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P. Tarkowski

Problems Connected with Tribological Tests of Metals Modified with thin Coatings

Technical University of Lublin, Mechanical Faculty, 36 Nadbystrzycka Str., 20-618 Lublin, Poland; E-mail: p.tarkowski@pollub.pl

Chosen problems concerning the processes of friction and wear of metal surfaces improved with thin layers have been presented in the paper. The scheme of the pin-on-disc test bench used testing thin layers as well as the results of preliminary tests have been presented.

Key words: tribology, thin layers, ion implantation, pin-on-disc.

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Introduction

Progress in the field of life and reliability of the machinery and its constituent elements is connected, among other things, with the developments in the techniques of constructional materials surface purification. In the systematics used in surface engineering – among other techniques of producing various kinds of surface layers – a group of so-called new generation techniques can be distinguished. PVD, CVD, laser, electron implantation and plasma techniques belong, among others, to that group. The common feature of mentioned above methods of constructing materials surface layers is obtaining very thin, hard coatings with exceptionally favourable functional properties.

The introductory stage of research work on changing tribological properties of surface layers usually consists in carrying out laboratory tests concerning friction and wear processes on special test benches.

I. General characteristics of friction and wear research methods

The choice of the test bench designed for studying friction and wear processes depends on the conditions in which elements whose surface layers properties can be varied are used. Motion dynamics and kinematics of machine mating elements, contact geometry and the dimensions of associated elements, kind of friction as well as kinds of materials are, among other things, taken into consideration.

Typical test benches used during tests differ in macrogeometry of sample and countersample contact. The most frequent association cases in that field are the following:

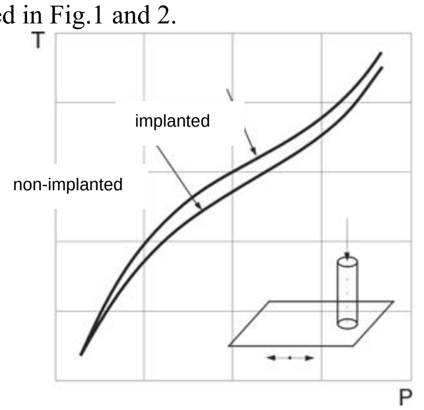
cylinder with flat surface,
flat surface with flat surface,
cylinder with cylinder,
sphere with sphere,
sphere with plane.

The choice of conditions for carrying out tribological tests requires individual approach and depends mainly on the properties of the tested layer. In the case of thin layers, the conditions taken into consideration are, among others, values of pressure between sample and countersample, used lubricant, value of sample-countersample relative velocity and dimensions of mating elements. Parameters characterizing conditions for carrying out tests are usually determined in an experimental way in accordance with properties and thickness of sample improved layer.

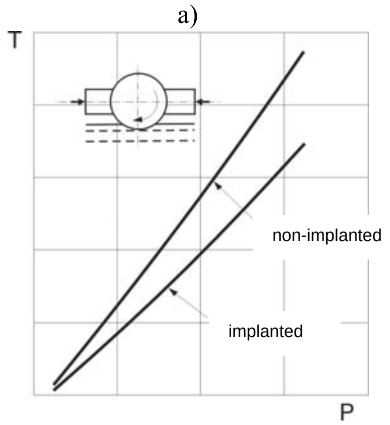
II. Example of studying tribological properties of thin layers

Tests of thin layers carried out at the Technical University of Lublin concern mainly the use of ion implantation method. In performing such tests, tribological test benches characterized by various constructional features were used. Already existing test benches constructed at some co-operating centres were employed. The parameters of sample-countersample mating were chosen experimentally on the basis of tests carried out earlier. Carburized and hardened 15HGM steel, widely used in machine constructing, was applied as the material for samples; nitrogen ions (accelerating energy – 120keV, dose 2x10 ions/cm^2) were used for implantation.

Example results of studying friction and wear processes in ion implanted layers, obtained during tests with the use of tribological benches characterized by various constructional features, have been graphically presented in Fig.1 and 2.



a)



b)

Fig. 1. Results of studying dependences between pressure force values and friction force values, obtained in the carried out tests: plane – cylinder (dry friction) – Fig. a, and two cylinders – disk (lubrication with paraffin oil) – Fig.b.

Example results of tests relating to the dependence of friction forces on pressure forces have been presented in Fig.1., for comparative studies of layers improved by implantation and non-implanted ones [2]. On the grounds of two cylinders – disk test results, it was stated that in the conditions of lubrication after implantation, friction forces decrease, while in the conditions of dry friction (cylinder – plane test) the reverse tendency can be observed.

