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Influence of Deformation Measurement Time on the Rubber Element of a 'SEGME' Flexible Coupling †

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Abstract

Particular attention is devoted to the characteristics of elastic couplings as essential connecting elements within machine drive systems. The operational characteristics of such couplings are determined under both static and dynamic loading conditions, while also taking into consideration the nature of the working environment and the specific type of driven machinery, such as crushing machines, mills, and related industrial equipment. The relationship between the transmitted torque load and the deformation of the coupling's rubber working elements constitutes a significant factor contributing to the compensation of vibrations and shaft misalignments. Furthermore, the rubber elements are characterized by inherent damping properties and residual elastic deformation. The parameters governing damping behavior and deformation exhibit variations over time, which is of particular importance in deformation analysis and measurement. A series of experimental investigations was carried out to evaluate the influence of measurement time on the deformation state of the rubber element in a "SEGME"-type coupling. Four time intervals—5, 10, 20, and 30 s—are considered for recording the instantaneous deformation of the working element. Based on the obtained experimental data, mathematical relationships describing the energy dissipation and damping capacity of the rubber working elements are established as functions of the deformation measurement time. In addition, a coefficient characterizing the influence of deformation measurement duration was determined.

Keywords: flexible coupling "SEGME" type; static loading; stiffness; nominal torque; angle of rotation; coefficient; mathematical relationships; test bench; nonlinear characteristic

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1. Introduction

Flexible couplings with rubber elements [1,2] are widely used in mechanical engineering due to their ability to compensate for minor shaft misalignments, reduce dynamic loads, and limit the transmission of vibrations in drive systems. This paper considers a representative of flexible couplings of the "SEGME" type, characterized by simple design, easy installation, and reliable operation under various operating conditions.

One of the main parameters characterizing the performance of such couplings is their torsional stiffness [3,4], which defines the relationship between the transmitted torque and the angle of rotation between the coupling hubs. In practice, this relationship is strongly influenced by the properties of the rubber element, the loading conditions and the

duration of static load application. Due to the significant viscoelastic properties of rubber, deformation does not occur instantaneously but develops over time, leading to a nonlinear characteristic of the coupling.

In most engineering calculations, the stiffness of flexible couplings [5] is assumed to be a constant value, determined at nominal torque and at a fixed moment of deformation measurement. However, such an approach does not account for the influence of loading time on the angle of rotation and, consequently, on the calculated coefficients used in modeling the dynamics of drive systems [6,7]. This may lead to significant discrepancies between the actual system behavior and the results obtained from analytical and numerical models.

The present study describes the influence of deformation measurement time on the rubber element of a "SEGME" type flexible coupling under static loading. The main objective is to experimentally establish the mathematical relationships between applied torque, angle of rotation, and time, as well as to analyze the variation in effective stiffness [8] depending on the selected measurement time.

2. Materials and Methods

For the purposes of this study, a specialized test bench (Figure 1) for flexible couplings [9] was employed, allowing controlled loading of the coupling and precise measurement of the angular displacement at various torque levels and holding times. The test bench was developed at the Technical University of Varna, Varna, Bulgaria, to support scientific research conducted by the Department of Mechanics and Machine Elements. It is located in a laboratory dedicated to the study of elastic couplings.

