ASSESSMENT OF OPTIONS FOR APPLICATIONS TICN-MP + MOVIC DEPOSITED ON THE CONVEX-CONCAVE GEARING WORKING IN INTERACTION WITH THE ECOLOGICAL LUBRICANT

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Abstract
The additional article deals with the assessment of the possibility of applying the coating TiCN-MP + MOVIC deposited on the convex-concave gearing made of material C55E4 working in interaction with the ecological lubricant Biohyd MS46 and BioGear S150., where, based on scuffing FZG tests according to STN 65 6280 norm, are experimentally appreciated possibilities of its application.

Key words: *Non Standard C-C gears, Scuffing, FZG Test, Coat, ecological oils*

INTRODUCTION

Considerable share on the pollution of environment has mobile equipment used for the implementation of a wide variety of construction and ground works. Mobile machinery directly affects the quality of the environment. They are a potential source of pollution of soil, water and air. Noise and vibrations emitted by the machine have negative impact on humans, also other living organisms in the vicinity of the source (*Gulan, 2005*). Risk is also leak of working fluids into the environment, which can cause ecological accident, as most of operating fluids used in mobile working machines is of petroleum origin. One of the ways, how to prevent widespread contamination of soil or water, is the use of ecologically easily biodegradable lubricants and oils. Use of biodegradable lubricants is recommended wherever it is necessary to minimize possible effects of the machine actions on the environment. Some countries, such as Germany and Sweden require the use of biodegradable oils in all applications working in environmentally sensitive areas, such as the area of protection of water resources (*Staša*, 2012). But, biodegradable oils, in most cases do not reach the performance parameters of mineral oils.

MATERIALS AND METHODS

With increasing loading of gears are increased also contact pressures of gearing, friction and temperature, whereby at creation of tooth side damage plays size of contact pressures an important role. The higher resistance against disturbances can be achieved by increasing the surface carry capacity of the tooth side. Arrangements, by which we can achieved it, are mainly change of the geometry of gearing, the use of higher quality oils and materials, respectively increasing the surface hardness of tooth sides, where can be also included application of thin hard coatings. Regarding the change of geometry, (*Orokocký, 2004, Bošanský et al, 2012, Vereš et al, 2006*) they present favorable results in terms of contact pressures, specific slips and wear of convex-concave gearing compared with involute gearing.

Currently there is deposition of coatings in gears in practice not widely used, despite the fact, that in field of their application were proceeded several studies (*Michalczewski et al, 2013, Lümkemann et al, 2014, Tuszynski et al, 2015*),whereby were solved particularly TiN, TiCN, TiAlN, CrN and other thin hard coatings with a top layer with a low coefficient of friction. From used methods deposition of coating layers analysis results, that the application in gears is due to less heat affecting of the basic material, PVD method most appropriate.

From of convex-concave gearing analysis (*Bošanský et al, 2012, Vereš et al, 2006*), we chosed for application coating TiCN-MP+MOVIC (MoS_2), as an appropriate combination of hard layer TiCN-

MP and softer layer with a low coefficient of friction MOVIC. Coating TiCN-MP is often used to increase hardness and sliding properties of tools for forming and machining of steel with lower strenght limit and also is used for surface treatment of callipers. Coating show high hardness and good sliding properties. MOVIC coating is a coating based on MoS_2. It's a sliding coating with a low friction coefficient applied mainly in shaping machines and screw taps. It can be applied separately, directly to the surface of component, or to any hard coating. Basic parameters are listed in the tab. 1 (*Liss, 2015*). This coating was applied by PVD method on tested gears, which were made of material C55E4. Demanded surface hardness of the tooth sides was achieved by laser hardening, the parameters of which are mentioned in (*Míšaný, 2015*).

Tab. 1 Properties of the coatings deposited on the test gear

	Nano hardness [GPa]	Thickness [μm]	Coefficient of friction with steel	Maximum operating temperature [°C]
TiCN-MP	32	1 to 4	0,2	400
Movic (MoS_2)	20	0,5 to 5	0,1	400
TiCN-MP+ MOVIC	32	1,5 to 5,5	0,15	400

The scuffing experiment was carried out by standard Niemann test with closed power flow on the scuffing (Fig. 1).

