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EFFECT OF CARBON CONTENT IN STAINLESS STEELS ON QUANTITY OF GRINDING ENERGY

ABSTRACT

The paper presents a study of the process of grinding stainless steels with different carbon contents. Verified the size and scope of the energy which is introduced in the surface layers for different types of abrasive grains and binders. The influence of parameters in plunge grinding process was considered in studies. The energy ratio was used for this purpose, which was calculated by multiplying energy and time of grinding wheel contact with the workpiece. To investigate influence of different carbon content on the level of energy density generated during grinding process special parameter B_p have been evaluated. The grinding tests were conducted in dry grinding technique.

Key words: grinding, stainless steel

INTRODUCTION

Stainless steel products are manufactured in countless variations and requirements. They are applicable in wide areas and domains of life. Regardless of the version and destination, these devices have a common property, are made from expensive materials, which include the different varieties of stainless steel. In fact, these are mainly steels with specified participation of chromium and nickel, their rustproof provides the chromium content of 12%, growth of this component increases its resistance to state aggressiveness in particular chemical environments. The chromium content determines the structure. Today there are many types of steel, from ferritic steels (17% Cr) to martensitic steels (up to 20% Cr). Figure 1 shows the classification of stainless steels depending on the share of individual elements, not taken into account the consideration of precipitation hardened steels

Each of the groups presented in Figure 1 includes appropriate combinations of alloying components deciding on their use and purpose in certain areas, depending on the technological requirements.

An important component determining rustproof is also carbon which tends to form carbides. Two types of stainless steel with extreme carbon content were selected for testing. From the first group of the used steel X42Cr13, possible for the heat treatment, the carbon content is on the level of 0,42%. The other stainless steel is 1H18N9T with carbon content of 0.10% (chemical composition was analyzed with the quantometer ARL-360).

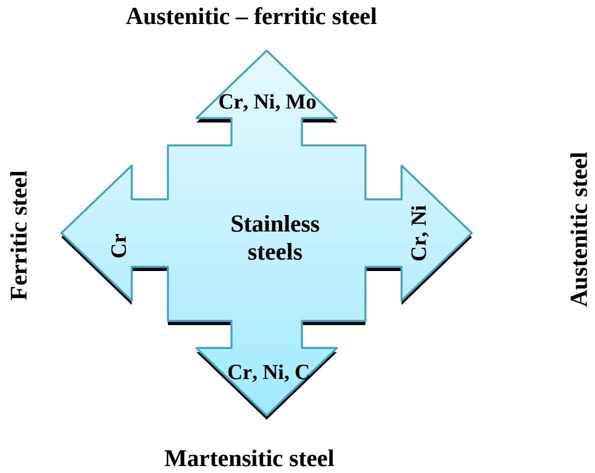

Fig. 1. Stainless steels classification depending on the chemical composition

Using the processes of quenching and tempering in the first case (X42Cr13) may be obtained the relevant properties of the surface layer, which increases the resistance to fatigue failures.

The decrease in carbon content creates a structure resistant to chemically aggressive environments. Plunge grinding process was performed on flat samples in one pass. In real terms grinding without cutting fluid should be avoided. However, the aim was to determine the maximum value of energy flux during the grinding process of steel. Liquid cooling - lubricating share reduce the fraction of energy flux, what does not mean that the problem of damage of surface layer does not exist.

Efforts to conduct research for a broad group of abrasives, included new materials solutions of grinding wheels that have arisen as a result of research over time. Selected abrasives and their parameters are shown in Table 1.

