JOURNAL OF ENGINEERING annals OF FACULTY OF ENGINEERING HUNEDOARA
TOME VI (year 2008), FASCICULE 2, (ISSN 1584 – 2665)

COATINGS AS A POSSIBILITY TO INCREASE THE LOAD CAPACITY OF C-C GEARING

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Abstract:
In the article we describe the possibilities of increase of the contact load capacity of unhardened C-C toothed gear. The use of metal coatings proves to be one way. On the basis of a comparison of the individual methods of depositing the coating the technique of PVD proves to be suitable application for the case of toothed gears. This technique is used for depositing the hard coatings. C-C toothed gear, coated with this method, in interaction with ecological lubricant was experimentally verified with respect to scoring on test stand by Niemann.
Keywords:
Metal coating, C-C tooth gear, PVD technique, scoring, ecological lubricant, test stand by Niemann

1. INTRODUCTION

The magnitude of contact pressures or radius of tooth flank [1] plays an important role in a matter of the load capacity of toothed gears, while from the point of surface damage it is a matter of pitting, scoring and plastic deformation.

Above mentioned failures cause damage of tooth on surface or only in small depth of body of tooth itself. To prevent the damages on the tooth flank it is necessary to know not only course of stresses, but also the magnitude of stresses which formed at the contact of mating flanks. On the basis of the above mentioned course of stress it is possible to state the thickness of layer of tooth flank, where it can come to its damage. This determination of thickness of layer of tooth flank can then, according to a concrete type of gearing, facilitate at the design of a concrete technique by which required hardness of tooth flank will be reached and thereby increased its contact load capacity.

2. MATERIAL AND METHODOLOGY

Increasing requirements for resistance of components against abrasion as well as increasing the load capacity of frictional point are not sufficient to reach this characteristic without any surface finish. These facts led to development of field of theory of surface layers. The theory, inter alia, deals also with depositing the coatings on basic material.

The coating is understood as every substance deposited on surface of basic material. In practise, in addition to the coatings which are purposefully deposited the spontaneous coatings can be formed also by exposure to external environment.

The coatings according to character and the way of formation can be divided as follows:

1. inorganic
- metallic (electrolytic, thermal spraying, deposit welding),
- ceramic (oxidative, non-oxidative),
- metallic-ceramic (homogeneous, heterogeneous),
- other inorganic compounds (phosphate enamels, glass enamels),

2. organic
- coating compositions (polyester, powder),
- plastics (plastomer, duromer, elastomer),
- preservative coatings (applied oil, vaseline).

The coatings deposited by thermal spraying belong to category of metallic coatings which at present represent the most used technology of depositing the coatings thanks to own wide offer of used materials.

The use of coatings in trains of wheels turns out as very specific task contrary to another tribological systems (sliding bearings, pins etc.) namely in particular for the reason of magnitude of the contact pressures and sliding conditions which are created at operation of gearings. Own kind of gearing (cylindrical, bevel, worm gearing etc.) as well as its type (involute tooth system, convex-concave, cycloidal etc.) plays also an important role here. The gearing is to have after depositing the coating sufficiently hardness, resistance to high temperatures in contact and at shear with its regular thickness and required roughness. It is obvious that these requirements in application on gearing are rather specific in comparison with commonly used coatings which are applied in other tribological systems. The use of thermal spraying with appropriate material turns out as one option.

Thermal spraying is the deposition of molten medium on properly cleaned and roughened substrate by spraying with air flow. The sprayed material, which is fed in form of powder, wire stock, cord, or rod stock, is melted by:
- electric arc,
- plasma
- flame.

The molten particles are propelled on cold (not molten) basic material to form the function layer (Figure 1). Technology of thermal sprayings enables to form coatings, on practically all types of materials of substrates, from kinds of ceramics, metals and its alloys where do not come to disintegration under melting point. The process is performed and enabled on roughened surface of substrate by mainly mechanical anchoring of coating. Technological procedure guarantees temperatures of component, where is the deposition applied, deeply under temperature of phase and structural changes (approximately 80..120°C) thereby also impede undesirable deformations of component.

