World Academy of Science, Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering
Vol:7, No:8, 2013

An Advanced Technology for Renovation of Extruding Shafts

Dimitar Karastoyanov and Vladimir Monov

Open Science Index, Mechanical and Mechatronics Engineering Vol:7, No:8, 2013 publications.waset.org/16053/pdf

***Abstract*—**The paper is concerned with the technological process of renovation of shafts used in industrial manufacturing for extruding of sheet material. In the classical renovation technologies, a chrome based coating is applied to the working surface of the shaft in galvanic baths. The process, however, is known to be exclusively harmful due to the waste cyanide products. In this work, we present an advanced nanotechnology based on nonelectric chemical laying of a nickel coating with included nanoparticles. The technology is environmentally harmless and the new coating features an increased hardness and wear resistance. Results from experimental tests of the nanostructured nickel coating are presented and discussed.

***Keywords*—**Materials processing, nanoparticles, nickel coating, shafts renovation.

I. Introduction

THE products of extruding (pressing by pushing) of sheet material from nonmetal materials (Plexiglas, PVC, packing folio, other plastics) are widely used in households. Gifts, flowers, sugar and chocolate packing is made from thin aluminum or Plexiglas sheets. Thin Plexiglas sheets are used to make pack boxes, and thick nylon sheets are used to make bags, raincoats, etc. The vast amount of production of smooth sheets of various sizes from these materials has brought to the development of technologies in which the material is pressed and pushed out (extruded) between shafts of various diameters (100–500 mm) and various lengths (1–3 m), [1]. The shafts are chromed, have very narrow tolerances of diameter size and very high degree of smoothness by polishing. Schematically, a technological line for sheet production is shown in Fig. 1.

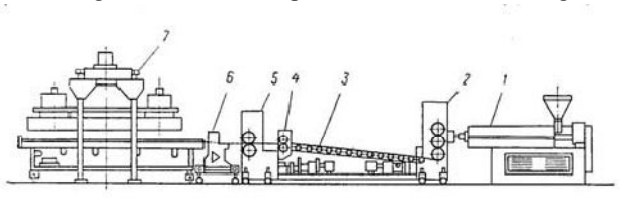


Fig. 1 Technological line for sheet production: 1- extruder; 2 – calender; 3 – rolling for the sheet cooling; 4 – unit for longitudinal cutting; 5 – stretching shafts; 6 – guillotine for crosswise cutting; 7 – packing unit

V.Monov is with the Institute of Information and Communication Technologies, Bulgarian Academy of Sciences, 1113 Sofia, Bulgaria (phone: +359 2 979 2474; fax: +359 2 870 7273; e-mail: vmonov@iit.bas.bg).

D. Karastoyanov is with the Institute of Information and Communication Technologies, Bulgarian Academy of Sciences, 1113 Sofia, Bulgaria (e-mail: dkarast@iinf.bas.bg).

With the time and at high production rate, shafts age, their surface wears out, and sometimes scratches appear in incidents. All this makes the shaft surface not precisely circular and even. Because of the very high price of a new shaft, renovation of the defected shaft is performed by applying a new coating and polishing it to mirror shine. However, renovation itself is a high precision operation which is also expensive, high energy and time consuming and in some cases it is a technological secret of the companies performing this operation.

In view of the above, the problems of development of an industrially applicable technology and the design of the respective technological line are of great economical importance for the technical support of all kind of extruding and rolling mills producing sheets of various plastics and aluminum alloys. In this paper we describe an innovative nanotechnology for shafts renovation by laying a nickel coating with included nanoparticles. The results from laboratory tests of the new coating are presented and discussed.

II. Description of the Technology

A. Classical Approach

The renovation process takes place in technological lines specially designed for laying of coatings with high mechanical wear resistance and surfaces moothness in order to restore the working surface of the shafts. A typical technological line for chrome based smooth shaft renovation should include at least the following technological cells and operations:

1. Grinding of the old chrome layer at a given roughness.
2. Coating of a new chrome layer in a galvanic (cyanide) bath.
3. Rough grinding of the coating down to a predetermined diameter and roughness.
4. Fine grinding of the shaft down to a predetermined roughness.
5. Polishing of the chrome to a predetermined smoothness (Ra ~ 0.03).