***Table 1.** Characteristics of grinding wheels*

Abrasive	Grain and hardness	Binder	Designation in the development
38A	60 J	VBE	38A/J
25A	80 G	VBEP	25A/G
3XGP	54K	VX	3XG/K
3TGP	54K	VY	3TG/K
1TGP	46G	VX	1TG/G
3SG	60K	VS	3SG/K

As is well known that temperature generated during grinding process has great influence on material properties of final product. The temperature is directly connected with power density, which can be easily evaluated by means of dynamometers or power measuring equipment [13]. To have opportunity to compare results concerning power generation for different types of stainless steels, parameter B_p has been used. The B_p parameter is a product of the power density P' and grinding wheel/workpiece contact time t_c (1).

$$B_p = P' \cdot t_c \tag{1}$$

For obtaining power density P’ (2) tangential component force F_t have been measured during the grinding tests. Others parameters such as grinding wheel speed, grinding width can be easily calculated.

$$P' = \frac{F_t v_s}{b_D \cdot l_e} \tag{2}$$

Time of contact between grinding wheel and work material can be calculated from formula (3).

$$t_c = \frac{l_e}{v_w} \tag{3}$$

After putting into formula (1) formulas (2) and (3) equation for indicator B_p is as follows.

$$B_p = \frac{F_t v_s}{b_D \cdot l_e} \cdot \frac{l_e}{v_w} \tag{4}$$

Finally indicator B_p for grinding flat surface is represented as formula (5)

$$B_p = \frac{F_t \cdot v_s}{b_D \cdot v_w} \qquad \left[\frac{W \cdot s}{mm^2}\right] \tag{5}$$

where:
F_t- tangential force component [N],
v_s- grinding wheel speed [m/s],
b_D- grinding width [mm],
v_w- workpiece speed [m/s],
l_e –geometric length of the grinding wheel contact with the material.

GRINDING PROCESS PARAMETERS

The testing samples were flat, made in two dimensions 100x40x10 mm and 100x40x4 mm. Samples thickness (40 mm) assured resistance to thermal deformation (second variant was used to further study on the distribution of internal stresses). Chemical composition of examined stainless steels are given in Table 2.

Table.2. *Chemical composition of examined stainless steels, wt.%*

Designation	C	Si	Mn	P	S	Cr	Ni	Ti
X42Cr13	0.38-0.45	03-0.5	0.2-0.4	0,03	0.03	12-14	8.0	--
1H18N9T	max.0.10	0.8	2.0	0.04	0.03	17-19	8.0-10	0.8

Tests performed on flat samples due to material costs, using plunge grinding in one pass on the grinder SPD-30 with the parameters range shown in Fig. 2, which only shows grinding wheels designations and process parameters.

For measuring the grinding force components the dynamometer 9272 was used, where samples holder was installed. The signal from dynamometer was sent to the amplifier 5011A and the card DAS 1602, which was placed in the PC. The station, together with the software was described in articles [11, 12].

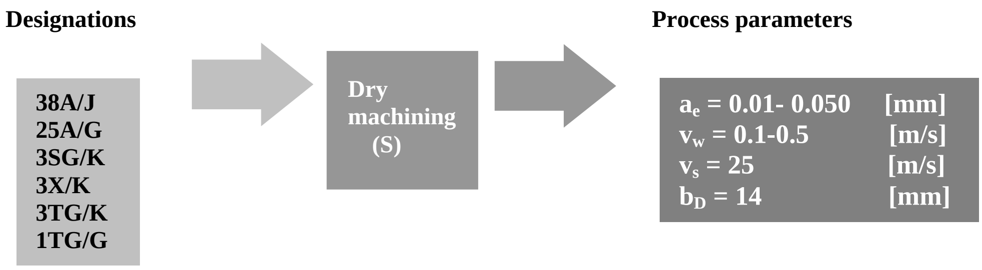

Fig. 2. Summary of designations and parameters of the grinding process

RESULTS

Research evaluation allowed to determine the effect of process parameters on grinding indicator B_p giving the response about state of the energy of grinding process (energy flux density). Only selected results are presented due to the broad spectrum of research.

As a result of high energy generated during grinding process structural changes may appear. This phenomena might cause dimensional differences in accordance to parameters which have been set on the grinder machine. The actual depth of cut was checked on the profilometer. Measurement of spatial 3D topography implemented using profilograph Hommel TurboWaveline60.

Device allows to visualize roughness and waviness of the surface layer in the form of topography maps. The measurement was carried out in following way: entire sample surface was levelled then the grinding wheel was shifted in order to create a datum in respect of which the actual depth of cut was referred (Fig. 3, for example).

