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THE PROBLEM OF MODELLING OF TESTING OF ABRASIVE WEAR IN AREA OF FORMING OF POWDER MATERIALS

Introduction

Abrasive wear is the predominant type of wear encountered for forming powder metals in technology of powder metallurgy (PM).

By observation of macrosurface of active pressing parts of the tool there were noticeable traces - grooves that were shaping in the direction of forming force. This forming tool with its use value is no longer met with the required functions. Theoretically, these processes are justified increasing in works (Blaškovič, P. - Balla, J. - Dzimko, M., 1990, and Barysz, I. et al. 1995). It may be noted that the grooves on the surface formed as a product of the process of pressing, respectively in its two phases, which are linked to each other. At some stage and under certain conditions there is penetration of powder particles (a mixture) to harder material of active parts and there is intense wear of surface. It is necessary to state this as fact - active parts of forming tool meet with the requirements of approximately 30,000 pressings, and after reaching that amount they are disabled. When analyzing the pressings there is visible footprint (strip) in the longitudinal axis of forming (there were observed and evaluated the cylindrical pressings). After the discovery of this primary character on pressings, there is sign of a possible seizure of the active parts of tool. Of course, regarding the size of the batches of pressings, it is lower (at least usually) as the total series, so the tool is set and sort on forming machine several times. Based on this fact, it can be concluded that on the wear on the surface of the active parts of tool also had influence his setting on the press that means that adapted surfaces basically move and fall into different relative positions. There will also be a condition where the maximum will won't be evenly distributed, but occurs only in one section, and conversely- in case of minimum will, which is confirmed by observation and practice.

Present imposes requirements for optimization of materials used in PM technology for parts of forming tools. Used steel of grade 19 436, quenched and tempered to 60 HRC, retain their status, even if there are applied more modern kinds of materials in the field, because for their optimal commercial realities for the given type of work. Material costs for quality steels are very high and is certainly appropriate to seek for alternative materials. However determination of optimal material provides requirements for testing materials. They are generally used two types of tests - operational and experimental.

1. Experimental device and principle of the test

The design of experimental equipment with regard to the its function in the process of simulating conditions of wear, it is necessary to define in detail the conditions under which the process of wear will be experimentally studied.

Schematic representation of exposure loading parameters is shown in Fig.1. The principle of testing is the comparison of standards (steel 19436) with the proposed materials with the same test conditions. After testing the samples with a chemical-thermal treatment are evaluated and compared with a reference standard. The assumption is that in some interval of strokes (speed) tested material has identical performance as the same material used.

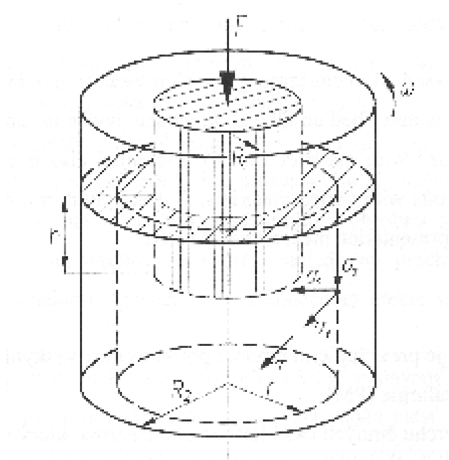

Fig. 1 – Schematic representation of burdensome activity parameters

If the assumption was confirmed, the new material could be used for smaller series of pressings, with an optimal number of about 10,000 pieces. The principle of the experiment is that the sample is placed in the cavity space of grinding chamber filled with the powder used, whether based on iron or bronze. There was the sample wear steadily in equipment, because unlike real conditions, where parts are moved in the direction of the vertical axis, and where may play a role even a will in line of tool, which has the effect of increasing local wear. This effect is excluded in the experimental equipment. There is a scheme of the equipment of the experimental test of abrasive wear in Fig. 2.

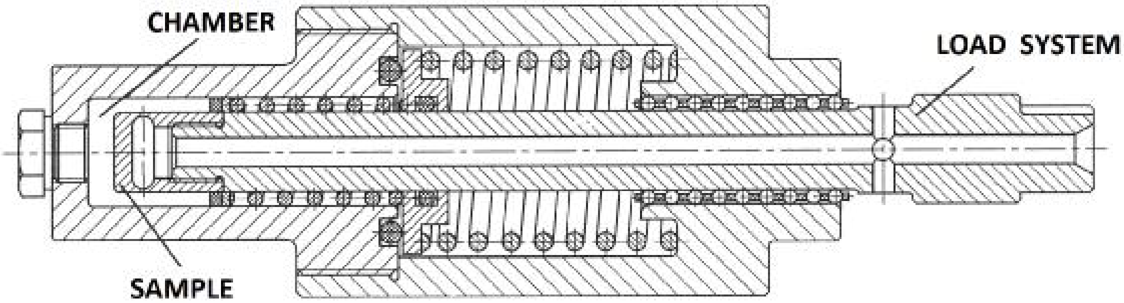

Fig. 2 – Equipment for experimental tests of abrasive wear

There will be examined movement according to fig. 1 (flow of the powder in a cylindrical tube in place between the inner cylinder - sample ($\omega = 0$) and the outer cylinder - grinding chamber ($\omega \neq 0$).

