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The surface topography influence on tribology phenomenon proceedings in exploitation investigation of drawing dies

Key words

Coarseness, profile, cooling lubricant agent, surface layer.

Słowa kluczowe

Chropowatość, profile, ciecze chłodząco-smarujące, warstwa wierzchnia.

Summary

The actual contact area of cooperating surfaces is dependent on the geometric sketch of surface profile and the loud accrued on it. Cooperating surfaces have very small actual contact areas, producing an effect in that the friction and wear are determined by high tension in contact zone and extreme concentration friction energy. Many tribology phenomena can happen due to the reciprocal coerced effects of the unevenness of being in the contact surface, before surface wear. During the conducted experiments, surface profile measurements were taken using Talysurf 4 and Taylor-Hobson type profile meters. It was done to determine the characteristic value of the geometric structure surface of material and tool parts being in contact. The goal of the mentioned measurements is to gain information for the analysis of topology surface influence on the final co-operation effect.

Introduction

Surface unevenness of cooperating parts can be considered as set of singular atoms or an apparent set of rows and bulges (protrusion), depending of their dimension. Most of that unevenness have a crucial influence on friction and wear processes. The basic friction principles are the research result of the actual

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area contact of uneven surfaces. In spite of that, the parameter of unevenness base on linear measurements and the unevenness has a three-dimensional character, and the unevenness parameters can provide important information on the specified tribology process. Acquired information of surface topography can help in the analysis of upper layer changes during the friction and wear process. This is true when friction and wear process occur during drawing process. Surfaces of tools used in the drawing process are particularly exposed to changes of surface unevenness (from micro to macro scale), which is caused by tribology phenomenon and by process of plastic deformation as well as.

2.1. Measurement of THE topogrphy parameters of investigated surfaces

2.1. Introduction

The investigated dies of the drawing process were made of sintering carbide G10. The material is processed by drawing a copper wire aggregate. The drawing process was conducted in operational (terotechnology) conditions in four series with the application of four different lubricating cooling agents [1]. The drawing experiment lasted 8 hours for the all mentioned die series.

2.2. Investigation method

In frame of investigation the surface profile measurements were conducted using Talysurf 4 and Taylor-Hobson type profile meters. It was done to determine the characteristic value of geometric structure surface of parts in contact. The determination of the R_a parameter on sample surface was impossible, because the length of minimum measurement distance was bigger than the actual measurement length of investigated sample. Technology condition of measurements allows only the measurements along the trace of plane section including die axis. The tester tip edge copying profile, runs perpendicular to processing traces of investigated die for new samples. The trace of tester tip edge cuts the trace line of drawing process with a very small angle for dies after time of work.

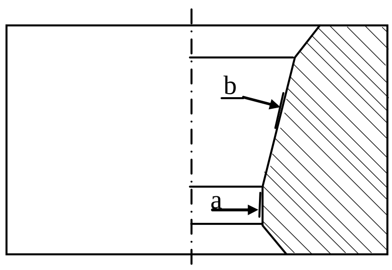

Fig. 1. Drawing die – a & b the unevenness measurement places
Rys. 1. Ciągadło – a i b miejsca dokonania pomiarów chropowatości

The measurements were conducted on properly adequate working surfaces. This was the surface of the calibrating part and taper part (Fig. 1) of drawing die, and, in case of samples of processed material, i.e. cooper wire, on wire surface before and after deforming by the drawing die.