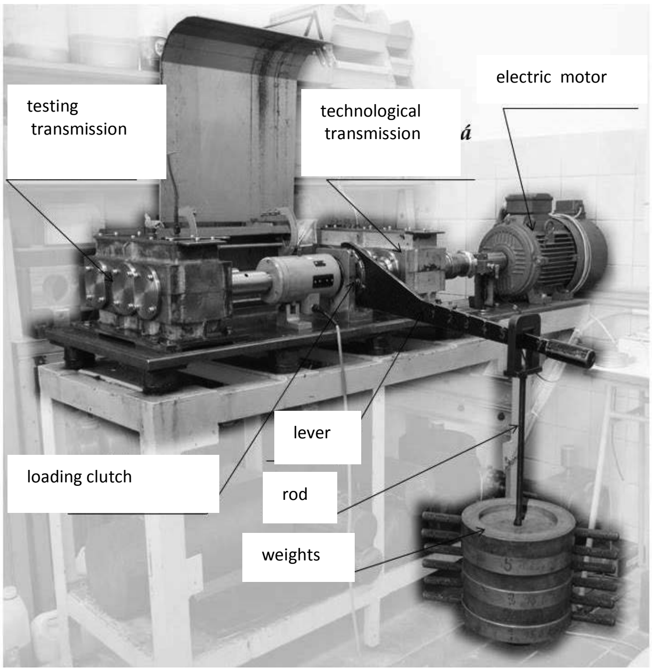

Fig.1 Niemann stend

In this experiment were used two types of biodegradable oils. Hydraulic oil OMV Biohyd MS46, its basic specifications are listed in tab. 2 and gear oil OMV BioGear S150, its basic specifications are listed in tab. 3.

Tab. 2 Technical data of Biohyd MS 46 oil

Property	OMV Biohyd MS 46	Unit
Viscosity grade ISO VG	46	-
Viscosity at 40°C	46	$mm.^2s^{-1}$
Viscosity at 100°C	9,2	$mm.^2s^{-1}$
Viscosity index	187	-
Density at 15°C	915	$kg.m^{-3}$
Pour point	-51	°C
Ignition point	237	°C

Tab. 3 Technical data of Biohyd S 150 oil

Property	OMV Biogear S150	Unit
Viscosity grade ISO VG	150	-
Viscosity at 40°C	150,7	$mm.^2s^{-1}$
Viscosity at 100°C	21,4	$mm.^2s^{-1}$
Viscosity index	167	-
Density at 15°C	947	$kg.m^{-3}$
Pour point	-27	°C
Ignition point	224	°C

Scuffing occurs according to DIN 51354 and STN 65 6280 with the degree of load, when the difference of the sum of the wheel weight losses and pinion in two consecutive degrees is greater than 10mg. Degree, at which seizing reflects, is considered as damaging level and thus is limit level previous encumber one. For gears weighing were used Mettler Toledo PR2003 scales, able to be encumbered up to 2100 g and with sensitivity of 1 mg. Due to the fact, that they were evaluated for scuffing and also gears were coated, where weight loss was also affected by the loss of the coating, thus next evaluation criterion were measuring of surface roughness. Measurement was carried out by contact roughness gauge Taylor-Hobson Surtrnic 3+. According to the evaluation of surface roughness it is a damaging step marked the one in which value of surface roughness Rz_{DIN} reach limit 7μm.

RESULTS AND DISCUSSION

Weight losses of test gearings for the various loading stages are shown in Fig. 2 and Fig. 3. By continuous exposure to loading occurred increase of weight loss, which was caused by scuffing the soft top coat, thus in the early levels of loading occurred to wearing of the upper lubricate coating MOVIC, as Fig.. 4 confirmed.