Example results of comparative tests relating to the rate of abrasive wear of samples improved by implantation and of those in the standard version [2.3] have been presented in Fig.2. The assessment was carried out on the basis of the results of the following tests: two cylinders – disk (lubrication with paraffin oil) and cylinder – flat surface (dry friction). The grounds for assessment were both the results of profile measurements of wear trace surfaces and microscopic pictures of those surfaces. In the case of both tests, the decrease in wear rate being the result of nitrogen ions implantation could be observed.

Model laboratory tests and maintenance tests of implanted fuel spray nozzles and punches proved the tendency observed during bench tests of friction and wear processes [4,5].

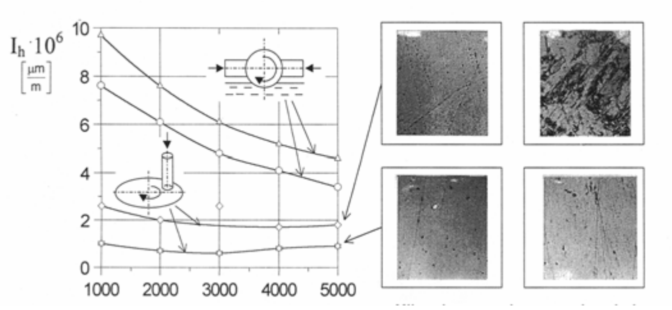


Fig. 2. Results of wear tests for implanted samples (bottom curves) and non-implanted ones (top curves). I = Δh/Δs, where Δh – value of linear wear on path Δs.

III. Conception of the bench used for tribological tests of thin improved layers

In extensive professional literature concerning studies of tribological properties of thin improved layers, pin- on - disk test benches are widely described. However, precise technical data relating to the ways of ensuring conditions for mating of sample – countersample pair associated in the tests are rarely given by the authors of published papers. Similarly, detailed data concerning testing possibilities of particular test benches of that kind are rarely presented.

In the course of designing the pin-on-disk test bench meant particularly for testing thin improved layers, it was assumed that the bench should:

make it possible to control values of pressure forces in a broad range,

ensure smooth control of sample rotational speed,

ensure the possibility of testing the process of dry friction and friction in the conditions of lubrication, make it possible to carry out tests in controlled atmospheres and in the conditions of low pressure.

Full measurement automation and the control of a computer system with electronic archiving of obtained results were assumed.

As a result of executing the project meeting mentioned above requirements, the bench making it possible to carry out in a continuous way measurements of friction force values depending on friction path, and in a periodical way - measurements of sample and countersample wear was obtained. Tribological tests can be carried out for various gauge diameters on disk-shaped samples which are 10 to 50mm in diameter. The countersample is a mandrel ending in a ball which is O,5 to 10mm in diameter. The schematic diagram of the bench described above is presented in Fig.3.

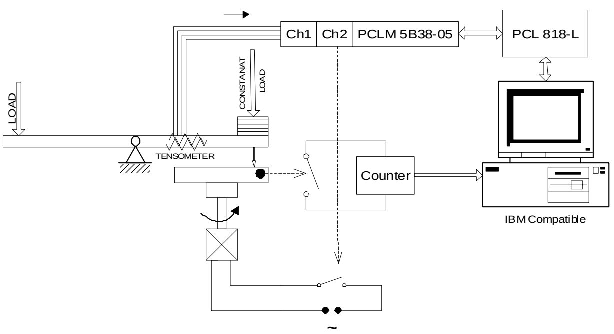


Fig. 3. Schematic diagram of the pin-on-disk test bench.

IV. Conditions and results of bench preliminary tests

While testing the prepared bench, measurements of friction coefficient value changes depending on the number of cycles (i.e. friction path) for various gauge diameters, and of wear for a few example gauge diameters (Φ=10-14mm) after 2500 revolutions of the sample [1].

Samples were prepared as disks made of Armco iron and NC10 steel and were 50mm in diameter; countersamples were balls made of tungsten carbide (WC) whose radius of curvature was 0,5mm. NC10 steel was exposed to standard heat treatment (hardening and tempering), applied to that kind of steel, after which its hardness was about 63HRC. Before the beginning of tests, all the samples were polished until their roughness parameter was R ≈ 0.02µm. Detailed conditions characterizing carried out measurements are presented in Table 1.

Table 1.