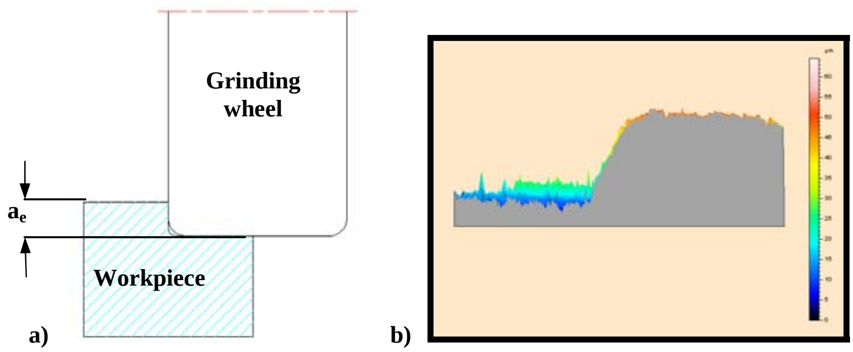

Fig. 3. Method of checking actual depth of grinding: a) scheme, b) result

Figure 4 shows the distribution of points from different range of the parameter v_w, chosen equations describe the distribution of the results of research. Tests for individual points were repeated three times.

The increase in work piece speed and depth of cut determines energy state. The highest values of energy generated during grinding process have been observed for v_w=0.1 m/s. At that time the most of energy is generated and the greatest damages of surface layer have been observed. This results in material tempering, structural changes and many other negative consequences in case of 0.05 mm allowance. All surface layer damages are catastrophic for further operating.

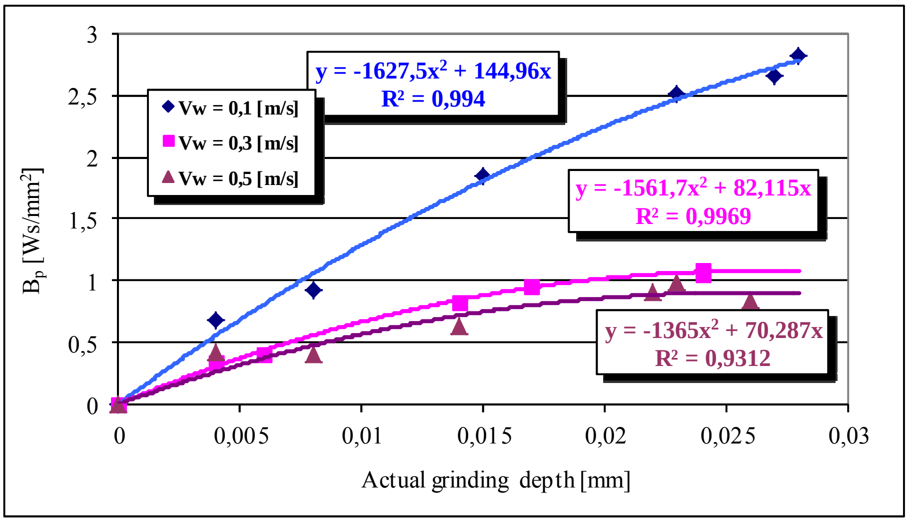

Fig. 4. Influence of grinding process parameters a_r, v_w on the value of indicator B_p

Also presented a graph showing the influence of the parameters, the grinding subject speed and adjustable allowance. Both values in a large extent decide on indicator value B_p - the energy state of the process. This is important for the state of the surface layer in the case of the heat-treated materials as well as the materials with a low carbon content that are not subject to heat treatment. This concerns burns that cover the entire range from streak to continuous burns, also obtained secondary recrystallization and other forms of the surface changes.

In case of stainless steel with a low carbon content, any surface layer damage determine susceptibility to intergranular corrosion in particular for the grinding process which is technologically final operation.

