Study on the friction in the tripod type couplings with external contacts

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Abstract. One of the basic criteria which is influencing the choosing process of a tripod coupling in a mechanical transmission is the friction. Due to their construction the elements being in contact between the driver and the driven elements, are suppose to be optimized; this optimization it could be according to the shape or/and according to the materials. In the paper there are performed tests for the case of the line type contacts between the driver and the driven elements, in analogy with the tripod coupling with the cylinder on cylinder contacts. There are studied two cases: steel pin on steel disk and steel pin on PA66 polyamide type contacts. The test are performed for a set of rotational speeds of 500, 1000, 2000 and 3000 rpm and a set of normal forces as 3, 5, 7 and 9 N, in non-lubricated conditions. There are identified conclusions regarding the friction coefficient evolution and values in the case of steel on steel and steel on PA66 polyamide type contacts.

1. Introduction
The tripod type couplings with external contacts are used in applications which require higher loading conditions. One of the criteria which are influencing the choosing process of the tripod type couplings in different applications is referring on their mechanical efficiency.

The literature in the field of the tripod couplings presents studies about the friction between the different components in relative motion and about the behaviour of the lubricants under several working conditions. In [1] is studied the influence of the frequency and the amplitude of the reciprocating motion on the lubricant film thickness and pressure in the case of the tripod sliding universal joints; according to the conclusions the film thickness increases with the increase of the amplitude and the frequency.

A four ball tester and a linear oscillation testing machine is used in [2] in order to study the friction, wear and the grease degradation for constant velocity joint used in the transmission of vehicles that travelled various distances.

The static and dynamic analyses achieved for the tripod couplings have been achieved by developing different friction models. In [3] it is created a kinetostatic friction model of an automotive transmission with a tripod coupling and an outboard ball joint. In the model, the rollers between the tulip and the tripod are neglected; in the numerical model is considered a Coulomb friction model which produces shudder effects without velocity dependencies.

The kinematics and the static analysis for tripod constant velocity joints of spherical end spider type is made in [4], for any values of the friction coefficients between the parts being in relative motion. The analysis is performed by considering a set of conditional equations with the forces and the
moments acting on three cylindrical rollers, on the spider and on the housing. In [5] the friction between the rollers and the tulip ramps of a tripod coupling is modelled with two theories: the theory of the viscous friction and the theory of the Coulomb friction. For the viscous friction approach are provided the analytical expressions of the forces and of the torques; the Coulomb friction approach offers as results only numerical simulations.

One of the aims of the theories and tests performed in the references is to predict the tripod joint frictional behaviour in different working conditions; in this way, in [6] is developed a dynamic friction model of a tripod joint on the base of tests in different operating condition as: oscillatory speeds of the plunge, different articulation angles, torques and lubrication. The conclusions are predicting the variation of the generated axial force of the tripod coupling. A kinematic and static analysis is developed for any values of the friction coefficients is developed in [7], for tripod joints of the spherical end of spider type.

A joint friction test rig is developed in [8] which operate under different test conditions as: oscillatory speeds, torques and joint angles. A tri-axial force sensor measures the internal tripod coupling forces including friction.

A complete study of the friction phenomenon and its influence of the global power loss in a mechanical transmission is presented in [9].

According to the references, the mechanical efficiency of the tripod type couplings with external contacts is influenced mainly by the shapes and the materials which are used in the construction of the elements being in contact. Due to the external contacts, the tripod coupling with cylinder on cylinder contacts – figure 1 – assures higher loading capacities [10]. According to the external cylinder on cylinder contacts, the paper presents the tests performed for a pair of cylinder on cylinder type contacts in two variants: steel on steel and PA66 polyamide on steel external contacts.

2. The equipments
The tests are performed on a UMT type tribometer [11] which is presented in figure 2. The force sensor allows forces measurements about 2 axes – the vertical one and a horizontal one – in the interval of $F=10 \ldots 1000 \text{ N}$ and the resolution $R_F=50 \text{ mN}$. The normal force is adjusted by the vertical stroke which maximum value is $d=150 \text{ mm}$ with the speed of $v_d=0.001 \ldots 10 \text{ m/s}$. The maximum lateral positioning stroke is $l=75 \text{ mm}$ with the speed of $v_l=0.01 \ldots 10 \text{ m/s}$; the lateral positioning resolution is $R_l=2 \mu \text{ m}$. The tribometer allows wear measurements with an accuracy of $R_r=50 \text{ nm}$. The oil bath can be heated up to $t=150 \degree \text{C}$.

The rotational motions are achieved on the block-on-ring module – figure 3 – which is a component of the tribometer [11]. On the block-on-ring module there may perform tests for line type
contacts between couple of materials as metallic on metallic, metallic on plastic or plastic on plastic. The rotational speed can be adjusted up to \( n=3000 \) rpm, about two ways.

![The tribometer.](image)

**Figure 2.** The tribometer.

The module is equipped with a force transducer which allows to measure loads up to \( F=1000 \) N with a resolution of \( R_r=1 \) µN. The stroke of the reciprocating module can be controlled in an interval as \( s=0.05 – 25 \) mm with a frequency of the motions as \( \nu=0.1 – 60 \) Hz.

![The block-on-ring module.](image)

**Figure 3.** The block-on-ring module.
3. The tests

The tests are performed at a room temperature of 22°C, in non-lubricated conditions, for a line type contact between the steel made pin and 2 disks: one steel made and one PA66 polyamide made – figure 4.

![Figure 4. The pin on disk contacts.](image1)

The disks are mounted in the testing device as it can be observed in the figure 5.

![Figure 5. The test rig with the disks.](image2)

The tests are performed for a set of normal forces as $F=3$ N, 5 N, 7 N, 9N and rotational speeds as $n=500$ rpm, 1000rpm, 2000 rpm, 3000 rpm.

4. Results and conclusions

The variation of the friction coefficient with the rotational speed, for a set of normal forces is presented in figure 6; in all the cases the steel on PA66 polyamide contact has a smaller friction coefficient than the steel on steel contact. The friction coefficient has a small decrease with the increasing of the rotational speed.
Figure 6. The variation of the friction coefficient with the rotational speed.
Figure 7. The variation of the friction coefficient with the normal force.
Figure 7 presents the variation of the friction coefficient with the normal force, for a set of rotational speeds. In all the cases the value of the friction coefficient in the case of the steel on PA66 polyamide type contact is smaller than the value of the friction coefficient in the case of steel on steel contact. The friction coefficient has a small decrease with the increasing of the normal force.

As a general conclusions, the PA66 polyamide on steel type contacts may be used as a solution for the design of the tripod couplings with external contacts; this type of couple of materials, for all the tested cases, has a smaller friction coefficient than the steel on steel type of contacts.

5. References
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