The grinding of the old chrome layer is a routine and easy operation if one has lathes with long guides, accurate screws and good bearings. Usually 120 μm to 150μm of the old chrome are taken off, where greater roughness is required to enable the new chrome layer to stick better.

The laying of the new layer of chrome can be done in a galvanic bath where part of the shaft is dipped and it is slowly rotated. Thus relatively big thickness (120-150 μm) and

Open Science Index, Mechanical and Mechatronics Engineering Vol:7, No:8, 2013 publications.waset.org/16053/pdf

unevenness of the coating is achieved. The evenness is improved through the next operation.

Like the previous stage, if one has lathes with long guides, accurate screws and good bearings, one can achieve enough accuracy of shaft's diameter, a decent smoothness (unlike operation 1 where bigger roughness is required) and one can take off the excess chrome.

Thus, the first three operations are common, traditional and well-known. They can be done using the available machinery in the majority of machine-building plants after a certain renovation of machinery. The main research and experiments in the renovation process need to be done for the last 2 operations – finishing and polishing. The reference and marketing studies as well as the consultations by experts, who have observed such operations in companies abroad, lead to the following conclusions:

- Various types of abrasive and erosive technologies are used for such special cases. Electromechanical, electro chemical, electro physical, laser and other methods of processing are known [2] and applied in practice.
- The finishing or polishing material is often put in a magnetic field, which aligns the particles. The particles are additionally placed and streamed along the shaft in a fluid.
- Having already achieved enough circularity and smoothness of the shaft, the purpose of these operations (especially polishing) is only to hone any tips above the chrome coating.
- Literature references show methods of simultaneous finishing and polishing as one finishing operation of sheet material.
- Because of the relatively thick chrome coating (120-150μm) when small defects or minor wearing out are observed, an intermediate finishing and polishing are applied, without laying a new chrome coating, only operations 4 and 5 listed above are repeated. These operations take off 10-15 μm each time. This can be repeated several times, until the thickness of the cover gets below 80-100 μm which is considered the maximum technologically recommended, also for geometrical reasons. Then the whole procedure of laying the new chrome coating has to be done.

B. An Advanced Nanotechnology

A simple analysis of the existing technology for shafts renovation reveals the following general characteristics of this technology.

- All methods of finishing and polishing of shafts coating require special equipment, high processing precision and they consume large amounts of electrical energy.
- Chrome coatings, which are still in use, ensure the necessary hardness and wear resistance, but the technology is known to be harmful and it does not comply with the contemporary environmental and ecological requirements. In particular, the EU Directives characterize chrome coatings and waste products (cyanides) from chrome baths as highly harmful.
- As a rule the finishing and polishing of steel (from which shafts are made) is more developed, cheap and successful as well as less harmful than processing with chrome, especially for big details and smooth finish.

Based on the above observations, an advanced technology for shafts renovation is developing by the authors and their co-workers under a project "New Methods and Means for Renovating of Shafts for Folio Extrusion" supported by the National Science Fund of Bulgaria.

Our technology is oriented to comparatively small shafts (400-800 kg) with cylindrical shape for extruding plastics. Fig.2 shows a smooth (hollow) cylindrical shaft with the attachment journals.

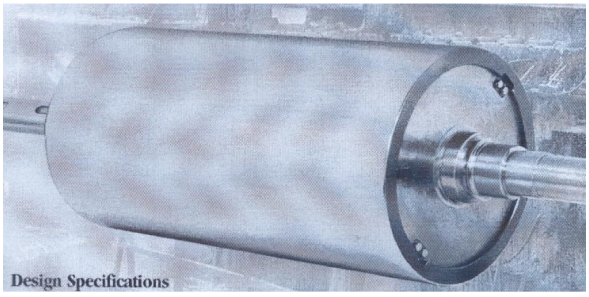


Fig. 2 Hollow smooth shaft for extruding of folio

The technology is based on nanostructured composite coatings obtained by electroless nickel plating method developed at the Technical University in Sofia [3]. It enables us to polish the steel base of the shaft by laying a thin (10-15 μm) nickel coating with nanoparticles in it, or by laying a thicker coating (25-50 μm) including other micro and nanodispersoids for increasing hardness and wear resistance. The usage of chemical nickel coating is characterized by several important advantages [3], [4]:

- High evenness in the layer thickness i.e. it is a sized coating requiring minimal finish processing;
- High hardness and wear resistance. The friction coefficient with many materialsis relatively low;
- Low porosity/high corrosive resistance;
- Excellent polishing ability because of greathardness and microcrystal structure;
- Convenient disperse coatings matrix.

