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THE INFLUENCE OF THE CARBON CONTENT ON THE MACHINABILITY OF SINTERED VALVE PLATES

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The quality of processedsinteredvalveplatesdepends on variousfactorsderiving both from thecharacteristics ofthe rawmaterial and the grinding process.The change of valve plate's materialis defined based on the requirementsto reducethe priceofthe inputmaterial.This paperexamines the impact of the carbon content on themachinability ofsinteredvalve plates.
In evaluation the highest level of attention has been given to parameters critical to quality (CTQ - critical to quality), and that using the Minitab statistic tools.

Key words: sintering, carbon, hardness, pearlite, ferrite

INTRODUCTION

According to the customer requirements for the lower price of household compressors it has been established that sintered valve plates (Figure 1) with lower carbon content would be 20 % cheaper than the current price: 0,45 instead of 0,54 € per product.

The existing variant of the valve plate is made of sintered material, a pearlitic structure,with the carbon content ≥ 1,2 %. The required carbon content after the change should be at ≥ 0,8 %. It is necessary to determine if the change in the composition will have any influence on the machinability of materials and consequently on the quality of the final product, and to what extent.

The surface flatness of a valve plate has been taken as the decision criterion. The supporting parameters are the material structure and the surface wear degree after a 4000-hour wear test. Both supporting parameters shall be treated visually.

EXPERIMENTAL PROCEDURE

Sintering is a thermal treatment of products after pressing previously prepared powder mixtures. Due to the complexity of the powder preparation, its impact will not be considered in this paper [1].

The choice of optimal time and temperature selection is performed by the method of experimentation *("try and repair")*. The experiments are repeated so many times until product does not obtain the required properties [2].

Additional mechanical treatment of the product is often necessary after the sintering.In the case of valve plates there are sometimes remains of sinter, and that in the suction or the discharge hole (Figure 2).

In the case of visual remains, they can be removed by brushing, which is done by the supplier of raw material. It sometimes happens that the remains in the mass

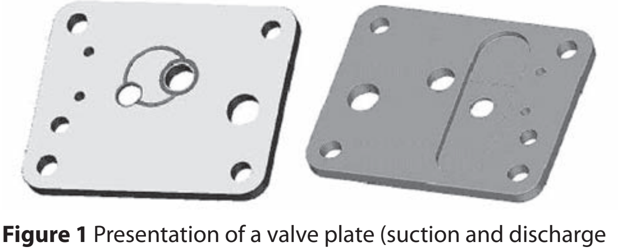

Figure 1 Presentation of a valve plate (suction and discharge side)

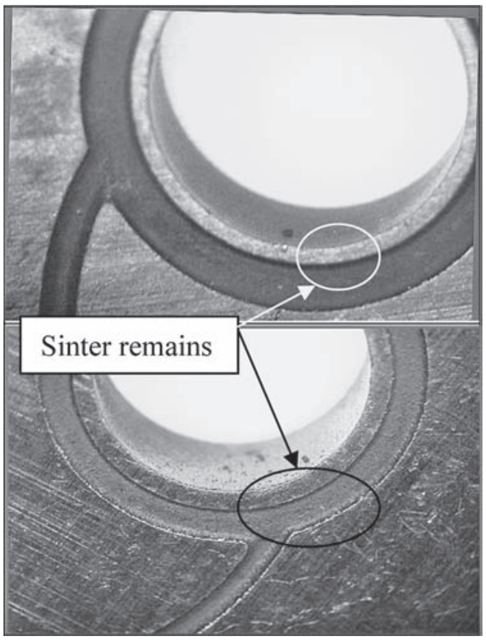

Figure 2 Sinter remains after sintering

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production are less visible and cannot be removed using the valve plate processing procedures (grinding, brushing, washing). This can result in the compressor wear, cracking of valves etc.

A badly processed valve plate surface has a similar effect, primarily due to the burr which is a result of grinding.The preliminary research has shown that the frequency of the occurrence of the sintering residues does not depend on the changes in the carbon content.

Based on the specification requirements regarding the reduction of the carbon content (Table 1) [3], we find that there is a change in material - from hypereutectic to eutectic steel [4].

Table 1 **Sinter valve plate specification**

Material	/ mas. %C	≥0,8	≥1,2
	/ mas. %Cu	≥2	≥2
Density	/ g/cm^3	6,7	6,7
Structure	Perlite	yes	yes
	Ferrite / %	≤10	≤10
Hardness	Seat /HV	≥200	≥200
Hardness	Surface / HB	≥175	≥175

Purchasing, technology and development departments are trying to determine a valve plate structure with the lowest possible carbon content. The analyses have been made on the plates with 0, 0,8 and 1,2 %C and it has been found out that the plates with 0 %C included bad machinability (flatness of the valve surface after the final grinding).

