ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
Tome XIV [2016] – Fascicule 2 [May]
ISSN: 1584-2665 [print; online]
ISSN: 1584-2673 [CD-Rom; online]
a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara

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THE INFLUENCE OF MECHANICAL ALLOYING DURATION ON SELECTED PROPERTIES OF SINTERED DISTALOY SE SAMPLES

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ABSTACT: The iron alloy powder – Distaloy SE was used for the investigations. The following series of samples were studied: pure Distaloy SE (reference sample), Distaloy SE infiltrated with Cu, Distaloy SE after mechanical alloying with subsequent infiltration, Distaloy SE with the addition of 10% wt. Cu treated by mechanical alloying. The compacts were produced using two compaction pressures - 300MPa and 500MPa. The compacts were sintered under a pure dry hydrogen atmosphere at 1120°C for 45min. The heating and cooling rates were the same for all cases. The time of mechanical alloying used for investigation was 60 min. The infiltration was carried out under a pure dry hydrogen atmosphere at 1120°C for 15min with 10K/min heating and cooling rates. This paper presents the results of mechanical alloying duration and infiltration on the selected properties of sinters. The range of the research included measurements of green compacts density, sintered density, hardness as well as tribological tests (friction coefficient measurements, weight loss measurements and wear trace observations).
Keywords: distaloy SE, mechanical alloying, infiltration, powder metallurgy

1 INTRODUCTION

Powder Metallurgy (PM) is a highly developed method of manufacturing reliable ferrous and non-ferrous parts from powders that allows on elimination of the liquid phase throughout manufacturing process. PM has become widely recognized as a superior way of producing high-quality components for a variety of important applications [1]. Modern powder metallurgy technology commenced in the 1920s with the production of tungsten carbides and the mass production of porous bronze bushes for bearings. Further development of PM took place during the Second World War, which was caused by the production of a great variety of ferrous and nonferrous materials, including many composites [2]. PM technology is a cost-effective method for high-volume production of small elements with simple shapes and full-density compacts. Powder metallurgy allows to obtain homogeneous microstructure of products that are free of non-metallic inclusions and defects [1÷3]. PM is clearly superior to other technologies, especially if the degree of utilization of raw materials and level of energy requirements are taken into account [1,2,4,5].

This paper presents the results of mechanical alloying duration and infiltration on the selected properties of sinters.

2 MATERIAL AND METHODOLOGY

The iron alloy powder - Distaloy SE provided by Höganäs was used for the investigations. Distaloy SE is based on the sponge iron grade SC100.26 to which 4%Ni, 1.5%Cu and 0.5%Mo have been diffusion-bonded. The investigated powder has high green-strength. Additionally, Distaloy SE powder after mixing with appropriate amounts of graphite achieves high strength after sintering and responds very well to subsequent heat-treatment. Copper in the form of elemental powder (manufactured by the electrolysis, dendritic particle shape, purity of 99.9%) was used. The following series of samples were prepared:

- Pure Distaloy SE - reference sample (sample name for 300MPa compaction pressure: D300 and for 500MPa: D500),
- Distaloy SE infiltrated with Cu (sample name for 300MPa compaction pressure: D300_Inf and for 500MPa: D500_Inf),
- Distaloy SE after mechanical alloying with subsequent infiltration (sample name for 300MPa compaction pressure: D300_MA_Inf and for 500MPa: D500_MA_Inf),
- Distaloy SE with the addition of 10% wt. Cu treated by mechanical alloying (sample name for 300MPa compaction pressure: D300_10%Cu_MA and for 500MPa: D500_10%Cu_MA).

The powder mixtures were uniaxially pressed in steel dies at 300MPa and 500MPa compaction pressure to obtain cylindrical samples of 25mm diameter and 6mm height. The sintering process of all compacts was carried out in a laboratory tube furnace under a pure dry hydrogen atmosphere at 1120°C for 45min. The heating and cooling rates were the same for all cases. The time of mechanical alloying used for investigation was 60min. The infiltration was carried out under a pure (99.9992%) and dry (dew point below –60°C) hydrogen atmosphere at 1120°C for 15min with 10K/min heating and cooling rates. The densities of the green and sintered compacts were determined from the mass and the dimension measurements of the samples. The theoretical density (TD) was calculated using the simplified additive function, applying the formula [6]:

$$TD = \frac{100}{\left(\frac{P_1}{D_1} + \frac{P_2}{D_2} + \cdots + \frac{P_x}{D_x}\right)} \quad (1)$$

where the TD is Theoretical Density, P_x is mass percentage of respective elements, D_x is density of the respective ingredients in elementary form.