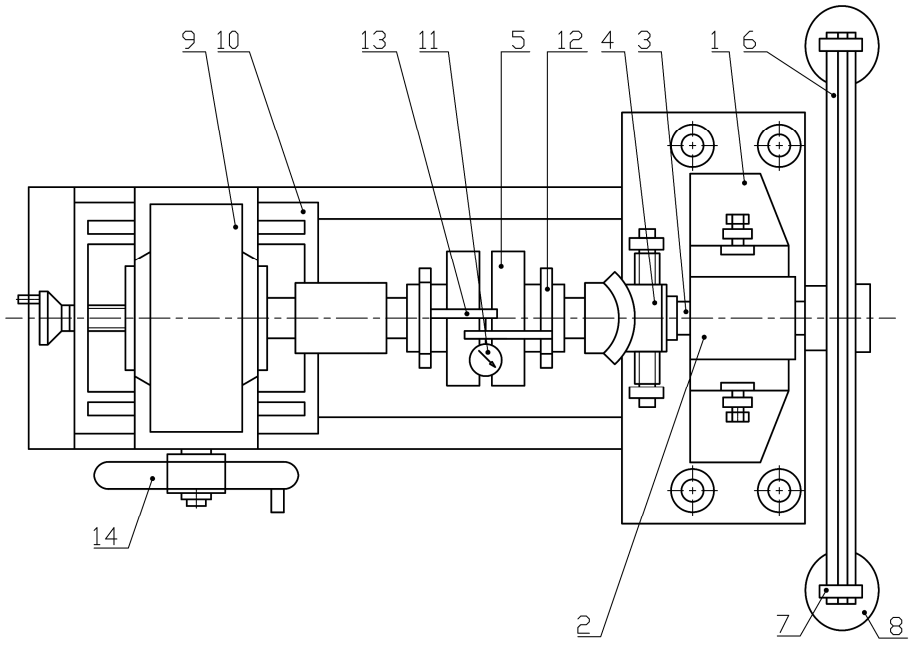


Figure 1. Flexible coupling test bench.

A bearing box (2) is mounted on a plate (1), in which the shaft (3) rotates on rolling bearings, on one end of which, by means of a sleeve coupling (4), one half of the coupling under study (5) is mounted. On the other end of the shaft (3), a two-arm bridge (6) is fixed with the hangers (7) on which the weights (8) are placed. The other half of the coupling is connected to the output shaft of the worm gear reducer (9), which ensures its immobility. The linear relative displacement of the driving shaft relative to the driven shaft under load is determined by an indicator clock (11) mounted on the bracket (12). The gear reducer is placed on a foundation (10). The distance between brackets (12) and (13) is measured by

the clock. The stand is equipped with a mechanism for rotating the cylindrical worm gear using handle (14).

A "SEGME" type flexible coupling, standardized according to BDS 16418–86 [10], was investigated. The coupling is designed for a nominal torque of T_{nom} = 25 Nm; however, for the purposes of this study, it was loaded to a maximum torque of T_{max} = 30 Nm. Figure 2 presents the driving coupling hub, through which motion is transmitted from the machine.

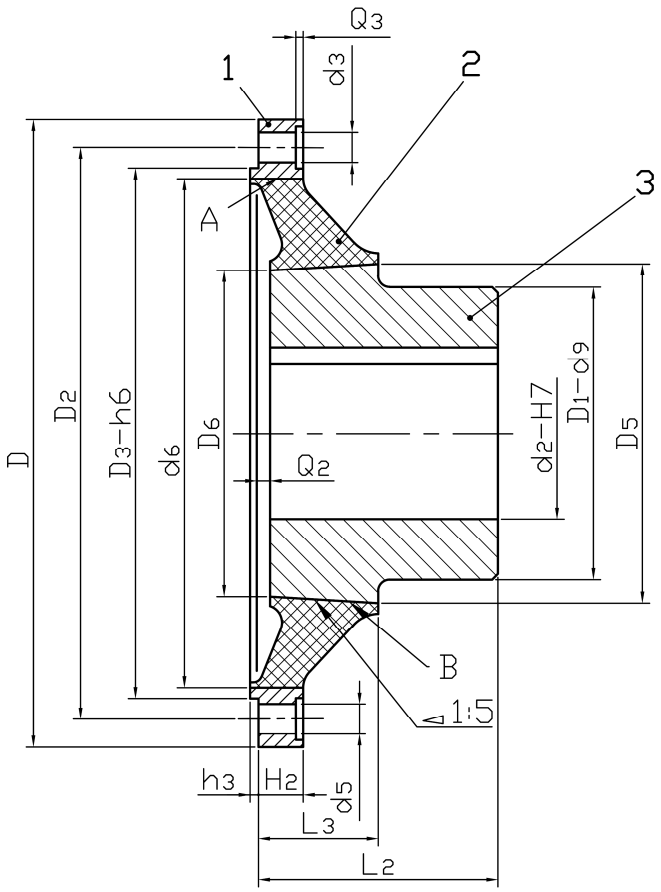


Figure 2. "SEGME" coupling hub—cross-sectional view.