Own sprayed material is very important at thermal spraying.

According to chemical composition we distinguish the sprayed materials as follows:

a) metallic basis – pure metal (W, Mo...), alloy (Ni – Cr , Ni – Cr- Mo)
b) ceramic basis - oxidative basis (Al_2O_3, TiO_2,..), non-oxidative basis – carbides (WC, TiC)
c) with exothermic effect – composite sprayed materials (basis Ni – Al, Ni – Ti)
d) special materials – cermets, which associate sprayed materials (hardness, high melting point) for example WC + Co, WC + Ni, Al_2O_3 + TiO_2 + NiAl.
e) on basis of plastics (polyethylene, nylon, thioplastics, polyamide)

Deposition of hard layers using above mentioned method demands the use of special technology for improvement of parameters of basic material (mostly hardness) under deposited layer (coating). It is not possible in advance to determine the technology of processing of basic material because governing factor in this case is the choice of type of deposited layer (coating) on surface of basic material. In principle it is possible to say the deposition of hard layers demands to have been the surface of basic material hard and in case of the deposition of soft layers (coatings), the surface of basic material can be soft. This fact is caused that in case of the deposition of hard layer (coating) on soft not treated surface should lead to the peeling of deposited layer (coating).

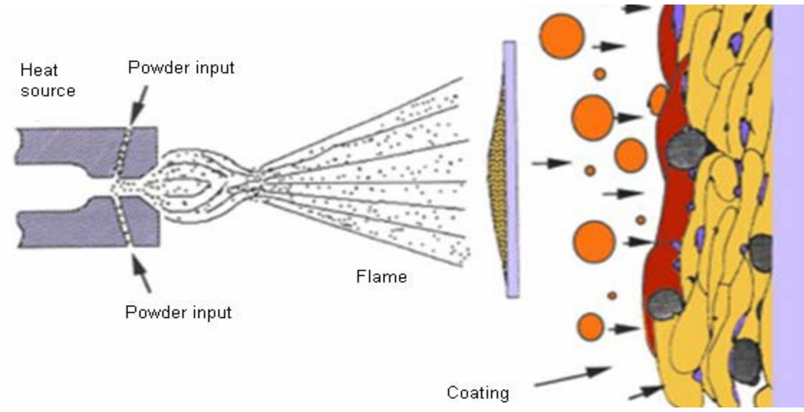

Figure 1. Principle of flame spraying

In case the use of coatings in convex-concave gearings we designed and tested TiN within the solution of grant projects VEGA 1/3184/06.

The convex-concave gearing as one of the not involute types of gearings is, apart from other types of gearings, the object of research on Institute of transport technology and engineering design []. In principle the gearing can be characterized by the tooting of which flank is created curvature which consists of curvatures with convex and concave part with inflexion point on pitch point C. This gearing is created when the line of contact has the shape of letter S (Figure 2).