A. The assumption $F = 0$

There is operate moment M on the powder in the entire area of gap $R_2 - R_1$. In the steady case is the direction of speed of the movement of the powder perpendicular to the axis of cylinder and changes in the radial direction, in which operate tangential stress:

$$\tau = -\eta \frac{dv}{dr}.$$

There is η which is the coefficient of internal friction (viscosity) and $\frac{dv}{dr}$ is the gradient of velocity in the radial direction. The coefficient of internal friction is a function of density, size and shape of particles, respectively corpuscle.

If it considers the volume of the powder in cylinder with a radius $R_1 < r < R_2$, so the total force which is applied on the surface of the cylinder under consideration $S = 2\pi rh$, is given by equation:

$$F_c = -2\pi rh\eta \frac{dv}{dr}.$$

It is the force of the internal friction of other powder, which operates on the powder in the selected cylinder. Moment of this force is compensated by the moment M, which causes rotational movement of the external cylinder, which can be expressed by the equation:

$$M = 2\pi rh\eta \frac{dv}{dr} r.$$

With further consideration $v = \omega r$, and after changes an equation will have form:

$$2\pi h\eta d\omega = \frac{M}{r^3} dr.$$

Where can be express the moment M, which external cylinder operates on the inner:

$$2\pi h\eta \int_{\omega}^{0} d\omega = M \int_{R_2}^{R_1} \frac{dr}{r^3},$$

$$2\pi h\eta\omega = \frac{M}{2}\left(\frac{1}{R_1^2} - \frac{1}{R_2^2}\right).$$

From where

$$M = 4\pi h\eta\omega\frac{R_1^2 \cdot R_2^2}{\left(R_2^2 - R_1^2\right)}.$$

B. The assumption $F \neq 0$

The calculation and relations will be similar as in the case of $F = 0$, with the difference that the tangential stress is enlarged by the value of σ_y caused by axial tension σ_z:

$$\tau' = -\eta\frac{dv}{dr},$$

$$\tau' = \tau + \sigma_y,$$

whichever is

$$\sigma_y = k\sigma_z,$$

where k is the ratio of the radial and axial tension:

$$k = \frac{\sigma_y}{\sigma_z}.$$

The coefficient of inner friction can be determined by the method of rotational viscometer (Brož, J. 1983). For the theoretical analysis of the size can be select process used to determine the effect of friction on the wall of pressing cavity (Píšek, F. et al. 1975).

2. Description of experimental methods and used materials

Size of wear usually represents losses in their volume or weight on unit sliding tracks. There was simulated the acceleration of character of tribological process in mentioned equipment. Samples of cylindrical shape in terms of abrasive wear were evaluated before and after the tests. Basically these are comparative tests, where the standard is compared with the samples under the same process conditions. As already stated, a reference standard sample was steel 19 436, and additional samples were made of steel are 13240. Chemical composition of steels is in table 1.

Table 1

Chemical composition of steels used

Element	*C*	*Mn*	*Si*	*P*	*S*	*Cr*
19 436	1,80 - 2,04	0,50	0,50	0,035	0,035	11,0 - 13,0
13 240	0,48 - 0,54	1,1 - 1,4	1,1 - 1,4	0,035	0,035	-

Samples were selected so that they can be objectively evaluated after performed tests. They have a rotating shape ø 22 × 30 mm. The material for samples was chosen for the following reasons:

a, relatively easy availability of materials in collaboration with practice,

b, the minimal costs

c, the feasibility of production samples and their thermal treatment without any financial burden on the verification work.

The number of samples was five pieces. Hardness of standard and test samples is in table 2.

Table 2

Hardness of standard and samples

Sample	Hardness (HRC)
E	62
1	60
2	62
3	61
4	60
5	60

Used powder was chosen for analysis in the manufacturing plant according to the following criteria:

a, according to the needs of businesses,

b, representative of the type according to criteria related compositions.

A composition of 0103, specific signature *TSH*26, contains 0,017 % carbon powder and Mo in the volume of 0,42 %, grease *HW* - 2, 0 %. The base (matrix) is *Fe* – with signature *H*26. Sieve analysis was made in the laboratory of production company* on sieves with meshes 0,212; 0,15; 0,45 mm, and it was found that through each mesh of sieve passed percentage volume of these particles:

to 0,012 mm – 0 %
0,150 mm – 0,90 %
0,045 mm – 81,30 % - remained on the sieve
17,80 % – passed through sieve
100,00 %

Strew volume 36,0 (cm^3 100 g^{-1}), strew density 2,77 g cm^3, compressibility 6,92 (MPa).

