The use of MXene nanosheets to optimize dry-running tribo-systems

Max Marian[1)*], Marcel Bartz[2)], Sandro Wartzack[2)] and Andreas Rosenkranz[3)]

[1)] Department of Mechanical and Metallurgical Engineering, Pontificia Universidad Católica de Chile, Santiago, Chile.
[2)] Engineering Design, Friedrich-Alexander-University Erlangen-Nuremberg (FAU), Erlangen, Germany.
[2)] Department of Chemical Engineering, Biotechnology and Materials, FCFM, University of Chile, Santiago, Chile.
*Corresponding author: marian@mfk.fau.de

MXene nanosheets were investigated regarding their tribological behavior when used as a solid lubricant in highly loaded steel/steel tribo-contacts. In component tests, the possibility to extend the service life of dry-running rolling bearings was demonstrated. Moreover, climate-controlled laboratory tests (ball-on-disk) revealed the dependence on contact and environmental conditions.

Keywords: MXene nanosheets; solid lubricant; machine elements; contact pressure; relative humidity

1. Introduction

Solid lubricants are intended to reduce friction and wear between two rubbing surfaces under substantially dry conditions. Besides state-of-the art materials such as graphite, graphene or MoS2, novel early transition metal carbides and carbonitrides (MXenes) seem to be promising due to their weakly bonded multilayer structure with self-lubricating ability [1]. Therefore, the performance of $Ti_3C_2T_x$-nanosheets - the most prominent MXenes so far - as a solid lubricant in highly loaded machine elements as well as the influence of load and ambient conditions was investigated in this study [2, 3].

2. Methods

The synthesis and detailed material characterization of $Ti_3C_2T_x$-nanosheets by means of HR-TEM, XPS, XRD TPD-MS and Raman spectroscopy were followed by detailed tribological testing. For this purpose, lifetime-tests with MXene-coated thrust ball bearings were carried out on a component test-rig [2] as well as friction and wear model tests on a climate-controlled ball-on-disc-tribometer under different load and relative humidity conditions [3].

3. Results and Discussion

The component tests revealed an averaged reduction of the frictional torque by a factor of up to 3.2, an extension of the service life by about 2.1 times and a decrease of the linear cumulative wear rate by up to 2.9 compared to uncoated reference bearings (see figure 1). This already featured results comparable to other state-of-the art solid lubricants [2].

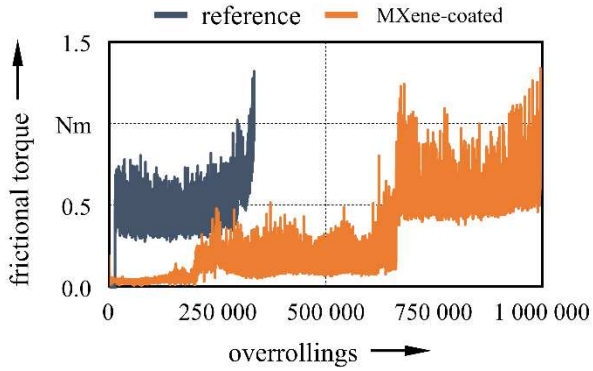

Figure 1: Frictional torque versus overrollings for a reference and a MXene-coated bearing. [2]

In the model tests, a 2.3-fold friction reduction and a 2.7-fold reduction of the wear volume (see figure 2) for MXene-coated samples compared to uncoated references were verified for moderate contact pressures and low relative humidity. This was due to the formation of a compacted tribo-film consisting of densified MXene–nanosheets. In contrast, too high pressures induced a partial rupture of the wear-protecting tribo-layer, thus reducing its beneficial effects. Additionally, no beneficial effects regarding friction and/or wear were found at higher relative humidities, which was correlated with the expansion of the basal spacings. Therefore, this summarizes favorable operating conditions for MXene-nanosheets [3]

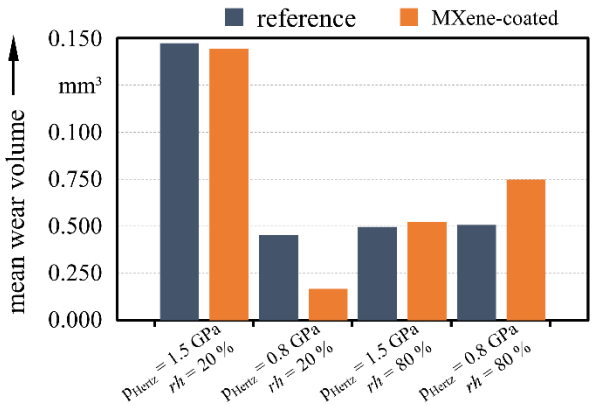

Figure 2: Cumulated mean wear volume of body and counter-body for reference and MXene-coated samples at different contact pressures and relative humidities. [3]

4. References

[1] Rosenkranz, A. et al., “2D nano-materials beyond graphene: From synthesis to tribological studies”, Applied Nanoscience, 10, 2020, 3353–3388

[2] Marian, M. et al., “MXene nanosheets as an emerging solid lubricant for machine Elements – Towards increased energy efficiency and service life”, Applied Surface Science, 523, 146503, 2020

[3] Marian, M. et al., “Effective usage of 2D MXene nanosheets as solid lubricant – Influence of contact pressure and relative humidity”, Applied Surface Science, 531, 147311, 2020