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ENHANCED RANGE AND CO_2 SAVING OF PASSENGER CARS BY REDUCING FRICTION AND WEAR

Experts of Plasma Technology and Surfaces – PLATO – at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Bremen, are developing surface functionalities and coatings. Their work ranges from fundamental research to pre-series and series production readiness. Currently, regarding the energy saving of automobiles, plasmapolymeric coatings on elastomeric substrates ("rubber") are being investigated concerning the effect of friction and wear reduction. In the power train of cars kinetic energy is getting lost due to friction and wear. A certain amount of the energy loss is contributed by dynamic seals that are necessary for holding back lubricating oil. PLATO has succeeded in applying a plasmapolymeric coating strongly on the flexible, viscoelastic elastomer material (Fig. 1).

Reduced friction and wear via plasmapolymeric coatings ...

The selected coating system reduces friction and wear at dry and also lubricated friction contact. For a dry running ball-on-disc contact, the friction value decreases from 1.24 for the uncoated base material to about 0.17 with the plasmapolymeric coating. Accordingly, the coating lowers the dry friction by 86 percent (Fig. 2). This is of special interest for applications with high level of purity where no lubricants are allowed. Lubricated running is of interest, for example, for dynamic seals in cars. Using a model experiment test rig with representative pin-on-disc contact a reduction of friction was also found due to the coating. At lubricated contact, model oils revealed friction reductions of 55 percent and commercialized oils with a full complement of additives showed a friction reduction of 23 percent (Fig. 3). Applying commercialized greases with full additive complement, as, for example, used for cassette seals in wheel bearings in series, the coating lowers the coefficient of friction by up to 71 percent (Fig. 3).

The transfer of this technology to components has already been successful: Using a component test rig, industrially produced seals coated at Fraunhofer IFAM have shown friction reduction of almost 20 percent for grease and oil lubrication.

1 *Radial shaft sealing rings coated with plasmapolymeric layer on the sealing edge.*

… obtains enhanced range and less carbon dioxide emissions

The reduced friction saves drive energy, lowers CO_2 emissions, and increases the range for a constant energy reserve, for example, gasoline or battery energy. In addition, even for dry running the wear is drastically decreased using the coating in comparison to uncoated base material. This significantly increases the service life of a seal and means longer intervals between seal changes. Figure 4 highlights the high wear resistance and load capacity of the plasmapolymeric coating. During the tribological testing with a steel ball, the specimen was indented by about 50 micrometers. The 1 micrometer thin layer even withstood long-term loading without problems. A compression set is all that can be seen in the elastomer base material.

Customized coatings

In order to optimize the reduction in friction and wear for the special case of elastomer friction of a seal, the coating was varied regarding the processing parameters, such as the gas mixing ratio and applied power.

For the characterization of coatings a high-quality test system for measuring friction, wear, and lubrication is being used: This new tribometer at Fraunhofer IFAM allows, with oscillating and rotating motion, the determination of friction and wear in dry and lubricated states at a defined temperature.

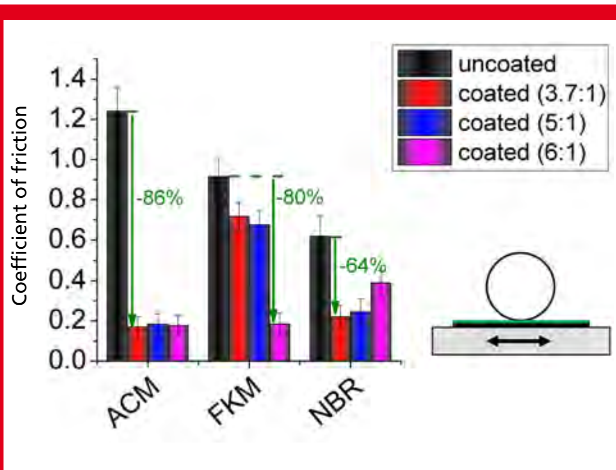

Fig. 2: Dry coefficient of friction and friction reduction of uncoated and coated elastomers. The O_2:HMDSO mixing ratio was varied in the coating process. Dry running, 1.5 MPa initial Hertzian contact pressure.

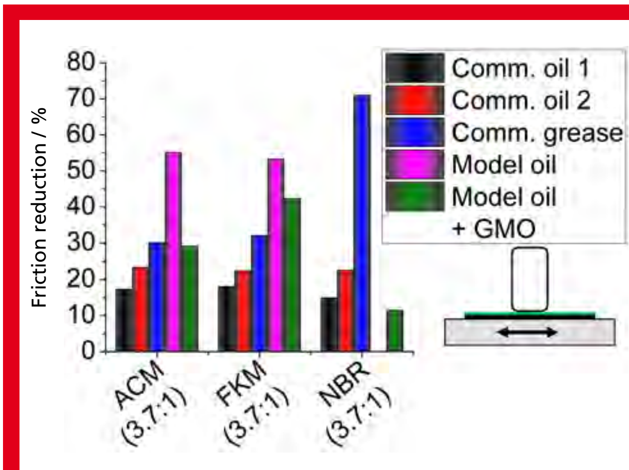

Fig. 3: Friction reduction in the lubricated system using the coating variant with an O_2:HMDSO mixing ratio of 3.7:1 on various types of elastomers. Lubricated running, 0.5 MPa initial contact pressure.