In order to demonstrate the influence of the carbon content on the valve plate machinability we have made tests using the same diamond grinding wheels on different samples, and that on the valve plates with 0,0, 0,8 and 1,2 %C (Figure 3).

Figure 3 shows that the highest dispersion of flatness is at 0 %C. Therefore, further analyses with this sample have been neglected.

Thus, in the continuation we have tried to find such structure which would satisfy the requirements both for the ferrite content and the product machinability (plate with ≥ 0,8 and ≥ 1,2 %C).

We have measured only the characteristics defined by the standard [1].With the input material (blank) we measure the hardness both on the seat as well as on the entire surface of the valve plate, the content of individual key elements (C and Cu), the density, and we investigate the structure of the material.

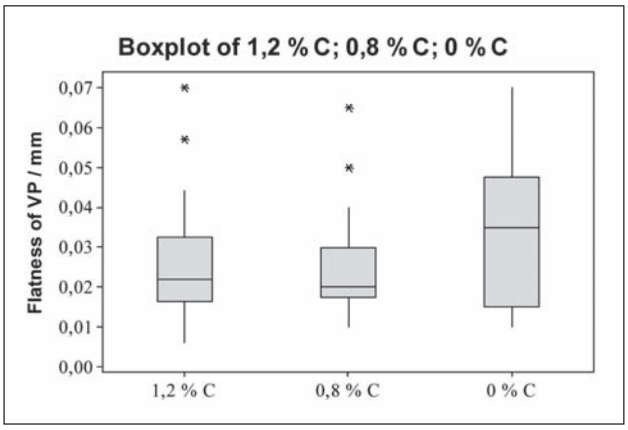

Figure 3 Comparison of the flatness of valve plates with various carbon contents

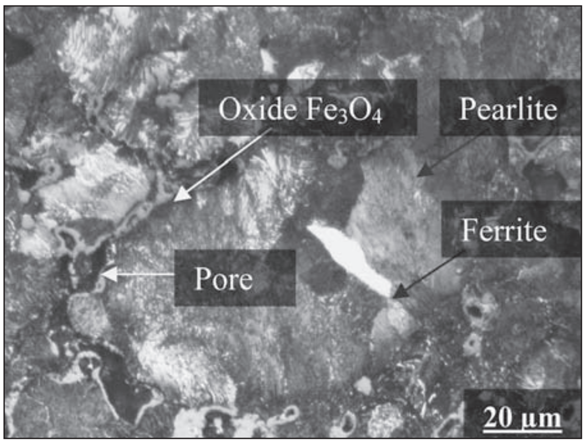

Figure 4 Valve plate material structure

The structure is determined so that the ferrite content is visually estimated, and that using a microscopic image. If the ferrite content is under 10 % of the total area (Figure 4), the structure meets the standard requirements.

At the carbon content higher than 0,8 % we are in the area of pearlitic structure with additions of secondary cementite, which is a disadvantageous microstructure mainly due to the increased hardness and brittleness of the material [5].

RESULTS

The analyses of the material structure of our samples have shown that the plates with ≥ 0,8 %C are comparable to the plates with ≥ 1,2 %C in the ferrite content (Figure 5 a,b).

It is evident from the Figure 5a that with the sintered material (with more than 1,2 %C) we also find Fe_3C at the boundaries of crystal grains, the quantity of which is not specified by the existing standards. Cementite largely worsens the machinability of the product, but this depends on the amount of carbon in the cementite form (higher content of C worsen the material machinability) [6].

The hardness of products in both structures varies by approximately 20 HV (higher values at higher carbon content) and meets the standard.

All of the above mentioned considerations provide a starting point for the optimal design of a valve plate processing procedure.

In order to check the process itself a comparison between the populations of 0,8 and 1,2 %C has been made in the form of a double *t*-test and an analysis of variance.In the double *t*-test the null and an alternative hypothesis on the equality of the mean values of the valve plate flatness have been set:

H_0: μ (1,2 %) - μ (0,8 %) = 0,

H_1: μ (1,2 %) - μ (0,8 %) ≠ 0.

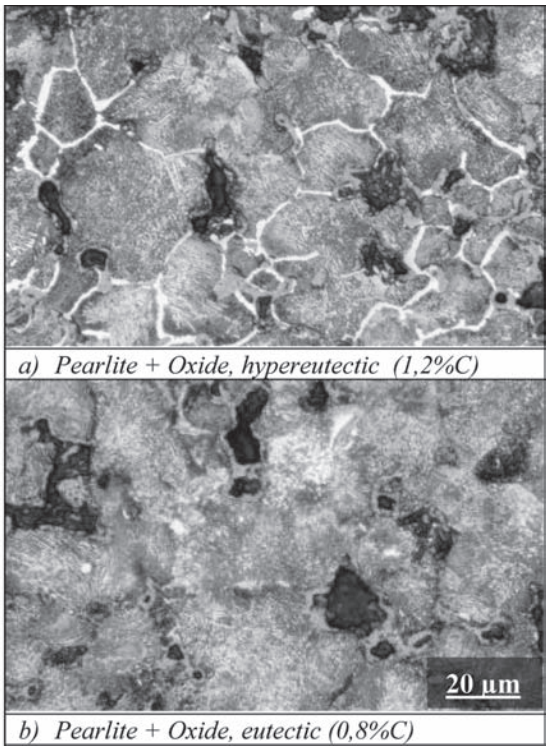

Figure 5 Comparison of the structures of plates with different carbon content [4]