The application of disperse coatings with nickel-phosphor matrix is widely used. The disperse coatings can include microscale and nanoscale insertions. At present there is a large variety of the existing microscale dispersoids and nanoscale particles [5]. Microscale insertions are mainly on the basis of carbides of silicon, titanium, tungsten and cobalt, characterized by high hardness and good bonding with the nickel matrix. Nanoscale particles are mainly nanodiamonds obtained through various technologies.

The process of extruding of sheet material is characterized by several negative peculiarities and conditions as:

– High working temperature - 200° C;

Open Science Index, Mechanical and Mechatronics Engineering Vol:7, No:8, 2013 publications.waset.org/16053/pdf

- Abrasive effect of the extruded material;
- Significant normal forces on the contact surfaceof the shafts;
- Noninterruptive working process.

In view of the above properties, the new type of coating offers improved characteristics and exploitation advantages regarding:

- Wearing resistance and microhardness;
- Corrosion resistance;
- Reduced porosity;
- Rapid reduction of the friction coefficient;
- Increased cohesion and adhesion.

The listed improvements and physical-mechanical features, due to the nanostructured nickel coatings, can increase the exploitation time of the extruding shafts 2 to 10 times while at the same time reducing the thickness of the coatings3 to 5 times. The reduced thickness compensates for thehigher price of the operation. The increased working time isan additional advantage. Furthermore, the replacement of the chrome coating with nickel one satisfies the requirements ofthe EU Directives on environmental pollution.

We have developed a stand (Fig. 3) for testing of coating's wear-resistance at working temperature (200 C degrees).

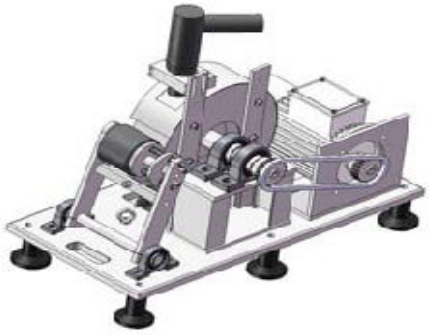


Fig. 3 Stand for testing of coating's wear-resistance

The stand consists of hollow shaft, driven by electric AC motor, and heater, blowing the shaft with hot air. A heat-resistant Teflon roller is pressed to the shaft, which serves as extruded material.

III. Experimental Results

Laboratory experiments were carried out in the Tribology Center at the Technical University of Sofia. The experiments included wear resistance testing of a coating obtained by chemical nickeling with nanosized particles of silicon carbide (SiC) as a strengthening material. The coating is deposited on steel samples with different surface roughness between *Ra*=0.3µm and *Ra*=2.1µm. The average size of particles is 35-40 nm. The thickness of the coating is 50µm and the density of SiC nanoparticles in the coating is 5-7 weight %. Some of the samples with composite coatings are put to a heat processing at 300^0 C for six hours to improve the mikrohardness and adhesion of the coating. The microhardness is measured by Knoop method under load of 0.5N.Five types of coatings are tested and the data for the tested samples are given in Table I.

The method for wear test includes preparation of the samples with the same ring shape and size before coating deposition. Grinding and polishing is applied in order to ensure surface roughness *Ra*=0.3µm and *Ra*=2.1µm.The sample is rotated on a special device where a friction force is applied by means of a counterbody of a special abrasive material. The weight of the sample is measured before and after a number of rotations with a precision of 0.1 mg.