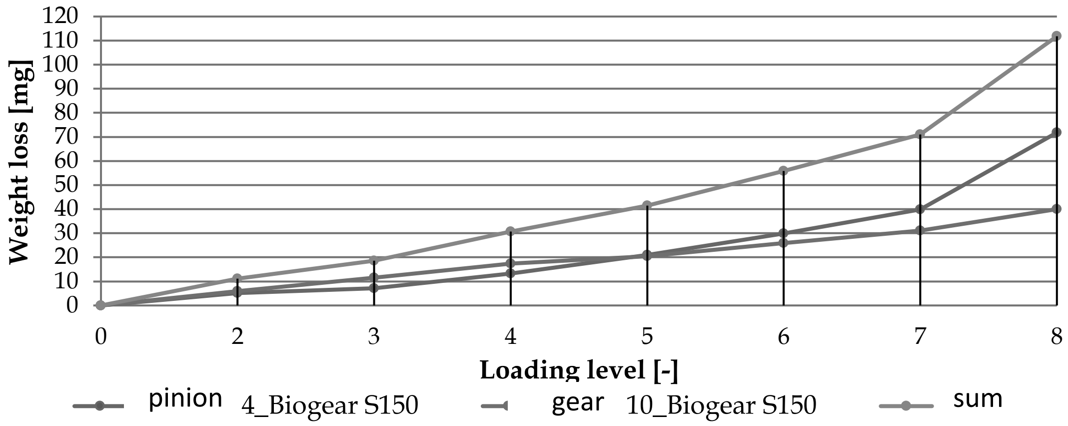

Fig. 2 Dependence of weight loss of gearing with coat TiCN-MP+MOVIC -lubricated by OMV Biogear S150 oil

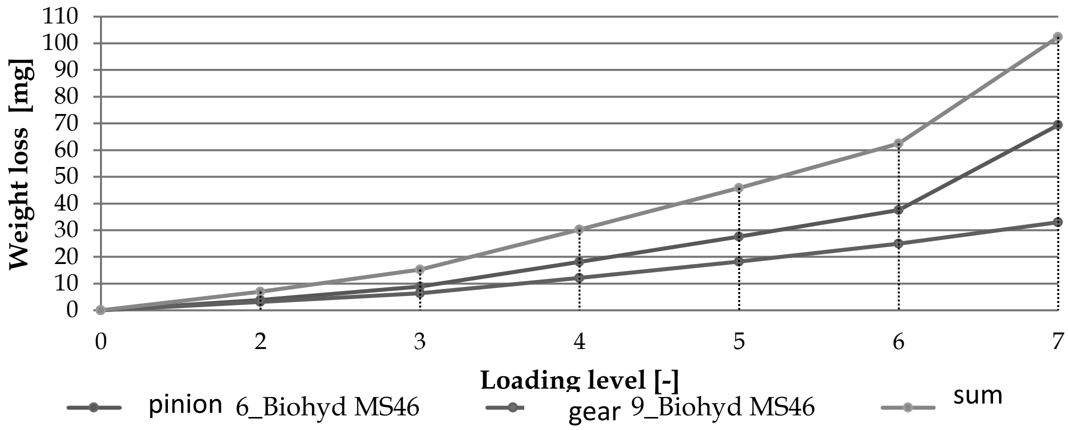

Fig. 3 Dependence of weight loss of gearing coated TiCN-MP+MOVIC -lubricated by OMV Biohyd MS46 oil

In the figure is clearly visible gray MOVIC coat and under it begins to emerge bronze-brown spots of coat TiCN-MP.