Additionally, the densification factor for all sintered specimens was defined, using the formula [6]:

$$DF = \frac{S_d - G_d}{T_d - G_d} \quad (2)$$

where DF is densification factor, S_d is sintered density, G_d is green density, and T_d is theoretical density.

The tribological tests included: determination of the friction coefficients as a function of the sliding distance, the weight loss measurement and wear trace observations. In order to determine the friction coefficients the tribotester T-01 was used. Steel ball of 6mm diameter (made of bearing steel ŁH15 with hardness 60HRC) was a counter body for samples. The measurements were performed under dry friction over a 500m distance for the following parameters: load of 10N, the linear velocity of 0.2m/s (speed 255rpm).

The hardness was measured with use of a hardness tester INNOVATEST CV-600 MBDL.

3 RESULTS

3.1. Density

Figures 1 and 2 show the results of green and sintered density measurements. It is evident that green density increases with compaction pressure for all cases. However, for the same compaction pressure the green density is different, due to differences in manufacturing process of samples.

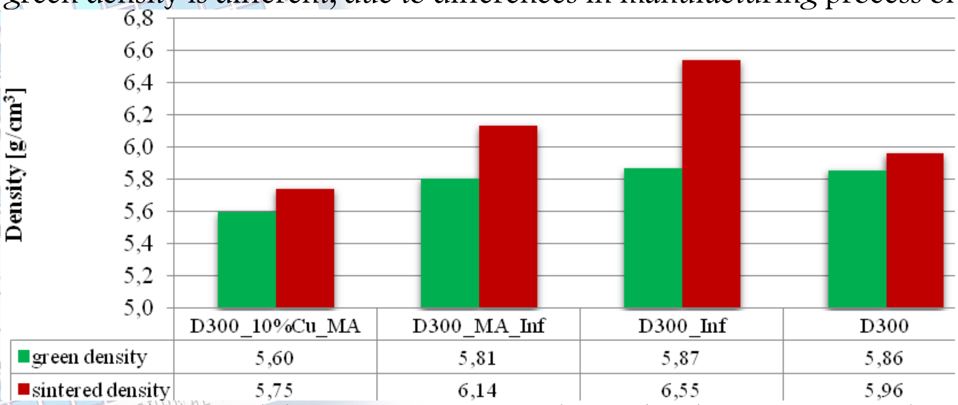
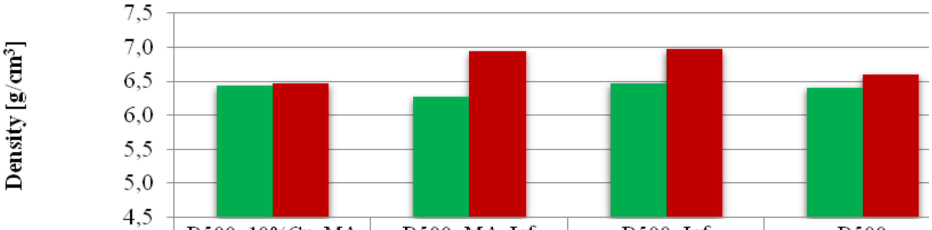


Figure 1: Green and sintered density of investigated samples that were pressed at 300MPa

The highest compaction degrees were obtained for two samples that were pressed at 500MPa compaction pressure: the sample infiltrated with Cu and sample made of Distaloy SE after mechanical alloying with subsequent infiltration. The slight difference in values for these samples indicates that the application of mechanical alloying in this case is irrelevant. However, in the comparison to the samples that were pressed at 300MPa it can be observed that higher value of density was obtained for sample with no mechanical alloying. That may be due to surface oxidation during the mechanical alloying or due to improper selection of the mechanical alloying parameters. The lowest density value was obtained for a sample made of unmodified Distaloy SE powder compressed at 300MPa. It shows, how important proper selection of compaction pressure is. It can be observed that the sintered density of samples made of powder with 10%wt. copper addition has not reached a satisfactory value for both used compaction pressures. It is caused by too high content of copper, which in turn results in secondary porosity.