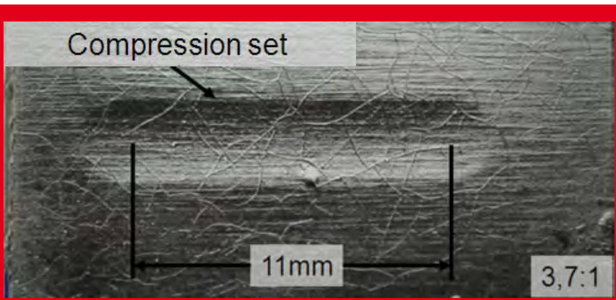

Fig. 4: Coated elastomer sample lubricated with commercialized oil after endurance testing (1.5 MPa initial Hertzian contact pressure) for approximately 785,000 cycles (ca. 17.3 km distance with oscillating motion): no wear is visible.

In order to reduce friction and wear, it is being found that the entirety of interactions between elastomer base material, coating, as well as lubricant must be considered. In the case of elastomers, not only, e. g. the hardness but also the damping behavior, tensile strength, elasticity, texture, and surface roughness, optimized for the relevant application, are important parameters. A particular demand on the coating and the relevant test method is the flexible elastomer base material with its viscoelastic deformation behavior. The coating must not be too rigid otherwise it will break and result in scales contributing to the friction contact – with the risk of enhanced wear. In addition, using a hard coating can have an adverse effect on the sealing function at corresponding application.

The experts of PLATO, with their expertise of coating release films and flexible anti-scratch layers etc., are able to apply coatings to meet the special requirements, on the one hand necessary following the movements of the elastomer and on the other hand resulting in lower friction and wear than would be the case for the uncoated base material. The coating also chemically interacts with the used lubricants and its various additives. Based on existing knowledge of the coating composition (Fig. 5–7), the coatings can be tailored for specific applications.

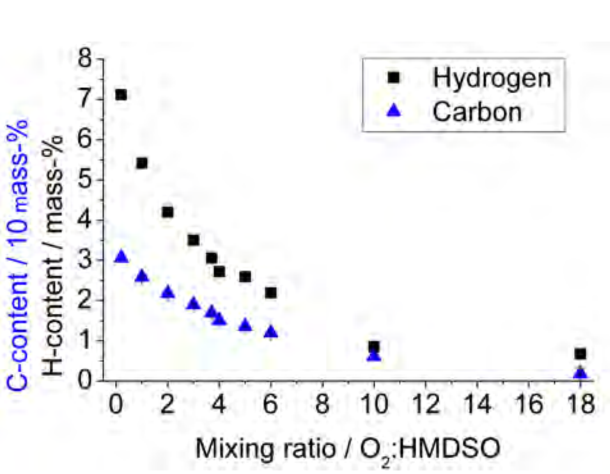

Fig. 5: Carbon and hydrogen content of the plasmapolymeric coating varying the gas mixing ratio. Fixed power of 1500 W.

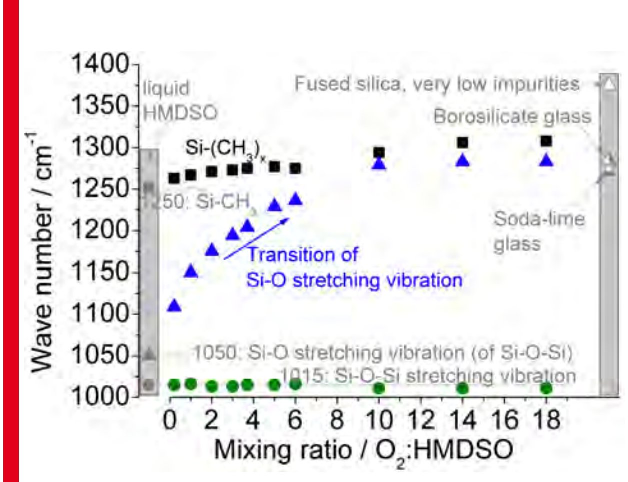

Fig. 6: Peak shifts in the IR spectrum of the plasmapolymeric coating varying the gas mixing ratio. Fixed power of 1500 W.

The newly acquired nanoindentation testing equipment at Fraunhofer IFAM allows measurement of the Young's modulus as well as nanohardness of the pure coating. The determined results show that these mechanical properties can be tailored via varying the process parameters (Fig. 7) according to requirements. Higher hardness can result in enhanced wear resistance.

Outlook

The PLATO scientists have already shown that the coating of radial shaft sealing rings can be realized for favorable-cost production. Current development work by PLATO is focusing on scaling up the coating process to the required piece numbers. The production costs applying the coating, due to the deposition method involved, are only a fraction of the component cost. Regarding comprehensive R&D work, the optimal layer composition is able to be selected for the specific component and application. This layer composition will be homogeneously applied on a large scale across the production series.

Acknowledgement

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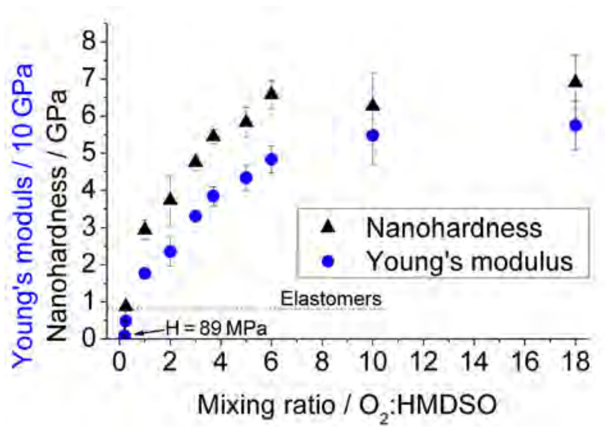

Fig. 7: Young's modulus and nanohardness of plasmapolymeric coatings varying the gas mixing ratio. Fixed power of 1500 W.

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