even vibratory movements currently encountered in motor vehicle operations. At the same time, the materials used in the road infrastructure can also be tested.

Through the transverse excitation controlled by the Arduino board, movement curves with a complex profile can be obtained, including the one corresponding to the human step, which is useful for bio-tribological studies.

REFERENCES

[1] G.P. Cimellaro, M. Tanganelli, M. Domaneschi, S. Viti: "*Developing a laboratory facility to assess friction coefficients of standing samples*," Procedia Structural Integrity, **vol. 29, 2020, pp. 142-148.**

[2] Mocanu, S., Rece, L., Burlacu, A., Florescu, V., Rontescu, C., Modrea, A., "*Novel Procedures for Sustainable Design in Structural Rehabilitation on Oversized Metal Structures*", Metals, **Volume12, Issue7, Article Number1107, 2022**, DOI: 10.3390/met12071107

[3] L. Căpitanu, V. Florescu, L.-L Bădiță: *"Damage estimator, a possible way to predict the failure of hip and knee endoprosthesis,"* Industrial Lubrication and Tribology, **vol. 69(1), 2017, pp. 71-80.**

[4] M. Gingarasu, E. Mereuta, V. Amortila, C. Humelnicu, M. Novetschi: "Wear of spherical joints of the vehicle steering Systems. Vibrations and their role in diagnosis," Mechanical Testing and diagnosis, **vol. 10, no. 3, 2020, pp. 16-20.**

[5] V. Recklin, F. Dietrich, P. Groche: "Influence of Test Stand and Contact Size Sensitivity on the Friction Coefficient in Sheet Metal Forming," Lubricants, **vol .6, issue 2, 2018, 41.**

[6] J.C. Pais, A. Ferreira, C. Santos, D. Presti: "Preliminary Studies to Use Textile Fibers Obtained from Recycled Tires to Reinforce Asphalt Mixtures," Romanian Journal of Transport Infrastructure, **vol. 7, issue 2, 2018, pp. 14-30.**

[7] A. Legendi, L. Rece, A.D.B. Pironea, V. Florescu: "Innovative Calculation Method of the Productivity of Vibrating Screens Used in Mineral Aggregates Sorting," Romanian Journal of Transport Infrastructure, **vol. 7, issue 2, 2018, pp. 1-13.**

[8] L. Căpitanu, Badita, L.-L., C. Tiganesteanu, V. Florescu: "The wear of the taper junction of the stem trunnion with the femoral head of a total modular hip prosthesis," Journal Tribologi, **vol. 23, 2019, pp. 61-75.**

[9] L. Capitanu, L.-L. Badita, V. Florescu, C. Tiganesteanu, L.F. Isvoranu: "Fretting manifestations in total hip prosthesis," IOP Conference Series: Materials Science and Engineering, **vol. 724(1), 2020, 012057.**

[10] L. Capitanu, L.-L. Badita, V. Florescu: "Stability loss of the cemented stem of hip prosthesis due to fretting corrosion fatigue," Tribology in Industry, **vol. 39, issue 4, 2017, pp. 536-546.**

[11] L. Capitanu, V. Florescu, L.-L. Badita: "New concept in durability improvement of hip total joint endoprostheses," Acta of Bioengineering and Biomechanics, **vol. 16, issue 1, 2014, pp. 75-82**

[12] Rontescu, C., Amza, C.G., Bogatu, A.M., Cicic, D.T., Anania, F.D., Burlacu, A., "*Reconditioning by Welding of Prosthesis Obtained through Additive Manufacturing*", **Metals, Volume 12, Issue 7, Article Number 1177, 2022**, DOI: 10.3390/met12071177