Position (1) represents the flange, which is connected to the other coupling hub through bolt holes. The driven coupling hub has the same geometry but is entirely made of steel. Six bolts are arranged in the holes, alternating between fitted and clearance bolts. The hub (3) is manufactured with a taper of 1:5 on its outer working surface. The torque is transmitted from the hub (3) to the flange (1) by means of a vulcanized rubber element (2). Measurements under load are conducted at four time intervals—5, 10, 20, and 30 s.

3. Results and Discussion

The results are shown in tables as averaged values from multiple tests for each time interval. Measurements were performed under both loading and unloading conditions. Table 1 presents the results corresponding to a deformation measurement time of 5 s.

Table 1. 5 s deformation reading.

					Load T, Nm			
Time, 5 s	**T, Nm**	0	5	10	15	20	25	30
	Δ_1, mm	0.00	2.24	4.85	7.30	9.66	11.95	14.36
	Δ_2, mm	0.00	2.23	4.78	7.30	9.46	12.05	14.40
	Δ_m, mm	0.00	2.24	4.82	7.30	9.56	12.00	14.38
	φ, rad	0.0000	0.0120	0.0257	0.0390	0.0511	0.0641	0.0767
					Unload T, Nm			
Time, 5 s	**T, Nm**	30	25	20	15	10	5	0
	Δ_1, mm	14.36	13.66	11.73	9.57	7.32	4.94	1.90
	Δ_2, mm	14.40	13.48	11.60	9.52	7.25	4.89	1.89
	Δ_m, mm	14.38	13.57	11.67	9.55	7.29	4.92	1.90
	φ, rad	0.0767	0.0724	0.0623	0.0510	0.0389	0.0263	0.0101

Table 2 shows the loading and unloading behavior of the "SEGME" coupling at a deformation measurement time of 10 s.

Table 2. 10 s deformation reading.

					Load T, Nm			
Time, 10 s	**T, Nm**	0	5	10	15	20	25	30
	Δ_1, mm	0.00	2.45	5.49	7.96	10.60	13.11	15.80
	Δ_2, mm	0.00	2.56	5.28	8.07	10.80	13.40	15.95
	Δ_m, mm	0.00	2.51	5.39	8.02	10.70	13.26	15.88
	φ, rad	0.0000	0.0134	0.0288	0.0428	0.0572	0.0708	0.0847
					Unload T, Nm			
	T, Nm	30	25	20	15	10	5	0
	Δ_1, mm	15.80	15.10	13.05	10.81	8.40	5.65	2.16
	Δ_2, mm	15.95	15.28	13.41	11.12	8.57	5.65	2.30
	Δ_m, mm	15.88	15.19	13.23	10.97	8.49	5.65	2.23
	φ, rad	0.0847	0.0811	0.0706	0.0586	0.0453	0.0302	0.0119

The deformation at a 20 s measurement time is reported in Table 3.

Table 3. 20 s deformation reading.

					Load T, Nm			
Time, 20 s	**T, Nm**	0	5	10	15	20	25	30
	Δ_1, mm	0.00	2.45	5.34	7.97	10.67	13.27	15.95
	Δ_2, mm	0.00	2.45	5.40	8.15	10.78	13.40	15.99
	Δ_3, mm	0.00	2.59	5.35	8.19	10.92	13.51	16.11
	Δ_4, mm	0.00	2.30	5.35	8.11	10.70	13.20	15.98
	Δ_m, mm	0.00	2.45	5.36	8.11	10.77	13.35	16.01
	φ, rad	0.0000	0.0131	0.0287	0.0433	0.0575	0.0712	0.0854
					Unload T, Nm			
Time, 20 s	**T, Nm**	30	25	20	15	10	5	0
	Δ_1, mm	15.95	15.15	13.27	10.90	8.40	5.65	2.10
	Δ_2, mm	15.99	15.30	13.40	10.91	8.47	5.64	2.29
	Δ_3, mm	16.11	15.20	13.29	11.05	8.50	5.57	2.22
	Δ_4, mm	15.98	15.15	13.22	10.85	8.46	5.66	2.19
	Δ_m, mm	16.01	15.20	13.30	10.93	8.46	5.63	2.20
	φ, rad	0.0854	0.0811	0.0710	0.0584	0.0452	0.0301	0.0118

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The results for a 30 s measurement time are presented in Table 4.

Table 4. 30 s deformation reading.