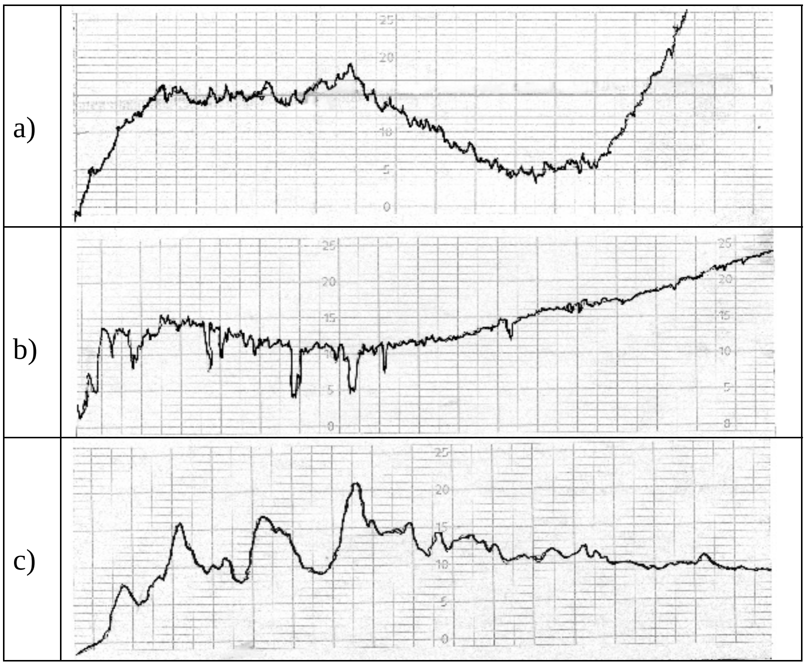

Fig. 2. Chart of profile meter registration for the deforming taper of the drawing die ($\varnothing_k$ = 5.5 mm), die before work, vertical magnification 100 000x, horizontal 100x after work, series "A," vertical magnification 20 000x, horizontal 100x after work, series "W," vertical magnification 1000x, horizontal 100x

Rys. 2. Profilogramy powierzchni stożka zgniatającego oczka ciągadła ($\varnothing_k$ = 5,5 mm), a) nowe, powiększenie pionowe 100 000x, poziome 100x b) seria „A", powiększenie pionowe 20 000x, poziome 100x c) seria „W", powiększenie pionowe 1000x, poziome 100x

2.3. Investigation results

The profile shape diagrams as exemplars of an investigated surface of drawing dies are pictured on Fig. 2. As a complement to the above mentioned charts are the registered profile diagrams of processed wire surface before and after deformation (Fig. 3). The magnification coefficients of vertical and horizontal axes are different, so the profile deformation is on the charts. The profile diagrams registered for bigger surfaces enabled to read extreme value of notch, jump aside, and calculate parameter R_z.

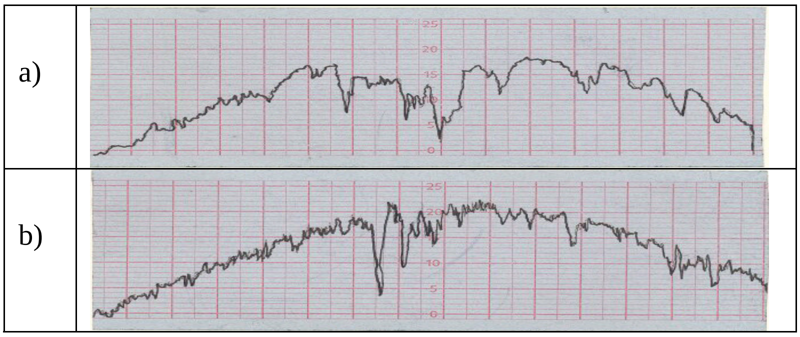

Fig. 3. Profile measurement diagrams of wire sample Φ_k= 5.5 mm series A Magnification: vertical 5000x, horizontal 100x

Rys. 3. Profilogramy powierzchni próbek drutu Φ_k= 5,5 mm z serii A. Powiększenie: pionowe 5000x, poziome 100x a) przed wejściem do ciągadła, b) po wyjściu z ciągadła

Table1
Tabela 1

No.	Serie	Diameter of calibra-ting part Φ_k [mm]	Characteristic of investigated surface			
			in deforming cone		in calibrating openings	
			R_z [µm]	Depth of rift y [µm]	R_z [µm]	Depth of rift y [µm]
1	A	5.5	1.5	2.0	1.04	1.6
2		1.5	-*)	0.04	0.068	0.08
3	U	5.5	3.08	4.4**)	14.8	20.0
4		1.5	-*)	0.1	0.08	0.1
5	H	5.5	-*)	0.6	0.98	1.3
6		1.5	-*)	0.04	0.06	0.2
7	W	5.5	-*)	0.04	-*)	3.0***)
8		1.5	2.1	2.5	0.88	14.0
9	new	5.5	-*)	0.03	0.03	0.03
10		1.5	0.065	0.12	0.05	0.12

*) impossible reading, **) single protrusion 60µm, ***) jump aside 20 µm.