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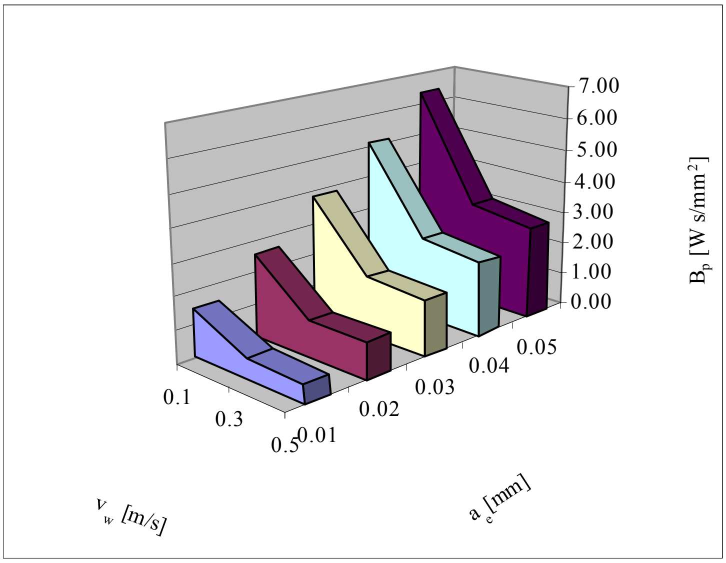

Fig. 5. Influence of grinding process parameters a_r, v_w on the value of indicator B_p

Later in this article in Figure 6 presented the shares of energy flux density generated by the particular grinding wheels during tests of steel X42Cr13, heat treated to a hardness of 56 HRC. In all examined cases involving individual grinding wheels with the same grinding process parameters, tests were performed without the participation of fluids, such steps have been taken deliberately to determine the flux density level. Under normal conditions of grinding process cooling fluids are used to reduce heat load in surface layer.

Presented speed ranges of the object v_w minimum 0.1 m/s and maximum 0.5 m/s. In terms of energy studied areas can be divided into two zones. The first range 5.39 – 4.8 W s/mm^2 concerns maximum allowance a_e=0.05 mm and v_w=0.1 m/s. Then, the contact time with surface layer is much longer, which results in greater thermal load in surface.

These are conventional grinding wheels made 25A/G of precious aloxite Al_2O_3, 38A/J and chromium aloxite 25A/G. The highest energy flux obtained for the microcorundum grinding wheel SG/K. In the second area were grinding wheels from XG and TG groups, they are characterized by a specific grain structure in the form of rods with ratio of 1:8 in diameter to length. Table 3 summarizes the results obtained during tests, specified surface layer damages.

Table 3. *Summary of the energy flux grinding process*

Grinding wheel		Steel	B_p [W s/mm^2]	Steel	B_p [W s/mm^2]
Area „I”	3SG/K	X42Cr13	4.98	1H18N9T	11.3
	25A/G		4.12		7.65
	38A/J		3.84		8.23
Area „II”	3XG/K		2.86		4.12
	3TG/K		2.21		3.75
	1TG/G		1.32		2.04

In Figures 6 to 7 results concerning application of different types of grinding wheels obtained for two types of stainless steels are presented. In all cases, the grinding wheels from XGP and TGP groups depending on the tools hardness obtained three times less impact energy compared to conventional grinding wheels. The smallest value of energy flux obtained during the grinding process using 1TG/G grinding wheel, here in both cases studied steels with the same process parameters, the ratio B_p was about six times lower, in none of these cases did not observe any damage to the surface layer. The only problem occurred called "pouring out the wheel", which accelerate self-sharpening.