Time, 30 s								
					Load T, Nm			
	T, Nm	0	5	10	15	20	25	30
	Δ_1, mm	0.00	2.50	5.45	8.29	10.89	13.51	16.10
	Δ_2, mm	0.00	2.61	5.57	8.35	10.97	13.64	16.24
	Δ_3, mm	0.00	2.65	5.43	8.28	10.93	13.58	16.22
	Δ_4, mm	0.00	2.62	5.39	8.25	10.98	13.58	16.20
	Δ_m, mm	0.00	2.60	5.46	8.29	10.94	13.58	16.19
	φ, rad	0.0000	0.0139	0.0292	0.0443	0.0584	0.0725	0.0864
					Unload T, Nm			
	T, Nm	30	25	20	15	10	5	0
	Δ_1, mm	16.10	15.31	13.31	10.89	8.50	5.65	2.25
	Δ_2, mm	16.24	15.32	13.32	10.90	8.51	5.72	2.07
	Δ_3, mm	16.22	15.22	13.21	10.92	8.55	5.69	2.07
	Δ_4, mm	16.20	15.01	13.26	10.87	8.44	5.52	2.15
	Δ_m, mm	16.19	15.22	13.28	10.90	8.50	5.65	2.14
	φ, rad	0.0864	0.0812	0.0709	0.0582	0.0454	0.0302	0.0114

To illustrate the variation in the flexible coupling characteristic T = T(φ) [11–13] at different angular deformation measurement times, the corresponding relationships of the measured parameters are shown graphically (Figure 3).

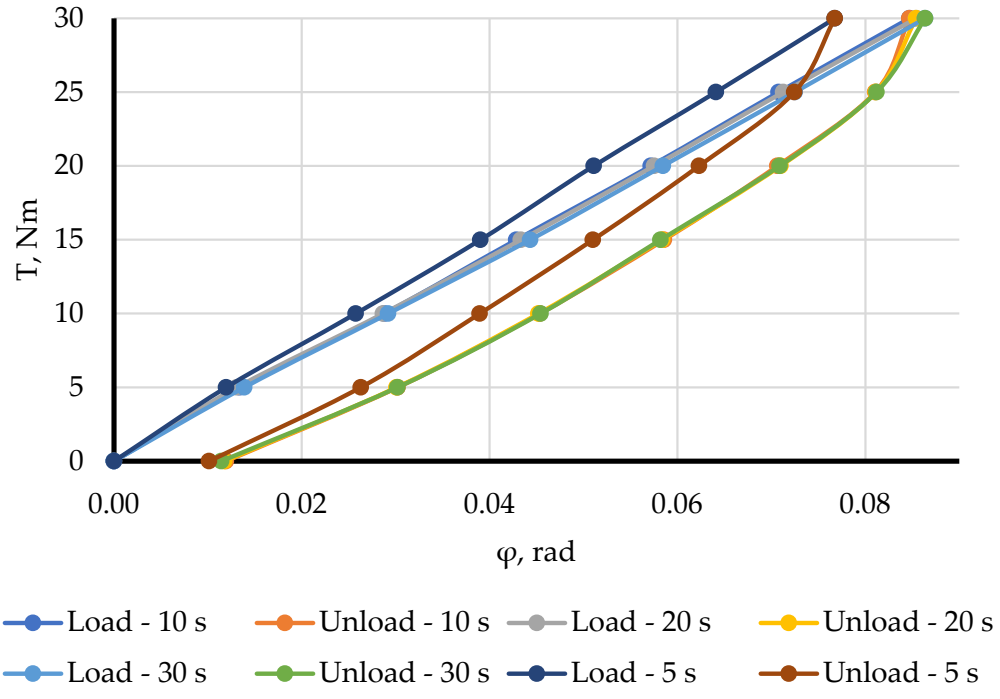


Figure 3. Elastic coupling characteristics of 5, 10, 20 and 30 s deformation readings.

As illustrated in Figure 3, the variation in angular deformation Δφ is significantly greater for measurement times between 5 and 10 s compared to the intervals of 10–20 s and 20–30 s. It can also be concluded that the relaxation behavior of the rubber element [14,15] has a negligible effect after 10 s. Furthermore, deformation measurements beyond 30 s are unnecessary due to the energy dissipated in the rubber element during deformation.