	D500_10%Cu_MA	D500_MA_Inf	D500_Inf	D500
green density	6,43	6,27	6,47	6,41
sintered density	6,47	6,94	6,97	6,60

Figure 2: Green and sintered density of investigated samples that were pressed at 500MPa

Figure 3 presents the ratio of sintered density to theoretical density for all samples as a function of different compaction pressures. It clearly shows that the density of the D500_MA_Inf and D500_Inf samples are closest to the theoretical value. The densification factor for all samples is presented in Figure 4. It is interesting to note that the values of the densification factor are lower for higher compaction pressure. A positive densification coefficient indicates shrinkage [6].

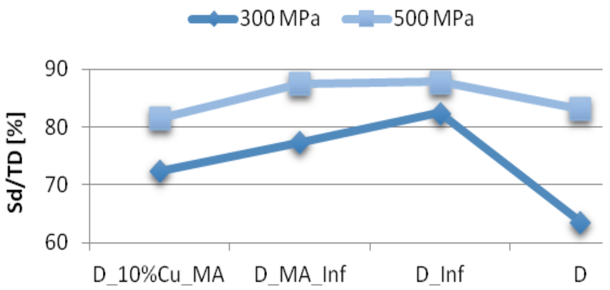


Figure 3: Sintered density to theoretical density ratio for all samples

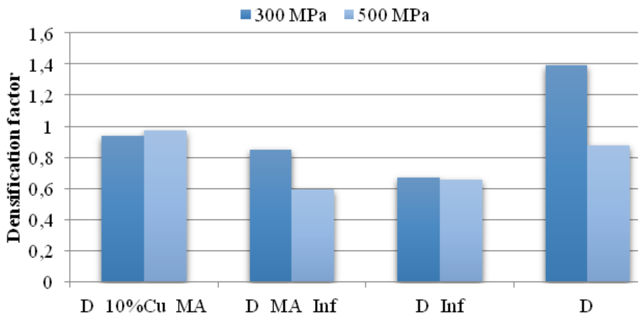


Figure 4: Densification factor for all samples

3.2.Hardness

Figure 5 shows the results of the Rockwell hardness measurements of studied materials. Red ranges show values of standard deviations which were calculated for all samples. These results confirm that the infiltration improves the densification as well as the hardness of the sintered Distaloy SE. As can be seen from this figure, the infiltration resulted in a significant increase in the hardness of the sintered samples.

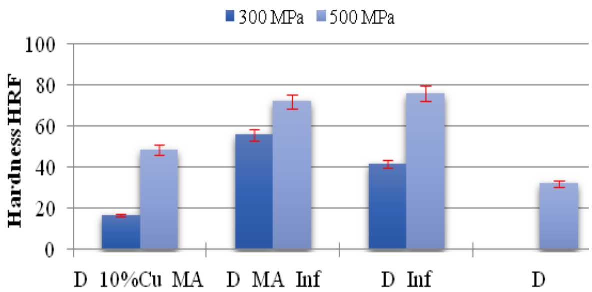


Figure 5: Hardness of investigated samples - value for sample D300 is below HRF scale

3.2. Tribological tests

On the basis of obtained results from tribotester, the curves illustrate changes in the friction coefficient as a function of sliding distance were created (Figure 6 and 7). The greatest impact on the abrasive curves character as well as on the friction coefficient have the material structure (including porosity), hardness and surface roughness. As can be seen, these curves have similar character - they are relatively smooth and have steady course. Samples that were unmodified are characterized by the highest friction coefficients. This is due to phenomena occurring at the border of contact surfaces of the sample and counterbody, for example: microcutting, scratching and ridging. The copper addition decreases the friction coefficient. The higher the copper content, the lower the friction coefficient is. Based on the obtained results it can be stated that mechanical alloying does not effect on the value of friction coefficient.