The values of unevenness, exceeding three times the average value, were not included in calculations of R_z. The rifts where simple unevenness exceeding three times the average value, or notches, were not included in R_z calculations because of the lack of the required fives peaks and pits on measurement interval. The calculated R_z and depth of rifts (from obtained diagram registrations) were gathered in Tables 1 and 2.

Table 2
Tabela 2

No	Serie	Wire before deformation $\phi_k = 5.5$ mm		Wire after deformation $\phi_k = 5.5$ mm	
		R_z [μm]	Depth of rift y [μ]	R_z [μm]	Depth of rift y [μm]
1	A	1.5	5.0	0.76	3.8
2	U	2.8	5.2	1.6	3.0
3	H	1.54	4.0	0.6	2.8
4	W	1.5	6.0	*)	3.0

*) measurement impossible
*) nie można zmierzyć

2.4. Result validations

The smallest coarseness of the eyelet surface of drawing die was obtained in the exploitation condition using “Hydropol” as a lubricating and cooling agent. Next in sequence of roughness were the surfaces of drawing dies working with “Alumol,” “W-35,” and “Unipol.” The obtained results of rift depth measurements of drawn wire samples allow us to state that the lowest destruction of the surface of the working tool is at the point of applying the “Hydropol” agent. The surface coarseness of the drawn wire sample is smallest when using “Hydropol” as a lubricating and cooling agent. Next in sequence are the values when applying “Alumol,” “Unipol,” and “W-35” (a different order exists in the coarseness of the working tool surface). The results obtained in rift depth measurements of the drawn wire indicate the lubricating and cooling agent “Hydropol” as the best from those under consideration. The surface profiles of the calibrating part of die eyelets with $\phi_k = 1.5$ mm and $\phi_k = 5.5$ mm are considerably deformed, compared to unused dies, for all tested lubricating and cooling agents (Fig. 4).

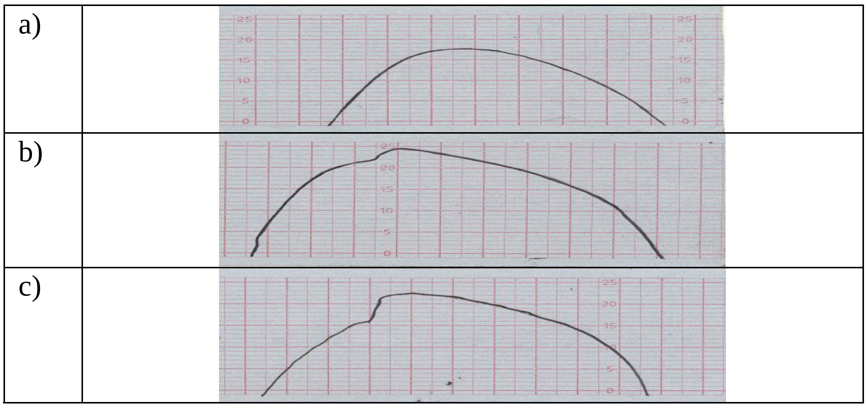

Fig. 4. Profile of calibrating part of the die with Φ_k= 1.5 mm magnification: vertical 500x, horizontal 20x a) unused die (new one), b) series A die, c) series W die
Rys. 4. Profile części kalibrującej oczek ciągadeł o Φ_k= 1,5 mm powiększenie: pionowe 500x, poziome 20x a) ciągadło nowe, b) ciągadło z serii A, c) ciągadło z serii W

Heterogeneity of coarseness in particular places of the investigated surface of drawing die eyelets, and not recurrent periodically macroscopic surface deviations, e.g. working surface concaveness, or big rift depth, especially for tool working with “W-35” and “Unipol” agents, prove the heterogeneity of the tool surface layer. They (surface concaveness or big rift depth) can be caused by non-uniform and different genus of surface wear. The mechanism of that phenomenon is very complicated, which is confirmed by observation of SEI electron images under surface layers of investigated die eyelet [2].

3. Influence analysis of topography changes of investigated surfaces on THE constitution process of THE surface layer of drawing die eyelets

The actual contact area in tribology is from the deformation of higher protruding elements of surfaces being in contact. The contact stress between those elements can lead to local plastic deformation. It is common opine that the most contacts between course surfaces have elastic form. The relationship between contact area and stress is exceptionally important in tribology considerations and wear processes. The values of the friction forces are independent of the actual contact area. The friction principles are compatible with elastic deformation principles at the contact of course surfaces but under the condition that the surfaces reveal existence of complicated [3] and hierarchical structure with the characteristic few micro-contact scales. The actual contact is distributed between plenty of micro-contact areas.