Conditions of measurements on the pin-on-disk test bench

	Armco iron	**NC10 steel**
Countersample material	WC	WC
Countersample diameter	0.5mm	0.5mm
Load	0.39N	0.49N
Number of cycles	2500	5000
Gauge diameters	4,7,10,20,30,40 (mm)	6,10,14,18,20 (mm)

Changes in friction coefficient values depending on the number of cycles (i.e. friction path) for various gauge diameters have been presented in the form of diagrams in Fig.4. Samples made of NC10 steel were subject to tests. During the analysis of the obtained results, repeatability of measurement outcome for the majority of sample-countersample mating diameters was observed. The exception are friction coefficient values measured for the gauge diameter Φ=6mm. In that case, friction coefficient values were much lower during the whole test. That resulted from the fact that it was impossible to set up precisely the countersample axis towards the sample revolution axis and towards the measurement lever. The set-up error, which might have occurred in the case of the diameter of the lowest value, resulted in the fact that the extensometer system placed on the lever measured only the component of friction force instead of its real total value. In the following tests, the measurement system geometry was corrected. The correction was carried out with the use of the collimated beam of laser radiation and the beam position detector. As a result of such a correction, the correct results were obtained, also for gauge diameters of low values.

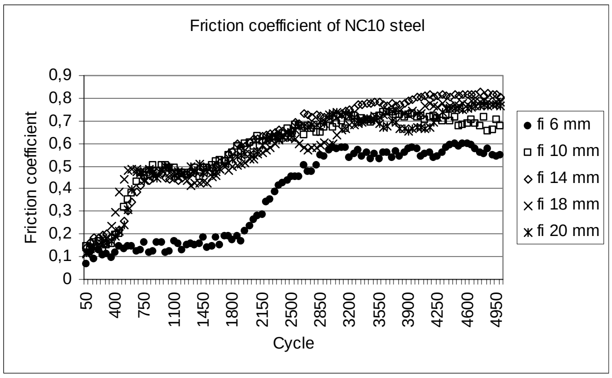


Fig. 4. Course of changes in friction coefficient values for NC10 steel depending on gauge diameter value

Wear of the sample made of Armco iron for various gauge diameters was determined on the grounds of values of mean cross-sectional area of profilograms made for a few randomly selected points on the profile of sample-countersample mating trace.

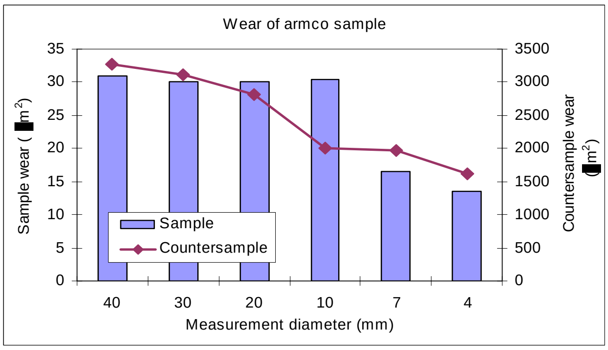


Fig. 5. Dependence of Armco iron samples and tungsten carbide countersamples wear on gauge diameter value after 2500 cycles

Results of wear measurements for a few example gauge diameters (Φ=10-40mm) after 2500 sample revolutions are presented in Fig.5. Additionally, data pertaining to countersample wear, determined on the grounds of measurements of their cross-sectional area reductions, are presented.

The obtained test outcome shows that the result of sample wear measurement for diameters ranging from 10 to 40 mm does not depend on the diameter of the circle on which the countersample is moving. However, wear decrease was observed for the smallest diameters Φ=4 and 7 (mm). That fact seems to be connected particularly with lower relative linear velocity of mating friction pair and with the shortening of friction path.

As it was assumed, countersample wear depends on friction path length, i.e. it decreases together with the decrease in gauge measurement value.

Conclusions

Some results of testing friction and wear of thin layers with the use of new generation techniques have been presented in the paper providing the example of steel implantation with nitrogen ions. The obtained results unambiguously prove the favourable influence of the applied method of modifying outer layer tribilogical properties. However, the peculiarity of carrying out diverse tests resulting in some differences in test benches constructional features limits the possibility of comparing them.

The pin-on-disk test bench presented in the paper was constructed for the sake of testing improved thin layers and due to its specific constructional features and observed test results repeatability seems to be useful for testing such layers.

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П. Тарковскі

Проблеми, пов'язані із питаннями трибології модифікованих металів із тонким покриттям

Люблінський технічний університет, механічний факультет,
вул. Надбистржицька, 36, 20-618, Люблін, Польща; E-mail: p.tarkowski@pollub.pl

Вибрано задачі, що пов'язують процеси фракції та зносу металічних поверхонь, покращених тонкими шарами. Протестовано лабораторну схему тонких шарів у якості доброго узгодження з заданими критеріями.