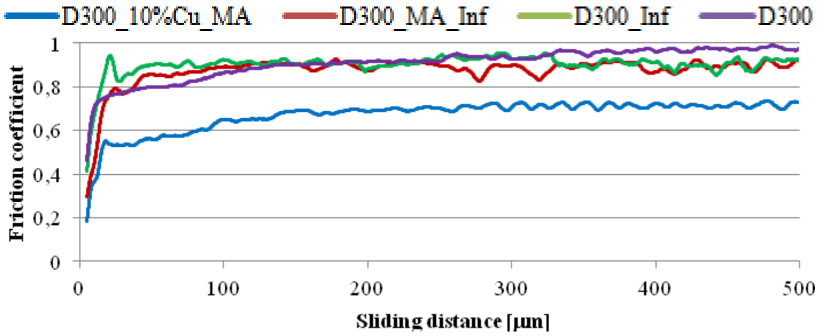


Figure 6: The curves illustrating changes in the friction coefficient as a function of sliding distance for samples pressed at 300MPa compressing pressure – average values

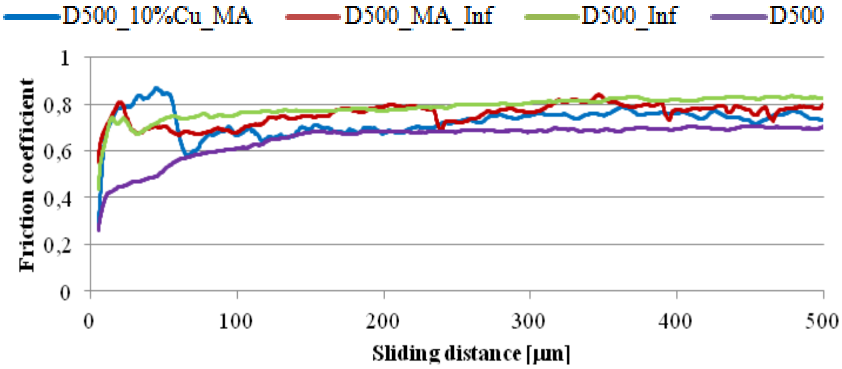


Figure 7: The curves illustrating changes in the friction coefficient as a function of sliding distance for samples pressed at 500MPa compressing pressure – average values

Abrasion resistance evaluation was also performed by observation of wear traces as well as their width measurements. Exemplary images of wear traces are presented on Figure 8. One of the methods for the abrasion resistance measurements is the determination of the weight loss of the sample after abrasion test. Figures 9 and 10 correspondingly show the measurement results of wear traces width and weight loss. Based on the obtained results of the tribological tests it can be stated that with increasing values of hardness the better tribological properties were obtained (the least weight loss and width of wear trace were obtained for the hardest material).

