Component assembly for determination of elastomeric vulcanize frictions

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Abstract. This article deals with the design and assembly of a component for determining the frictional properties of elastomeric vulcanizates. The component was design for a universal tensile machine, without needed of intervention to itself machine. The purpose of the work was designing a component in software SolidWorks and its subsequent assembly, as well as individual testing of frictional properties of selected specimens of elastomeric vulcanizates. Before of individual testing, the elastomer blends have to be vulcanised in the form of a block with a constant 16 mm height to ensure the same spring pressure on the specimens in the component. Then, by using rotary knife is from prepared vulcanizate cut a sample with 16 mm diameter. Result from friction properties measurement of samples is force needed to start of movement (shear) of sample over particular type of surface as well as graphical dependence of force (N) on movement of track (mm). From the graphical dependence, it is possible to determine the decrease or increase the force depending on the individual sections of the trajectory.

1. Introduction

Under the term friction or abrasion refers to a phenomenon that occurs when a body moves along another body, or when we want to set the body in motion by the action of an external force. As a result of friction, a frictional force is created, acting against the movement of the body [1, 2, 3]. So, we are talking about the creation of a resistive force, which is in most cases undesirable. When solving examples, friction is often neglected, due to the simplification of the calculation. Therefore, friction is sometimes perceived as an undesirable or unnecessary phenomenon. Friction can be unfavourable, but sometimes very necessary. Adverse effects include, in particular, material wear or slowing down the motion. On the other side, friction is an integral part of movement and also of some devices that directly use the action of frictional force - e.g. car brake system [4, 5, 6]. Without friction, one would not even be able to walk, hold objects in hands, drive a car, perform certain types of sports and many other things. Friction has wide used but also consequences. However, the magnitude of the friction force can be adjusted and
adapted. Various experimental studies are performed in order to be able to select a suitable material for product and to determine the influence of individual factors on the magnitude of the friction force [7, 8]. The aim of this work is to design and manufacture a simple test component that would allow to compare the friction force acting between the test specimen and the selected surface for samples from elastomeric vulcanizate with different chemical composition. The made component is designed for use with a universal tensile testing machine (UTTM), which is often standard equipment in experimental laboratories. By using UTTM are usually performed the tensile, compressive or bending tests. Thanks to the possibility of recording the dependence of the required force and displacement, this device can also be used to determine the friction force. The purpose of the component is to use experimental measurements using UTTM and then determine which of the test materials is more suitable for the desired purpose. The component is primarily made for testing samples of elastomeric vulcanizates. It can thus be used, for example, to test the adhesion and wear resistance of elastomeric blends from which the shoes soles are made.

2. Experiment

2.1. Software for component design

The design, assembly and simulation of the component itself to determine the friction of elastomeric blends was designed in the program Solidworks. The individual parts of the component were created in a model type - part, then assembled in a model type - assembly. Nonlinear static simulation was chosen to simulate the testing process of the sample due to the large displacement (pull-out of the part of the component). The last step of the component design was the creation of technical documentation of individual parts, for the actual made.

2.2 Materials

Conventional structural steel of class 11 was chosen for the realization of the component assembly. In the manufacture of the preparation, the total weight of the component was considered, because it will be clamped directly into the jaws of the tensile testing machine with the content of sensitive sensors for determining the forces to six decimal places. The second limitation in the implementation of the assembly was the length of the component itself due to the maximum trajectory of the tensile testing machine.

2.3 Testing procedure

A Shimadzu AG-X Plus (Shimadzu, Tokyo, Japan) universal tensile testing machine was used to test the functionality of the component as well as to determine the friction of elastomeric vulcanizates. The sample for friction determination was cut from the vulcanizate using a cylindrical rotary knife in shape of cylinder with dimensions 16x16 mm (diameter x height). Test speed was set at 100 mm/min.

3. Results and discussion

3.1 Component design in Solidworks

The first part created is the body of the component itself (Fig. 1). The body of the component is equipped with grip section which is used to clamp one part of the component into the jaw. Body of
component fulfils the main function and serves as a carrier for the sliding part of the component. The upper surface of the body is provided with an opening with the dimensions of the sample for its easy insertion into the component.