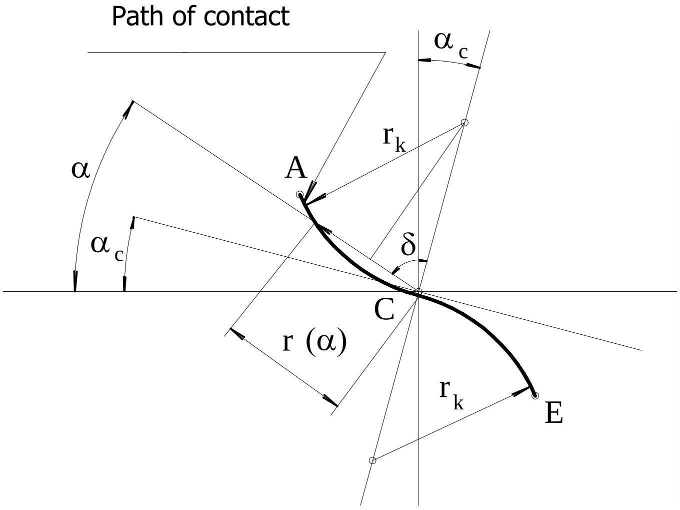

Figure 2. Path of contact of a convex-concave gearing

Figure 3. Symetrical convex-concave gearing

Accordingly whether the arcs of the line of contact are symmetrical, or not symmetrical we distinguish the symmetrical convex-concave gearing, or the not symmetrical convex-concave gearing. The case of the symmetrical convex-concave gearing is shown on Figure 3.

The present researches of convex-concave gearing came to the conclusion that in comparison with an involute type of convex-concave gearing the contact pressure are smaller. It is possible to state also that as well at the comparison of course of slippage circumstances in case of convex-concave gearing, more favourable values in comparison with an involute type of gearing are reached, Figure 4. It follows on from this also the possibility of the use of ecological lubricants at its lubrication with lower viscosity, or lubricants without additives EP. On basis above mentioned facts we have chosen then the convex-concave gearing with tooth number of z_1= 16, z_2=24, m_n=4.5mm, a_w=91.5 mm and on which we applied the hard coating of TiN, Figure 5. We have chosen this type of gearing also because after the hardening it comes to deformation of gearings and at present in Slovakia we were faced with a problem how to procure the grinding of this type of gearing in required quality and in accuracy which is required at operation of gearings.

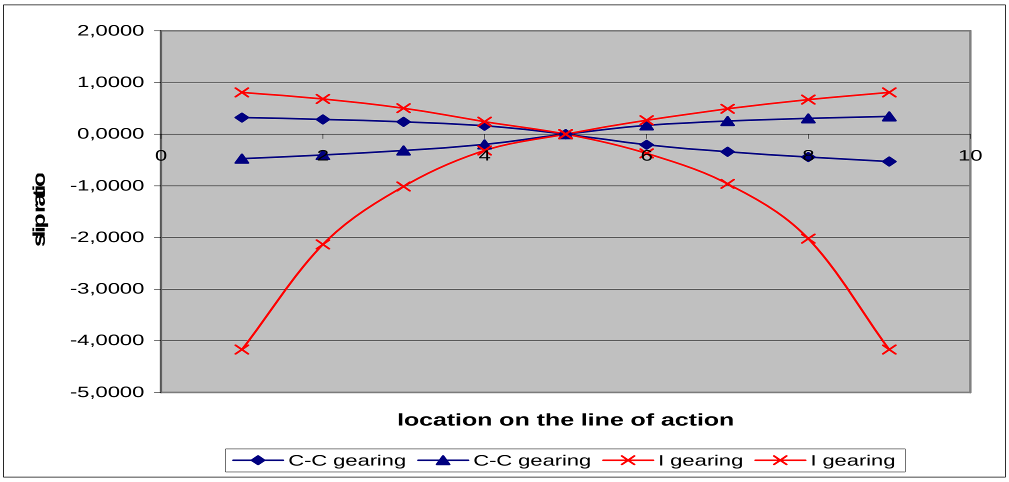

Figure 4. Specific lides in Involute and C-C gearing

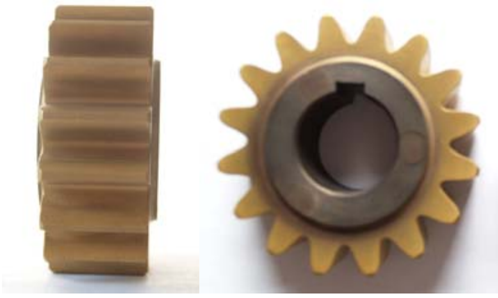

Figure 5. Aplication of TiN coating on C-C gearing

3. EXPERIMENTAL METHODS

Experimentally it is possible to test the load capacity whether about scoring, or pitting on test stand by Niemann, Figure 6 and namely both in case of the involute type of gearing and in case the convex-concave gearing.