Friction energy concentration on small local contact surfaces has a crucial influence on wear process. Real contact executed by the actual contact area can be found only if contact stress is extremely high, for example, in shaping process between machining tools and the shaped material. During the plastic shaping process, local temperature increases appear up to a very high value even with a relatively small share of friction energy. The obtained surface coarseness and the evaluation of structural deformation [2] of the upper layer of drawing die eyelets are the results of drawing process conditions and the influence of physical and chemical features of the lubricating and cooling agents. The drawing process is associated with high plastic deformation tensions. The deformation tensions are responsible for the plastic deformation of shaped material and the upper layer of shaping tool, i.e. the working surface of die eyelet. Cumulated process tensions may affect surface corrugation. That corrugation can be caused by vibration generated by drawn material translocation on the surface of the die eyelet. The shaped material translocation reduces the effect of actual contact areas by less of the actual contact point of working opposing surfaces. Contact restriction of opposing working surfaces is caused by particles of the lubricating and cooling agent as well. Another reason for contact restriction is the irreversible process of the wear product elimination directly after their removal from the wear contact zone. In the case when elements of the wear product are still inside contact zone but not joined with their original places, they may migrate. That movement is stimulated by the shifted surface of shaped material till the end of contact with the drawing die eyelet. The described phenomenon is one of the reasons for changes in the geometric structure of cooperating surfaces. The high temperature, particularly at the contact point, accompanying the drawing process, has a strong influence on the contact mechanism of moving surfaces in the drawing die eyelet. The tribology phenomenon changes continuously during process time and declining coarseness of cooperating surfaces during process have some impact on it. Secondary electron images (SEI) of the investigated surfaces of drawing die eyelets demonstrate changes in the surface layer of working tools compared to the unused ones.

Losses of binding components, i.e. cobalt, during the wear process from the surface layer cause losses of base component particles, i.e. sinter carbide, forming the tool surface [2]. The investigated tools with larger changes of the surface topography characterise themselves by larger structural changes of the working surface layer. The results of the residual stress investigation [4] of the surface layer of drawing die eyelets give evidence of different tribology conditions for particular series of tests. Acquired results of topology changes of investigated samples surfaces and changes in the constitution of the surface layer of the drawing die eyelets lubricated with “HYDROPOL” testify to the beneficial effect of that agent on the wear mechanism [1].

4. Closing observations

The investigation of the surface topography of drawing dies and processed materials proves the large distortion and local irregularity of surface structure. Imperfections and rifts of cooperating surfaces influence the chemical reactions in the presence of the lubricating and cooling agent. Observed irregularity of surfaces indicates the contact mechanism between opposing surfaces. The cobalt impoverishment from the surface structure of drawing die eyelets is unequal on whole area of investigated samples. It can be caused by the temperature rise at contact areas of surface micro irregularity as a result of adhesion splice opposing surfaces.

The investigations prove the simultaneous influence of the tribological phenomenon and the existing structural state of surface, which is changing during the wear process.

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Wpływ topografii powierzchni na przebieg zjawisk tribologicznych w eksplotacyjnych badaniach zużycia ciągadeł

S t r e s z c z e n i e

Rzeczywista powierzchnia styku jest funkcją geometrycznego zarysu nierówności i przypadającego na nią obciążenia. Współpracujące powierzchnie mają bardzo małe pola rzeczywistego styku, co powoduje, że zużycie i tarcie są zdeterminowane przez wysokie naprężenia w strefie styku i skrajne koncentracje energii tarcia. Wiele zjawisk tribologicznych może zaistnieć wskutek wymuszonych wzajemnie oddziaływań nierówności, zanim nastąpi zużycie. Dla określenia wielkości, charakteryzujących strukturę geometryczną badanych powierzchni przeprowadzono pomiary na profilometrze typu Talysurf 4, Taylor-Hobson. Celem tych pomiarów było uzyskanie informacji do przeprowadzenia analizy wpływu topografii stykających się powierzchni na końcowy efekt ich współpracy.