Fig. 1 3D design of component body

The body of the component is U letter shaped and for this reason, as well as due to the location of the pull-out part, it was necessary to place reinforcements on the open part of the body (shown in red in Fig. 1). The reinforcements prevent deformation of the profile (body of the component), which could distort the measurement results. The elevated part of the inner side of the body was realized due to the placement of the pull-out part in a parallel axis with the grip section on the basic body of the component. In the case of the pull-out part, the design of the component also dealt with the selection of the type of linear guides. In Fig. 2 shows the two types of linear guides that were studied in the design of component. The pull-out secured with linear bearings with an inner diameter of 10 mm is not suitable for the component, in particular due to the need to extend the guide rods for bearings outside the component body. For this reason, the length of the guide rods would have to be twice as the test path of sample (Fig. 2). Extending the guide rods would also cause an increase the length of the component itself and thus the initial zero (gauge length) distance between the jaws of the tensile testing machine too. On the contrary, the full-extension slide (Fig. 2) offers the construction of the pull-out part of the component without the need using guide rods. The basic part of the full-extension slide remains located in the body of the component even after ejection, which does not extend the total length of the component (the pull-out part of the full-extension slide is the bearer of part on which the friction of the elastomeric vulcanizate is determined). For these reasons, a full-extension slide was chosen for production of the component [9, 10].
Fig. 2 Types of linear guide’s a) linear ball bearings, b) full-extension slide and comparison of the required line length

Directly on the selected linear guide, the plate with the test surface holders is placed, as well as the surface determined for clamping in the jaws of UTTM (Fig. 3).

Fig. 3 Pull-out part of component

The sample of elastomeric vulcanizate must be loaded during the test with a specified force which will ensure a constant downforce of the sample on the surface area on which the friction will be determined [11, 12]. In the case of the friction of several samples is determined, the test must always be carried out with the same downforce in order to be able to compare the results. In our case, a compression spring (Fig. 4) with a force of 7 N was used (the force was determined by means of a UTTM with a compression corresponding to the compression of the spring when placed in a component for determining the friction of elastomeric vulcanizates). One of the created parts is also a model of the test surface in the shape of a plate with dimensions 25x150x6 (width x length x thickness). This model will serve as a pattern for the preparation of replaceable surfaces in the component [13].
The last step of the component design was to create an assembly of individual parts. In Fig. 5 we can see the final design of component for determining the friction of elastomeric vulcanizates. The individual parts of the component were connected using the mates function. Each part of the component was bonded to the other parts, which ultimately resulted to creating a compact component.

![Fig. 5 Finally assembled component](image)

### 3.2 Simulation of friction determination process

Created composition of component from chap. 3.1 was subjected to a simulation of friction determination process of elastomeric vulcanizates using the Solidworks. The result of the simulation is to obtained a graph of the force versus the simulation time, which is comparable to the displacement of the pull-out part of the component during the test (the simulation time must be multiplied by 10). In Fig. 6 is a component with a created mesh of elements (the parameters of the mesh of elements are given in Tab. 1) and with the display of defined parameters such as the downforce on the sample, fixation of the
component and prescribed displacement corresponding to the sample path along the test surface [14, 15].

![Diagram showing component and prescribed displacement](image)

**Fig. 6** 1. Prescribed displacement (100 mm), 2. downforce on the sample (7 N), 3. Fixation of component

| Tab. 1 Mesh elements parameters |
|----------------------------------|
| **Study name**                   | Nonlinear static (Default) |
| **Mesh type**                    | Solid Mesh                 |
| **Mesher Used**                  | Standard mesh              |
| **Automatic Transition**         | Off                        |
| **Include Mesh Auto Loops**      | Off                        |
| **Jacobian points**              | 4 points                   |
| **Element size**                 | 3.54123 mm                 |
| **Tolerance**                    | 0.177061 mm                |
| **Mesh quality**                 | High                       |
| **Total nodes**                  | 62245                      |
| **Total elements**               | 35485                      |
| **Maximum Aspect Ratio**         | 15.075                     |
| **Percentage of elements**       |                           |
| **with Aspect Ratio < 3**         | 96.8                       |
| **with Aspect Ratio > 10**        | 0.0197                     |
| **% of distorted elements**      | Jacobian                   |
| **Remesh failed nodes with incompatible mesh** | Off                        |
| **Time to complete mesh (hh:mm:ss)** | 00:00:06                  |
| **Computer name**                |                           |

In Fig. 7 and 8 are the results of a simulation of a component for determining the friction of elastomeric vulcanizates. From the result of the simulation, specifically the displacement, it can be seen that the pull-out part of the device has a red color due to the extension during the test (prescribed displacement of 100 mm).
Fig. 7 Result from simulation - part displacement

Another result of the component test simulation is the stress recorded during the test. From Fig. 8 shows that the maximum stress (red area) is recorded at the end of the pull-out part, because this part undergoes the largest displacement, which Solidworks evaluates as tensile stress. Using the Probe function, it is possible to graphically plot the stress dependence on the simulation time (in surface of test sample), after performing the simulation calculation, which is comparable to the displacement of the pull-out part of the component during the test (the simulation time must be multiplied by 10).