Results:

The attached tables content the values that were determined before and after the tests.

Parameters: - weight of the samples (Tab. 3),
- dimensional characteristics (Tab. 4),
- roundness (Tab. 5),
- roughness of the samples (Tab. 6).

Table 3

Weight of sample (g)

Sample	Starting weight	Final weight
E	46,4390	46,3210
1	46,0010	45,854
2	46,4376	46,3126
3	46,2560	46,109
4	45,9060	45,754
5	46,2230	46,100

Table 4

The external diameter (mm)

Sample	Starting diameter	Final diameter
E	21,992	21,983
	21,992	21,986
	21,992	21,988
1	21,994	21,981
	21,993	21,980
	21,993	21,981
2	21,992	21,980
	21,994	21,976
	21,994	21,978
3	21,992	21,980
	21,992	21,981
	21,994	21,981
4	21,993	21,980
	21,994	21,978
	21,994	21,976
5	21,994	21,978
	21,994	21,977
	21,993	21,977

Note: Measurements were carried out at three positions (heights) - 15, 20, 25 mm

Table 5

Tolerances of roundness

Sample	Plane A - A		Plane B - B		Plane C - C	
E	3,10	5,90	4,10	6,90	3,20	6,10
1	8,60	12,90	9,20	11,20	9,20	10,90
2	4,80	8,60	5,10	10,00	4,80	9,80
3	5,20	9,30	5,20	9,60	6,10	8,46
4	4,70	8,80	4,80	9,00	4,80	8,60
5	3,20	6,25	3,90	7,10	3,60	6,80

Note: Measurements were carried out on the equipment TALYROND in three places (sections):
section A - A 15 mm
section B - B 20 mm
section C - C 25 mm

Table 6

Roughness of surface - R_a (μm)

Sample	Starting roughness	Final roughness
E	0,07 0,08 0,08	0,19 0,14 0,16
1	0,10 0,08 0,08	0,29 0,32 0,30
2	0,09 0,10 0,11	0,37 0,40 0,32
3	0,10 0,12 0,10	0,36 0,40 0,32
4	0,09 0,10 0,09	0,30 0,28 0,30
5	0,09 0,09 0,10	0,29 0,30 0,30

In professional literature as a criterion for evaluation of resistance of materials against abrasive wear (abrasive effect of particles) shows the equation:

$$\psi_a = \frac{W_{he}}{W_{hrz}} \cdot \frac{\gamma_{rz}}{\gamma_e},$$

W_{he}, W_{hrz} – weight loss of standard, respectively tested material (kg);

γ_e, γ_{rz} – measurement weight of standard, respectively tested material (kg/m^3).

After the calculations, it was concluded that the samples of steel 13 240 after 10 000 speeds for this interval meet the conditions. The total evaluation can be summarized into order specified in Tab. 7

Table 7

Order of samples

Sample	1	2	3	4	5
Order	IV.	I.	III.	V	II.

3. Discussion

Resistance to the wear is not an inner characteristic of material, such as some of its mechanical or physical characteristics that may significantly affect the wear resistance. Resistance of wear depends on the friction pair, environment and conditions in which the interaction process is done. When comparing the two materials with identical conditions and number of speeds in the test equipment were obtain objective results of the process of wear. It is important to realize that his influence here has a chemical composition of the material and its hardness. Hardness has a decisive influence at work in the conditions of forming in area of powder metallurgy. In the work of Moravec, J. 1999, there was shown that the hardness of some active parts in spite of its importance is not always decisive, but it is necessary to choose a softer material and best below 40 HRC. In addition to the parameters evaluated is desirable to complete the tests determined the temperature of the sample to achieve a comprehensive overview. The present study was approached with the hypothesis that in cycle 10 000 speeds tested material 13 240 can be compared to steel 19436. This hypothesis was confirmed and results of tests turned out positive. There are difficulty areas for identified the material suitable for the problem because to the process enters a large number of variable parameters for every product.

The conclusions drawn in research trials are difficult to generalize, but it should be borne in mind that what applies to an interval may not be suitable for another, though related. Tested steel 13 240 have been proven in the production of such material for pipes and spines showed that under certain conditions may be an alternative to the PM industry also for active parts of forming tools. Objective results of operation can be achieved only when running tests.

4. Conclusion

Each test has its limitations, thus it has bounded technical purpose and prognostic value. The biggest problem of tribological tests is interpretation of their results into practice.

It is desirable that the mentioned contribution served along with real output obtained in experimental works for the needs of practice and allow the solution to replace expensive material used in some selected cases. The economic criterion and comparison of solutions in the financial statements show the suitability of the suggested materials and solutions in terms of PM.

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