The intensive work (energy absorption accompanied by deformation) of the rubber element in the coupling is observed in the range of 5 to 10 s of reading time. After 10 s, a calming of the elastic deformation is already noticeable. For this reason, experimental studies should be read after 10 s, but not more than 15 s, because after that the change in the deformed state of the working element is insignificant.

Based on these considerations, the following recommendation is proposed: "*The static stiffness of a 'SEGME' type flexible coupling should be determined at a maximum torque of* T_{max} *= 30 Nm and a deformation measurement time between 10 and 15 s.*"

The loading and unloading curves at measurement times of 10, 20, and 30 s appear to follow a mathematical relationship. To verify this, a correlation will be established to describe, with good accuracy, the variation in two key material parameters of the rubber element: energy capacity A_{en} and damping energy A_d.

The energy capacity A_{en} can be determined as the area under the loading curve of the coupling, while the damping energy A_d corresponds to the area enclosed between the loading and unloading curves (Figure 4).

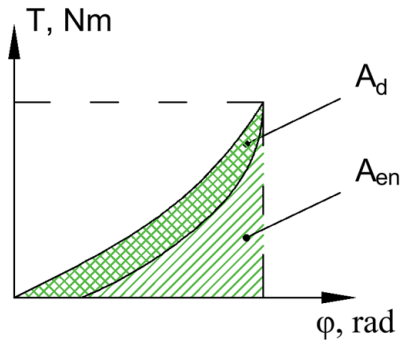


Figure 4. Energy capacity A_{en} and damping energy A_d.

To establish a mathematical relationship, the exponential increase and decrease in the two parameters are examined. The calculated values of A_{en} and A_d [5] are listed in Table 5, and the corresponding graphs are shown in Figure 5.

Table 5. Values of A_{en} and A_d.

Time, s	A_{en},J	A_d,J
10	1.26425	0.39375
20	1.2795	0.38475
30	1.2845	0.3665

After several iterations, the values of A_{en} are found to follow the relation:

$$A_{en} = A - B.e^{-k.\,t}, \quad (1)$$

where $A = 1.287$, $B = 0.069$, $k = 0.111$ и $t = 10, 20, 30$s.

The agreement between the calculated and experimental values is 100%.

An exponential decrease in A_d is observed (Figure 5), and after several calculations, the following relationship was found to provide a better fit:

$$A_d = A + B.e^{(-k.\,t)^p}, \quad (2)$$

where $A = 0.353$, $B = 0.06$, $k = 0.033$, $p = 1.43$ and $t = 10, 20, 30$s.

The accuracy achieved with this approach is approximately 99.95%.

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Based on the conducted investigations, the main scientific and applied contributions of this study are as follows:

A procedure for investigating the static characteristics of a "SEGME" type coupling (BDS 16418 [10]) is proposed, in which the coupling is tested at a maximum torque of T_{max} = 30 Nm and a deformation measurement time between 10 and 15 s.

An exponentially increasing relationship

$$A_{en} = 1.287 - 0.069.e^{-0.111.\ t}, \quad (3)$$

is established, characterizing the variation in energy capacity at deformation measurement times of 10, 20, and 30 s.