The basic test parameters are:

- absolute mass wear, [mg]: the lost of coating weight in the process of wear estimated as the difference between the samples weight before and after a number of friction cycles;
- mass wear rate, [mg/min]: the lost weight of the coating in a minute;
- wear intensity: dimensionless parameter determined as the lost coating thickness in one friction cycle ;
- absolute wear resistance: dimensionless parameter determined as the reciprocal value of the wear intensity;
- nominal contact pressure, [N/cm^2]: the normal load distributed on unit contact area.

TABLE I
COATINGS DATA

No	Contents	Thermal processing	*HKO,O2*	*Ra [µm]*
1.	*Ni*	360^0C 6 h	860	0,3
2.	*Ni + SiC*	-	473	0,3
3.	*Ni+SiC*	360^0C 6 h	980	0,3
4.	*Ni+SiC*	-	485	2,1
5.	*Ni+SiC*	360^0C 6 h	940	2,1

The parameters of the contact interaction are nominal contact area 26.10^{-6} [m^2], nominal contact pressure 47.15[N/cm^2] and average speed of sliding 17.9[cm/s].

The obtained experimental results for the five types of coatings are graphically shown in Fig. 4, 5 and 6.

A diagram for the wear resistance of the coatings at N=900 cycles and N=1800 cycles of friction is shown in Fig. 7.

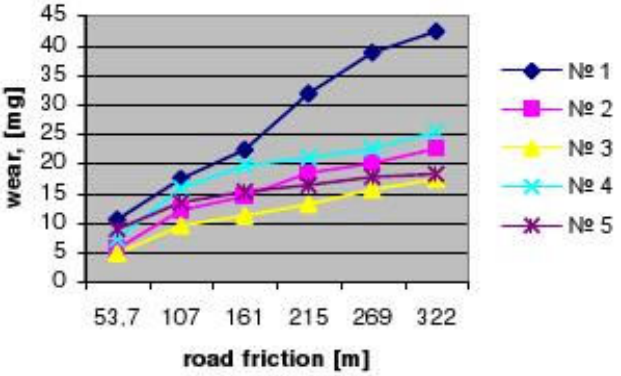


Fig. 4 Dependence of the mass wear on the rotation road

Open Science Index, Mechanical and Mechatronics Engineering Vol:7, No:8, 2013 publications.waset.org/16053/pdf