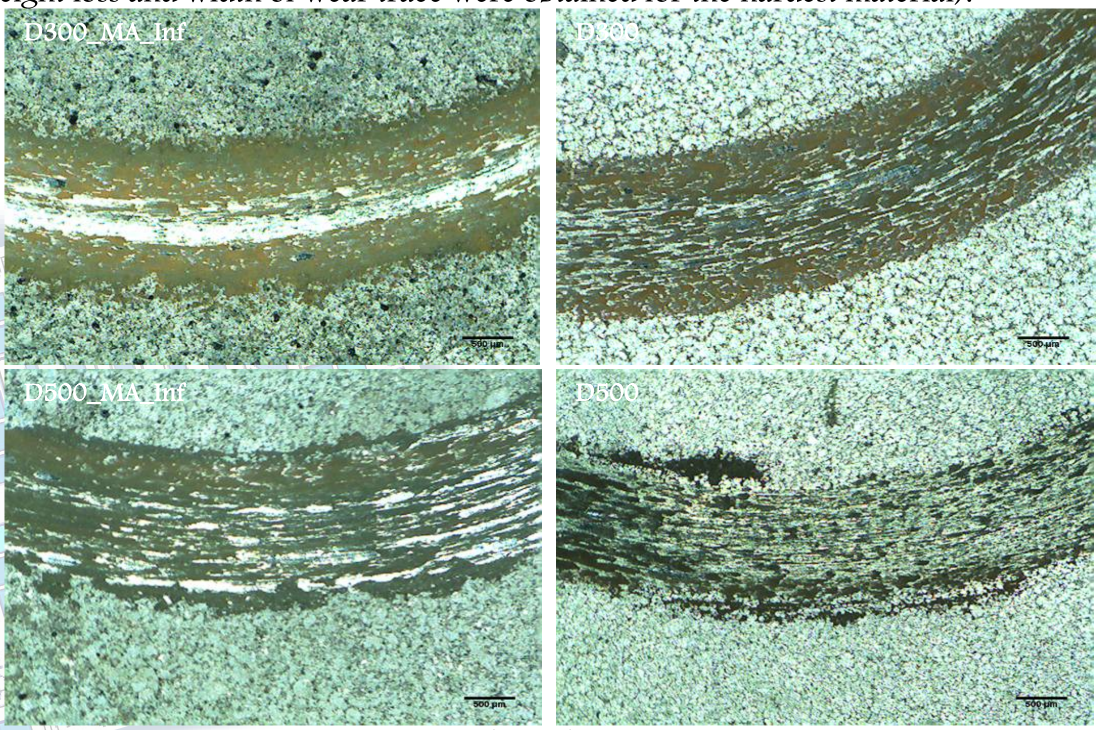


Figure 8: Exemplary photos of wear traces

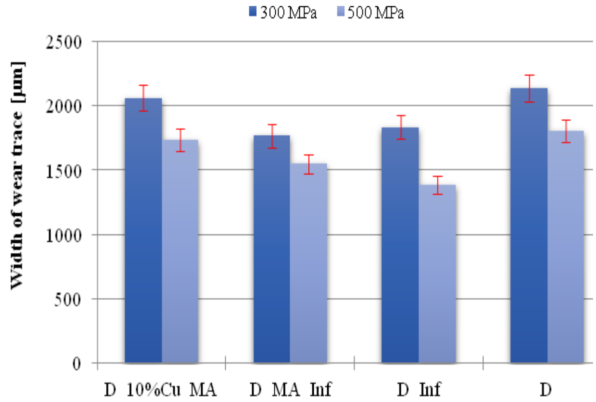


Figure 9: Average values of width wear trace for all samples

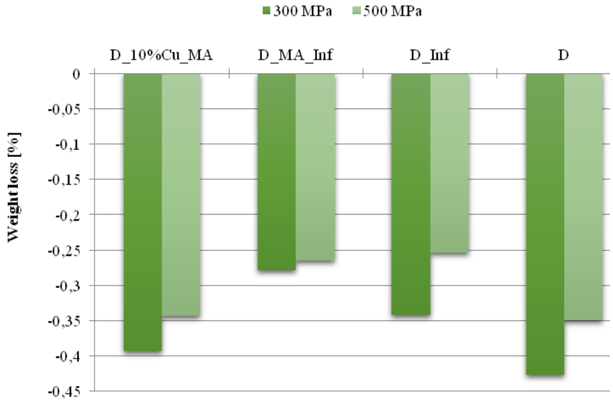


Figure 10: Weight loss for all samples

4 CONCLUSIONS

Based on all performed investigations the following can be stated:

» The sinter densities increase with increasing compaction pressure. Applying of infiltration also has great impact on densities of the sinters. Furthermore, the mechanical alloying of the powders can be an effective way to increase densities when compaction is carried out at low pressures.

» Excessive addition of copper in mechanical alloying powder leads to reduction of compactibility which in turn results in lower hardness and abrasion resistance.

» The increase of hardness and abrasion resistance can be obtained by increasing the compaction pressure and applying the infiltration with copper.

» Friction coefficient depends strongly on the compaction pressure as well as modification of the sinters. The higher the compression pressure, the lower the porosity is. This results in better surface quality and consequently in lower value of friction coefficient. Friction can be also reduced by applying the infiltration process. The mechanical alloying does not affect the friction coefficient.

NOTE: This paper is based on the paper presented at the 9th International Conference for Young Researchers and Phd Students - ERIN 2015, May 4-6, 2015, Monínec, Czech Republic, referred here as[7].

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