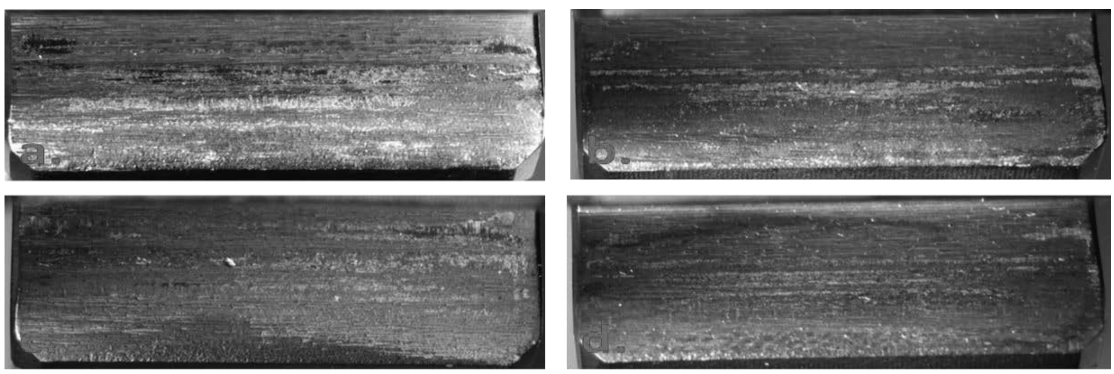

Fig.4 *Surface wear of the tooth side after fourth level of loading*

a/c pinion in interaction with OMV Biohyd MS46 / OMV Biogear S150 oil
b/d wheel in interaction with OMV Biohyd MS46 / OMV Biogear S150 oil

At next levels of loading has occurred wearing of coating across the whole dedendum area. This is evident from Fig. 5, where is wearing of bronze-brown coating TiCN-MP visible as a dark gray area (hardened base material buffed to a mirror shine).

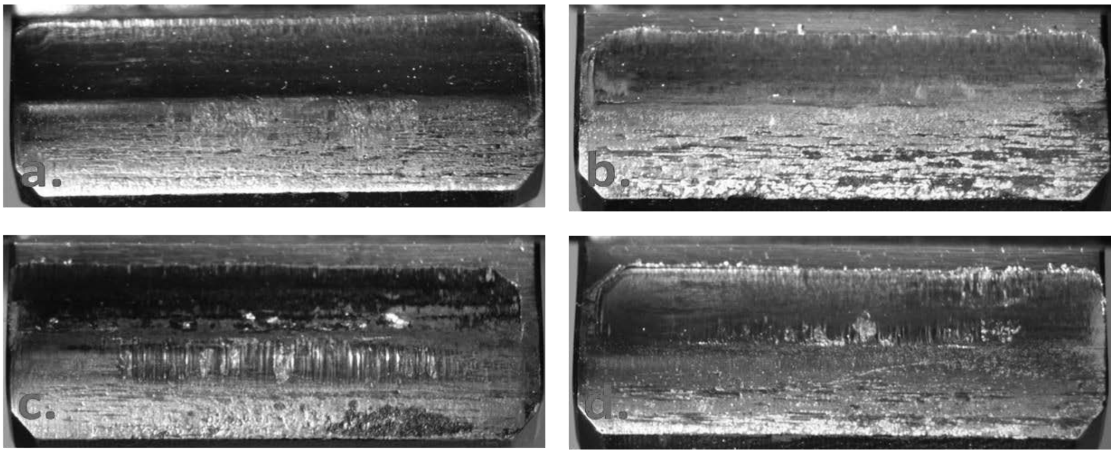

Fig.5 *Surface wear of the tooth side after 1.loading level*

a/c *pinion in interaction with OMV Biohyd MS46 / OMV Biogear S150 oil*
b/d *wheel in interaction with OMV Biohyd MS46 / OMV Biogear S150 oil*

CONCLUSIONS

Based on evaluation of the scuffing with Niemann test from the loss of material point of view came to scuffing already at 7. level in the interaction with the OMV Biohyd MS46 oil and at the 8. level in the interaction with OMV BioGear S 150 oil, in terms of roughness at 11. and 12. level (*Míšaný, 2015*). At these levels came to partial coating wear in the dedendum of the tooth. Already, based on these results, can be stated better adhesion of the coating TiCN-MP + MOVIC in convex-concave gearing than it was with DLC film deposited as well in a convex-concave gearing, at which came to due to (*Zápotočný, 2014*) scuffing from the weight loss point of view already at 5. level with OMV Biohyd MS46 oil and at the 7. level with OMV BioGear S150 oil, while at 4. level already came to rub off of DLC coating. In the context of comparative tests were also carried out tests for coatings TiN and MoS_2. From the achieved results it can be stated, there´s better carry capacity of multi coating compared with single layer coating MoS_2 (*Fedák 2008*).

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