Fig. 8 Result from simulation - stress display

From obtained stress values is possible obtained the values of force during the test. It is necessary to divide the stress values by the surface area of the sample pressed to the test surface (Fig. 9).
Fig. 9 Dependence of friction force from simulation time

3.3 Determination of elastomeric vulcanizate friction

The finally assembled component for determining the friction of elastomeric vulcanizates (Fig. 10) was clamped in the pneumatic jaws of the universal tensile testing machine Shimadzu AG-X Plus. The component placed in the pneumatic jaws and ready to perform the test is shown in Fig. 11.

Fig. 10 Component for determination of elastomeric vulcanizate friction

Fig. 11 Component clamped into pneumatic jaws
Experimental determination of friction was performed on two different samples of elastomeric vulcanizates at the parameters given in Tab. 2. The result of the determination is a graphical processed of the force required to induce the required displacement (100 mm path) at a test speed of 100 mm/min (Fig. 12 and 13).

| Parameter                      | Value / description               |
|--------------------------------|-----------------------------------|
| Test specimen geometry         | Cylindrical shape 16x16 mm (D x H)  |
| Downforce on test sample       | 7 N                               |
| Test surface                   | Ceramic tile                      |
| Condition of the test surface  | Dry                               |
| Temperature                    | Laboratory temperature            |
| Trajectory (displacement)      | 100 mm                            |
| Test speed                     | 100 mm/min                        |

The friction determination was repeated three times on each sample. From the graphical result, it is possible to see that the most important is the maximum force for inducing the movement of the sample on the test surface. By comparing the resulting average maximum forces of the samples, it is possible to determine which of the samples needs a higher force to induce motion and thus has a higher friction on a given surface (better adhesion). However, in terms of results, it is not possible to compare the results obtained with other friction determining devices. It is therefore possible to compare the friction values of vulcanizates only in the case of determination under the same conditions and thus also using the same devices [16, 17, 18].

![Graphically processed friction values for the first sample](image-url)
By comparing the graphs of Fig. 12 and 13 can be seen that sample A reached the higher maximum force required to induce the movement (Tab. 2). However, sample B did not show a significant decrease in force even after the displacement of 50 mm trajectory compared to sample A. From the point of view of adhesion, sample B is better (higher force value) but after overcoming the maximum force the sample slides on the test surface and the force value decreases significantly. Sample B is more preferable (smoother decrease in force value and lower decline of force value comparison with Sample A).

**Fig. 13** Graphically processed friction values for the second sample

Tab. 3 Maximum values of force measured for test samples

| Sample (test number) | Maximum force (N) | Deviation of maximum force from average (N) |
|----------------------|-------------------|-------------------------------------------|
| Sample A – 1         | 19,5301           | 0,0447                                    |
| Sample A – 2         | 19,4501           | 0,1246                                    |
| Sample A – 3         | 19,7442           | 0,1694                                    |
| Sample B – 1         | 16,6059           | 0,0069                                    |
| Sample B – 2         | 16,3325           | 0,2665                                    |
| Sample B – 3         | 16,8586           | 0,2596                                    |

**4. Conclusion**

In practice, the magnitude of the friction force can be modified depending on the requirements of the application, when the resulting friction force may be necessary or, on the contrary, undesirable. Several experimental studies were performed to determine the magnitude of the applied friction force and the influence of individual factors on its magnitude. The reason for the elaboration of the work was to make a simple component, which allows to determine the friction force generated between the test specimen and the selected surface. The first step was to design a component with the aim of determine the method of measuring the friction force and to provide a design solution to which ensure that the required experimental measurements are performed. The design was created using the SolidWorks CAD environment, which allows to make 3D models of the parts used and the assembly of the component, as well as to simulate the process of determining the friction of vulcanizate. For the required measurement of the value of frictional force acting between the test specimen and the surface, the component was
designed for use with a universal tensile testing machine (UTTM). The reason is the ability of the UTM to record the dependence of the required tensile force on the sample path. After completion of assembly of the component, experimental measurements were performed on two elastomeric vulcanizates samples with different chemical composition of the blend. Using the determined parameters of the experiment (Tab. X), three measurements were performed on each sample. We repeatedly measured a lower force required to induce movement in the second sample in comparison with the first sample. This means that the second sample developed less resistance to movement. Thus, it can be stated that the prepared component allowed us to compare the value of the friction force in two different samples and thus determine which of the tested vulcanize is more suitable in terms of better anti-slip properties (Sample A). We recommend further research to verify the functionality of the component and the accuracy of the results obtained. The aim of the research can be e.g. performing comparative analyses from measurements using a component and measurements using another available devices for determination of friction force.

5. References

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