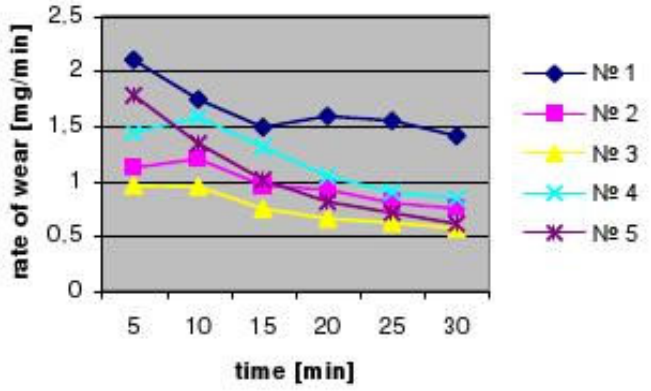


Fig. 5 Dependence of the wear rate on the time

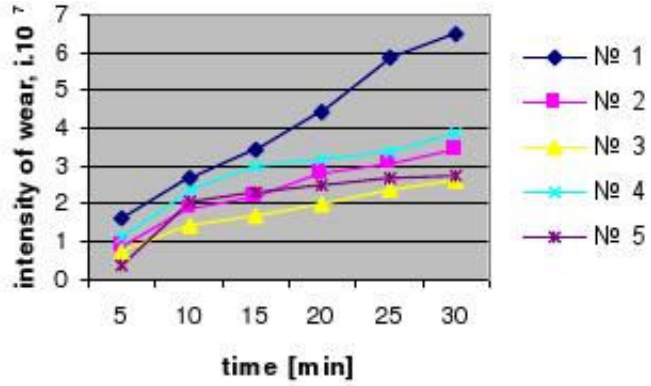


Fig. 6 Dependence of the wear intensity on the time

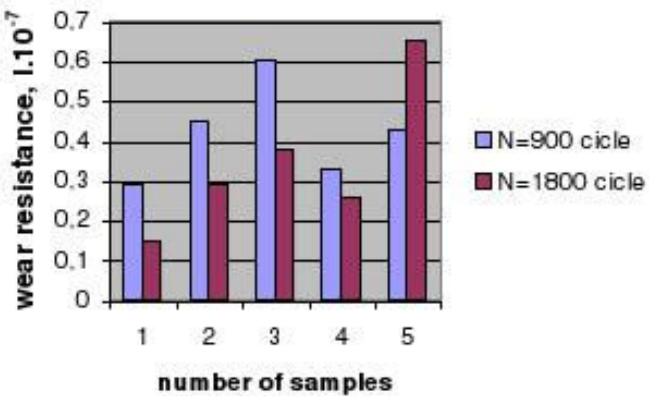


Fig. 7 Wear resistance of coatings at N=900 and N=1800

IV. Analysis of the Results

The variation in the mass wear value during the process of contact interaction under friction upon an abrasive surface is linear after a time of friction corresponding to the contact system running-in. The running-in process is with different duration: the highest value is achieved for pure nickel coating (sample №1): L=268,5 [m] , the lowest is achieved for the heat processed composite coatings (samples №3 and №5): L=107,4 [m], (Fig. 4). Maximum wear is observed for pure nickel coating (sample №1). The heat processed composite coatings have less wear than the coatings without heat processing. Minimum wear is observed for the coatings with smallest roughness (sample № 3 with Ra=0,3μm, Fig. 4). The mass wear rate and the intensity of wear have a pointedly nonlinear character over the time history (Fig. 5, Fig. 6). This confirms the thesis for the nonstationary character of the contact interactions, irrespectively of the constant values of the external dynamic factors as speed of sliding and nominal contact pressure. The influence is due to the contact area and additionally to the roughness.

An analysis of the results shows a significant influence of the roughness value at different stages of the contact interaction. It seems that the different resistance to abrasion is observed for the same coatings at different duration (cycles) of interaction. It can be argued that the higher wear resistance is achieved for the heat processed composite nickel coatings (samples № 3 and № 5). However, at different cycles the wear resistance depends on the difference in the degree of roughness. At N=900 cycles the coating №3 with lower roughness Ra=0,3μm has 1,6 times higher wear resistance than the rough coating №5 with Ra= 2,1μm. With twice as many cycles N=1800 the contrary is observed – the rougher coating has 1,5 times higher wear resistance. Clearly, further investigations are necessary in order to establish the dependences of the coatings properties on roughness, microstructure of the material, etc.

V. Conclusion

The main advantage of the proposed technology is the replacement of the chrome-coating in cyanide baths with nickel coating obtained by means of chemical nonelectric nickelling with included micro-scale dispersoids and nanoscale particles. The experimental results show a high wear resistance of the nanostructured coatings especially in the cases of heat processed composite nickel coatings. A further analysis and study of the microstructure and other physical and mechanical properties of the composite coatings is a subject of a future research.

Acknowledgment

The research work reported in the paper is partly supported by the project AComIn "Advanced Computing for Innovation", grant 316087, funded by the FP7 Capacity Programme (Research Potential of Convergence Regions).

References

[1] P.Velev, *Plastic manufacturing*, UCTM, Sofia, 2005.
[2] V. Kovalenko, *Technology and equipment of electrophysical and electrochemical methods of material processing*, Kiev, VishaSchola, 1985 (in Russian).
[3] G. Gavrilov, C. Nicolov, Electroless Nickel and Composite Coatings, Technika, Sofia,1985.
[4] G. Gavrilovand D. Karastoyanov, Disperse coatings on nickelbasisincludingmicro- and nano-dispersoids, in *Proc 19 International Conference , "Roboticsand Mechatronics'09",* Varna, Bulgaria, 2009, pp.66-72.
[5] D. Karastoyanov, T. Penchev, G.Gavrilov, Renovating of shafts for folio extrusion using new type coating with nano components, *in Proc. International Conference "Robotics, Automation and Mechatronics'11",* Sofia Bulgaria, 2011, pp.m17-m20.