Within the testing of the chosen convex-concave gearing from the point of scoring we used oil Biogear S. This one is biologically degradable gear oil for both mechanically and thermally very loaded gearings of various constructions, for lubrication of bearings in agriculture, forestry, building industry, sea transport and in nature reserves.

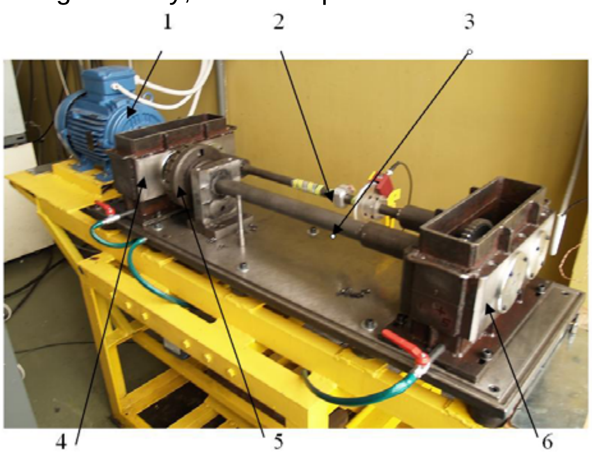

Figure 6. Equipment for measuring of the gearing strength in scoring
1-eletric motor, 2-torsial shaft, 3-shaft, 4,6-gearboxes, 5-strain coupling

Table 1. Parameters of oil OMV Biogear S

Product	Viscosity at 40°C [mm²/s]	Viscosity at 100°C [mm²/s]	Burning point of [°C]	Solidfication point [°C]	Density at 15°C [g/ml]
OMV Biogear S					
100	100	14,84	220	-30	0,940
150	150	24,45	224	-27	0,945
220	220	28,82	226	-27	0,951
320	320	38,02	228	-21	0,959

The basis parameters of mentioned oil are given in Table 1, while in experiment was used the accented oil. During the experiment the parameters of own oil were checked in particular temperature and contamination of oil. The results of tested gearing from the point of scoring are shown in Figure 7.

4. RESULTS AND DISCUSSION

Figure 7 shows the reached stages of loading for the convex-concave gearing. The hard coating of TiN by method PVD was applied on the gearing and was performed test of scoring on test stand by Niemann.