The normality test has shown that the data is not normally distributed. Therefore, we have used Leven´s test statistics in the analysis. The value of the test statistics ($p = 0,986$) shows that there is no significant difference in the mean values between the populations. We have also made an analysis of variance. The null hypothesis (H_0) here sets the condition of the equality in variances, the alternative hypothesis (H_1), however, presents the case in which the variance of the population with 0,8 %C is higher than the one of the population with 1,2 %C.

$$H_0: \frac{Var(0{,}8\,\%)}{Var(1{,}2\,\%)} = 1$$

$$H_1: \frac{Var(0{,}8\,\%)}{Var(1{,}2\,\%)} \neq 1.$$

According to the value of Leven´s test statistics ($p=0,633$) we can claim with 95% of confidence that the populations are equal. For the final confirmation of the change a 4 000-hour life test for compressors has been made. The standard life test usually takes 168 hours, depending on the type of compressors.

The test has been performed under the pressure that corresponds to the temperatures of -3 °C on the suction side and of 73 °C on the discharge side. Since in this case the refrigerant R134a has been used the pressure corresponds to p_{ses}= 2,45 bar and p_{tl}= 21,35 bar [7].

There are no measurable variables in this test. Therefore, we have made a visual inspection both of the total surface of the valve plate and the surface of the valve seat (Figure 6).

The figure shows that the populations are not significantly different. The smallest visible differences may be a result of the valve plate grinding process,

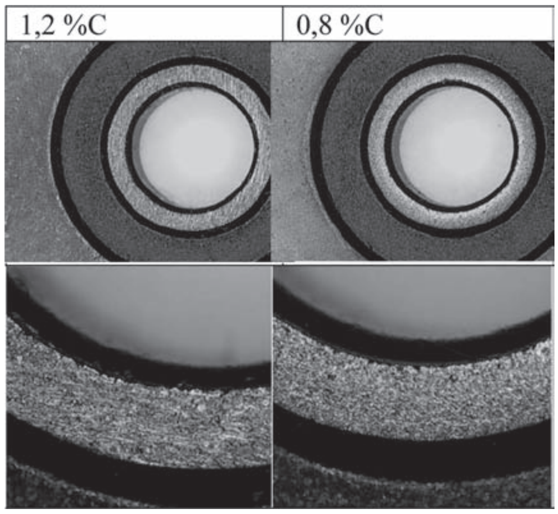

Figure 6 Presentation of the valve plate seat and the surface after the 4000-hour compressor life test

which can be seen in the surface roughness measured before assembling the valve plate into the compressor.

CONCLUSIONS

Based on the previous analyses, it has been established that the carbon content can be reduced from 1,2 to 0,8 %. With this change the raw material characteristics, the valve plate machinability and the characteristics of the final compressor remain unchanged.

These facts have been demonstrated in the following researches:

1. The visual inspection of the carbon content and the ferrite structures,
2. The analysis of variance and the double *t*-test for the flatness of the valve surface and
3. The visual inspection of the valve surface after the 4000-hour life test.

We have used blanks in the analysis, which showed no irregularities: dimensional deviations, impurities in the suction and the discharge hole, etc. Any irregularity would have changed the results of the research.

REFERENCES

[1] P. Besta, A. Samolejová, K. Janovská, M. Lampa, R. Lenort, Metalurgija, 51 (2012) 4, 457-460.

[2] M. Gostimirović, P. Kovač, D. Ješić, B. Škorić, B. Savković, Metalurgija, 51 (2012) 1, 105-108.

[3] Danfoss Standard 102R1026, "Sinter iron specification", Nordborg (2003).

[4] R. Hein, "Danfoss Untersuchungsbericht 04-0257-bilag", Danfoss Flensburg, 2004

[5] G. Kosec, A. Nagode, I. Budak, A. Antić, B. Kosec, Engineering Failure Analysis, 18 (2011) 1, 450-454.

[6] D. Klobčar, B. Kosec, L. Kosec, J. Tušek, Engineering Failure Analysis, 19 (2012) 1, 43-53.

[7] D. Nadarević, Optimization model for fine machining, PhD. Thesis in accomplishing, FS, University of Ljubljana, Ljubljana, 2013.

Note: The responsible translator for English language is Urška Letonja Grgeta, MOAR translating, Podgora, Slovenia