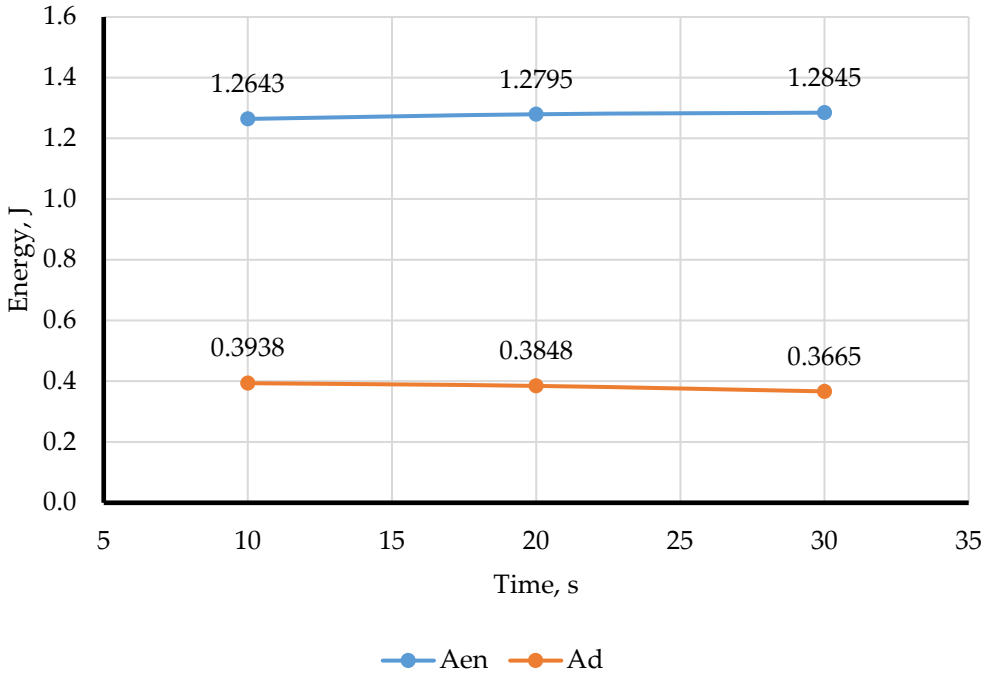


Figure 5. Graphical representation of the dependence between A_{en} and A_d.

An exponentially decreasing relationship

$$A_d = 0.353 + 0.06.e^{(-0.033.\ t)^{1.43}}, \quad (4)$$

is established, characterizing the variation in damping energy at deformation measurement times of 10, 20, and 30 s.

The above studies reflect the nature of the load on the tested coupling, for the specific model, with a maximum load T_{max} = 30 Nm. Temperature influence, aging of the rubber elements and sudden shock loads are not considered. The influence of these factors on the damping capacity and energy consumption of the elements will be predicted in subsequent tests of the coupling.

On the other hand, the derived mathematical dependencies can be compared with additional data obtained from the testing of another type of coupling "SEGME" (BDS 16418–86) with a different nominal torque. Then one can seek validation or improvement of the exponential models of the parameters A_{en} and A_d. But these are future ideas for additional research on the SEGME couplings.

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4. Conclusions

The conducted experimental investigations demonstrated that the measurement time exerts a substantial influence on the recorded angular deformation of the rubber element in the "SEGME" type flexible coupling. The obtained results indicate that the most significant variation in angular deformation $\Delta\varphi$ occurs within the initial 5–10 s of loading, whereas the deformation changes observed during the intervals of 10–20 s and 20–30 s are considerably smaller. This behavior confirms that the relaxation processes in the rubber element become practically negligible after approximately 10 s.

The analysis further revealed that extending the deformation measurement beyond 30 s is not justified, owing to the increased energy dissipation occurring within the rubber material during prolonged loading. Based on the experimental observations, it is recommended that the static stiffness of a "SEGME" type flexible coupling be determined at a maximum torque of T_{max} = 30 Nm and within a deformation measurement interval of 10 to 15 s, ensuring both reliable and representative results.

In addition, the loading and unloading characteristics corresponding to measurement times of 10, 20, and 30 s are found to exhibit well-defined mathematical relationships. The energy capacity of the rubber element, A_{en}, was successfully described by an exponential model with complete agreement between the calculated and experimental data. Similarly, the damping energy, A_d, was accurately approximated by a modified exponential relationship, achieving a correlation accuracy of approximately 99.95%.

The main scientific contributions of the present study consist of the experimental and analytical investigation of the influence of deformation measurement time on the mechanical behavior of rubber elastic elements in "SEGME" type flexible couplings. A scientifically substantiated recommendation for the optimal deformation measurement interval was established, enabling more accurate determination of the static stiffness characteristics of the coupling. Furthermore, original mathematical dependencies describing the variation in the energy capacity and damping energy of the rubber element as functions of measurement time are developed and experimentally validated with very high accuracy. The study also introduces a coefficient characterizing the influence of deformation measurement duration on the deformation behavior of the elastic element. These contributions provide a reliable theoretical and experimental basis for improving the evaluation, design, and operational performance of flexible couplings used in industrial machine drive systems.