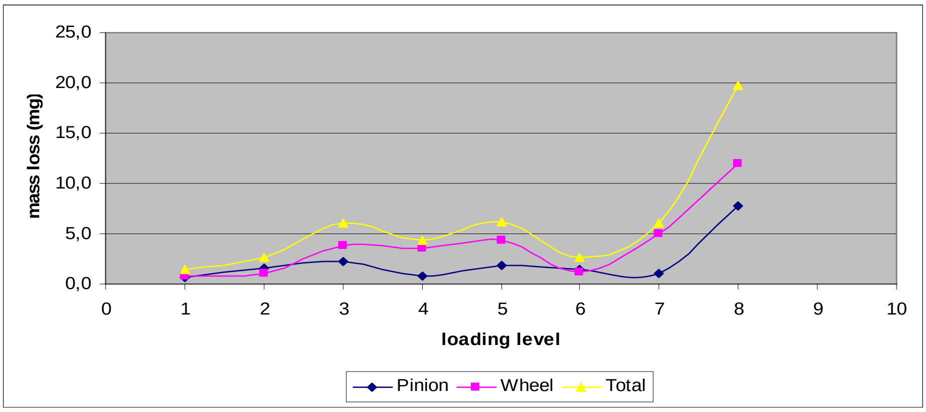

Figure 7. Test on scoring of TiN coating C-C gearing

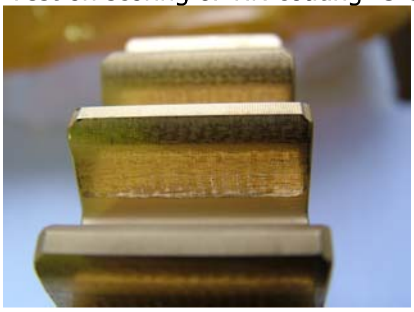

Figure 8. TiN coating C-C gearing after of test scoring

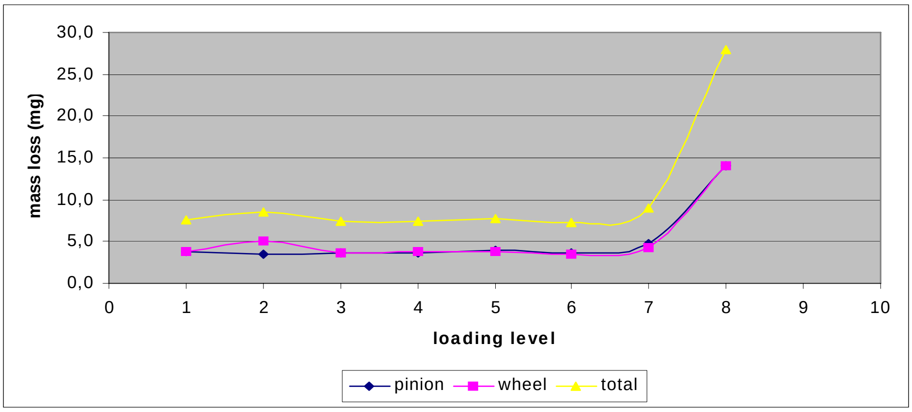

Figure 9. Test on scoring of hardened involute gearing

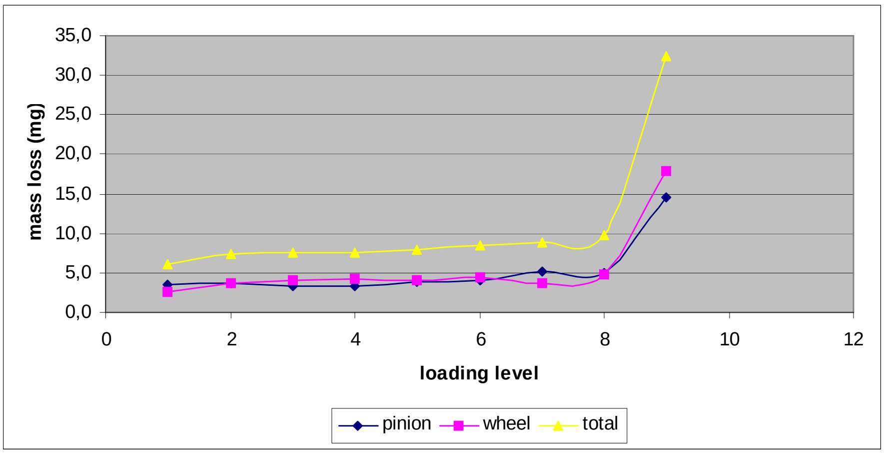

Figure 10. Test on scoring of hardened C-Cgearing

The curvature P represents loss of weight of pinion, the curvature K of wheel and S is total value of loss on both wheels which within the test must not exceed the value of 10 mg. On the basis of Figure 7 it is clear that the tested convex-concave gearing reached set condition for 7th stage of loading. The tested wheel after 8th stage of loading, where it came to scoring, is shown on Figure 8.

5. CONCLUSION

As mentioned in paragraph 1. Introduction the coatings until now in application with gearings was not used. The results of tests of scoring on test stand by Niemann show that the unhardened convex-concave gearing in interaction with ecological oil OMV Biogear 150 reached comparable results in comparison with the involvent gearing which was hardened, Figure 9. In both cases the scoring arose at the same stage of loading and in comparison with the hardened convex-concave gearing had only a tiny bit worse results, Figure 10. The results of test show that in case of subsequent research in a field of application of the hard coatings in the gearings the presumption is that will be reached even better results.

The work was elaborated within the solution of grant projects VEGA 1/3184/06

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