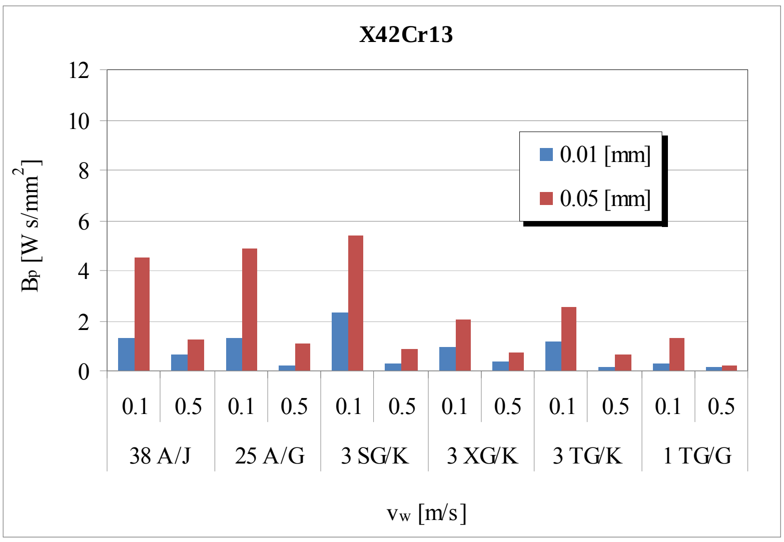

Fig. 6. Energy state level in the process of dry grinding of steel X42Cr13

Completed studies show that the structure of the grain within the meaning of shape is crucial for energy flux in plunge grinding. New generations of grains interact much more advantageous for the final condition of surface layer, this applies to both stainless steel with a high degree of carbon saturation and when the carbon saturation is several times smaller. In the latter case it is crucial for the formation of intergranular corrosion.

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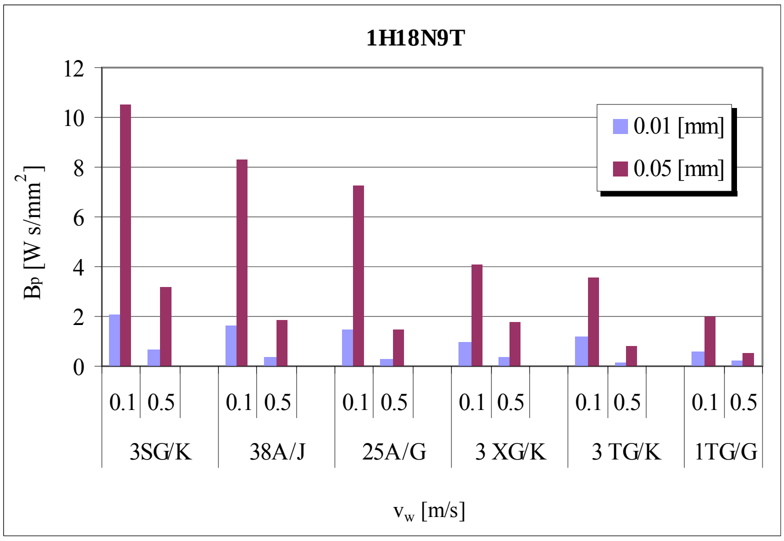

Fig. 7. Energy state level in the process of dry grinding of steel 1H18N9T

CONCLUSIONS

Research of specific stainless steels indicate that in case of increase of the carbon content the energy effect of plunge grinding process takes place at a lower level. Temper causes the surface layer requires less energy flux compared to steels with lower carbon content which nevertheless results in tempering, changes in microhardness and grinding burn.

However, if the grinding process of steel with carbon content at level of 0.10% at temperatures above 500°C occurs release of carbon excess in the form of network system on the austenite grain boundaries. This phenomenon affects the formation of intergranular corrosion. This is due to the fact that the diffusion rate of carbon is greater than the diffusion rate of chromium

Carbon is required for the precipitation of carbide is trapped at the grain area, while chromium only from areas that adhere to the grain boundaries. Accordingly, near the grain austenite matrix becomes depleted in chromium. As a result of this process, border areas are becoming not resistant to corrosion. Inclinations of steel to intergranular corrosion is dependent on the carbon concentration in the matrix, the temperature and time of sensitization.

During the grinding process of steel 1H18N9T (0.10% C) noticed differences in the density distribution of energy resulting from the percentage of carbon. However, not for all tested grinding wheels this is clear. Energy ranges for each wheel and materials vary. For the same grinding wheels and grinding parameters process was at much higher energy ranges than with higher percentage of carbon. In the case of stainless steel grinding parameters v_s = 25 m/s,

v_w = 0.1 m/s, and a_e = 0.05 mm was obtained damage in surface layer at depth of 0.08 mm, this is four times less than the depth of the structural alloy steel or tool steel.

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