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References

1. Li, Y.; Huang, R.; Mu, X.; Zou, Q.; Hu, H. Rigid–Elastic Coupling Aeroelastic Modeling for Flexible Aircraft: From a Gibbs Function Perspective. *AIAA J.* **2026**, *64*, 3341–3354. [CrossRef]
2. Zhang, C.; Yang, Z.; Huang, G. Research on vibration coupling effect of two-dimensional rigid-flexible coupling positioning stage with compliant joints. *Meccanica* **2026**, *61*, 12. [CrossRef]
3. Láštic, D.; Řehák, K.; Prokop, A.; Krpalek, D.; Šplíchal, J.; Žlábek, P. An Initial Case Study of the Computational Modeling of Cord–Rubber Segments. *Appl. Sci.* **2024**, *14*, 1117. [CrossRef]
4. Medvecká-Beňová, S.; Miková, L.; Kaššay, P. Material properties of rubber-cord flexible element of pneumatic flexible coupling. *Metalurgija* **2015**, *54*, 194–196.
5. Vasilev, T.; Ivanova, E.; Hristov, H. Study the influence of rotation speed on deformation process for flexible coupler with rubber elastic element. *Mach. Technol. Mater.* **2017**, *11*, 336–339.
6. Krajňák, J.; Grega, R.; Maláková, S.; Frankovský, P. Value of deformation energy depending on deformation of flexible pneumatic element. *Acta Mechatronica* **2020**, *5*, 19–22. [CrossRef]
7. Liu, W.; Deng, Y.; Qi, P.; Yin, X.; Yang, X.; Gao, L. Prediction of storage lifetime of rubber materials for flexible joint elastomers. In *Journal of Physics: Conference Series*; IOP Publishing: Bristol, UK, 2024; Volume 2760, p. 012081. [CrossRef]
8. Ghaisas, N. *Flexible-Element Couplings, Centrifugal Compressors in Hydrocarbon Processing Industries*; Springer: Berlin/Heidelberg, Germany, 2025; pp. 36–42. [CrossRef]
9. Patel, G.M.; Kulkarni, S. Investigation of viscoelastic coupling damper (VCD) behaviour developed from natural rubber using experimental and computational methods. *Asian J. Civ. Eng.* **2026**, *27*, 2907–2926. [CrossRef]
10. *BDS 16418–86*; Elastic Couplings with Rubber-Mmetal element. Basic Parameters, Dimensions and Technical Requirements. Bulgarian Institute for Standardization: Sofia, Bulgaria, 1986.
11. Gavrilovs, P.; Gorbacovs, D.; Eiduks, J.; Strautmanis, G.; Arshad, A. Examining failures in rubber-cord couplings within ER2 series electric trains. *Transport* **2024**, *39*, 183–196. [CrossRef]
12. Tarelnyk, V.; Hlushkova, D.; Martsynkovskyy, V.; Dumanchuk, M.; Antoszewski, B.; Kundera, C.; Konoplianchenko, I.; Tarelnyk, N.; Hudkov, S.; Zahorulko, A. Increasing fretting resistance of flexible element pack for rotary machine flexible coupling Part 1. Analysis of the reasons affecting fretting resistance of flexible elements for expansion couplings. In *Journal of Physics: Conference Series*; IOP Publishing: Bristol, UK, 2021; Volume 1741, p. 012048. [CrossRef]
13. Tarelnyk, V.; Dumanchuk, M.; Martsynkovskyy, V.; Mikulina, M.; Smolyarov, G.; Semernya, O. Increasing fretting resistance of flexible element pack for rotary machine flexible coupling Part 2. The influence of coupled shafts misalignment on flexible coupling flexible elements stress-strain state. In *Journal of Physics: Conference Series*; IOP Publishing: Bristol, UK, 2021; Volume 1741, p. 012049. [CrossRef]
14. Tarelnyk, V.; Dumanchuk, M.; Martsynkovskyy, V.; Dovzhyk, M.; Nahornyi, M.; Vasilenko, O.; Bondarev, S. Increasing fretting resistance of flexible element pack for rotary machine flexible coupling Part 3. The influence of dynamic loads on flexible coupling flexible element stress-strain state. In *Journal of Physics: Conference Series*; IOP Publishing: Bristol, UK, 2021; Volume 1741, p. 012050. [CrossRef]
15. Bouslema, M.; Fakhfakh, T.; Nasri, R.; Haddar, M. Effect of elastic couplings on the dynamic behavior of transmission systems. *Comptes Rendus Mécanique* **2022**, *350*, 343–359. [CrossRef]

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