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METAL MATRIX COMPOSITES AS TOOLS MATERIAL FOR THE DEEP DRAWING

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ABSTRACT: In order to improve the strength and high-temperature properties of sintered iron, metal matrix iron- Alumina (Al_2O_3) composite material has been studied. In the present investigation, iron powder added by 0-8 Wgt % Al_2O_3 powder where selected for the study. Powders where mixed, compacted and subsequently sintered at 1150°C in laboratory tube furnace, under an endo gas atmosphere. Composite material properties were evaluated. The outcome results is that 4 vol % Al_2O_3 is the optimal percentage of the Alumina to obtain superior properties of the metal matrix composite. The deep drawing die and punch have been designed by using metal matrix composite and experimentally tested.
KEYWORDS: sintering, compressing, strength, hardness, tools

INTRODUCTION

Sintered iron components are used for various commercial applications. However, inferior strength is a limitation of sintered straight iron powder metallurgy products in many applications. Therefore, it is very important to increase the strength of straight iron powder metallurgy products. There are references [1÷4] for sintered iron and iron-carbon premixes. However, sintering often is carried out in the relatively higher temperature. The purpose of the present investigation was to increase the strength of the sintered iron by incorporating ceramic particles and to obtain sintered materials at relatively lower temperature, than generally used in industry.

The Faculty of Mechanical Engineering in Skopje and Ljubljana have conducted project which is oriented to the usage of composite materials as materials for tool and die design and this material meets the requirements for mechanical properties to insure the strength of the tools for sheet metal forming.

The series of numerical and experimental analysis for defining the material characteristics have been performed to optimize the mechanical properties.

EXPERIMENTAL PROCEDURE

In order to define a composite material that will be most suitable for preparation of the working elements of the tools for deep drawing, which will have sufficient strength to withstand the pressure transmit the stresses of work, but will also have good properties of friction and lubrication, composites iron - alumina were examined ($Fe\text{-}Al_2O_3$).

Iron powder is product by Swedish company Hoganas. To determine the optimal composition of used materials for sintering technique and to obtain the maximal deformation strengthening behaviours of sintered iron-alumina composites was prepared different mixture.

Alumina and iron powder have been mixed by using a rotary mill regards of small portions of mixture (100 gr mixture). Then, in the mixed powders is added a certain quantity of polyvinyl chloride as a means of lubrication using laboratory mortar, to improve the plasticity of mixture for consolidation of shapes by pressing. Mixed material has been compacted into cylindrical shape (test pieces) with a diameter 12 mm and height about 15 mm by onsite uniaxial compressing in pressings tool (Fig.1). Compacting was curry out in a hydraulic press fabricated by Erichsen. For all five mixture are prepared test pieces by using four different compaction pressures of 200, 400, 600 and 800 MPa, with aim to determine the influence of pressure to green and sintered density and to optimising out coming sinter properties of pieces regards to straight and microstructure (optimal densification) of composite.

When the compressing and receiving process have been finished, compacts were placed in the furnace, for a very slow warm up to 100°C, hold 5 hours by this temperature and warm up to 200°C with 20 hours hold time, in order to dry and evaporate the polyvinyl chloride used as lubricator and bonding mean of the matrix and reinforcement. After drying and evaporation, weight measurement of test pieces was made, on the scales with an accuracy of 1 / 1000 grams and dimensional measurement with an accuracy of 1 / 100 mm.

The sintering of the green cylindrical compacts was carried out in a laboratory tube furnace (Fig.2), *equipped with tube made from stainless steel, with input and output of neutral and reduction gas furnace atmosphere. The sinter atmosphere coexist from 90% Nitrogen and 10% hydrogen.*

Fig.1 - Tool for compacting of test pieces

The whole process is carried out during 5 hours and 40 minutes. The sintering was realized by heating 1 hour and 40 minutes to the required temperature 1150°C and hold time of 1 hour and = 40 minutes at this temperature. Cooling was carried out gradually in the protective atmosphere of gases. When the temperature dropped to a temperature of 400°C, test pieces were left to cool to room temperature in the furnace, without the circulation of gases. If cooling is performed in air to temperatures up to 480°C, then the iron can oxidize.

Fig.2 - Sintering furnace

After sintering, dimensional and weight measurement was made. Then the hardness is measured by Rockwell method, use ball 1/16'' and force of 100 daN

Composite hardness

The most important characteristic that should have composite, since the goal and purpose that he should have this investigation, applying for the processing tools, is the hardness and wear. The aim of this investigation is to determine the most appropriate composition of the composite in terms of representation of Al_2O_3, the pressure at which it should be compressed by forming and consolidation of tools for deep drawing. The influence of sintering temperature shout is investigated in future.

On the figure 3 can be seen that the composite containing 4% Al_2O_3 has the largest hardness and this is achieved at pressures 600 and 800 MPa. This is another proof that the iron composite containing 4% Al_2O_3 has the best characteristics compared to other composites.

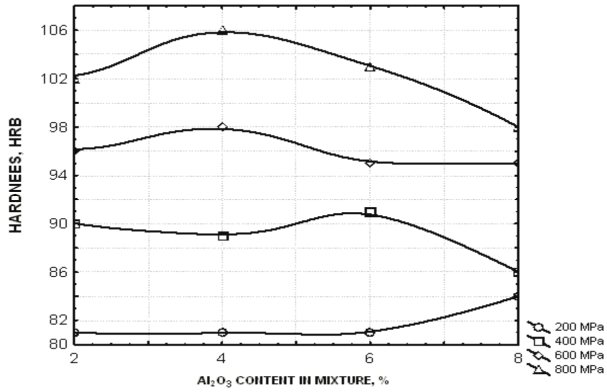

Fig.3 - Hardness diagram at iron composites depending by participation of Al_2O_3 and the compressing pressure

Microstructure

Metallographic images were made starting from 100% up to 92%Fe in mixture and for all pressures of the manufactured compact from 200 to 800 MPa, and analyze the structure of the compact. Figures 4 and 5 are showing metallographic some images of composite material with 100% Fe, compressed with pressure 200 and 600 MPa, and figures 6 and 7 show metallographic images of composite material of 96%Fe and 4 % Al_2O_3, during same pressures for compressing, as show of microstructure of pressing compacted and sintered specimens. All specimens are sintered on temperature of 1150°C in time of 45 minutes, as were pointed in advance.

Microstructure of sintered specimen's of pure Fe, show that is build bond between ferritic grains, with a amount of rest porosity, results from relative high forming porosity. The presence porosity show that the sintering temperature end time was not sufficient to obtain pore's free shape.

The build microstructure to specimen doped with Al_2O_3 show higher porosity as pure sintered Fe. The porosity increase with amount of added Al_2O_3. Fe grains are sintered in claster and between they are present Al_2O_3. Between Fe- and Al_2O_3 – grains are not enough close phase interface, which should be contribute to better mechanical properties of material, especialy to increasing of toughness. The added Al_2O_3 is isolated between Fe-grains or is depozited in pores. The present Al_2O_3 grains in the microstructure should be obstacle for free deforming of Fe grains, resulting to reinforcement of base Fe material coresponding to their hardness and deformation resistance. In the present microstructure, Al_2O_3 isolate grains could be contribute to satisfied mechanical properties of base Fe material for the goal of employment – as tools material for deep drawing. The presents of relative high porosity contributed to keep lubricant to surface of tools and drawing goods.

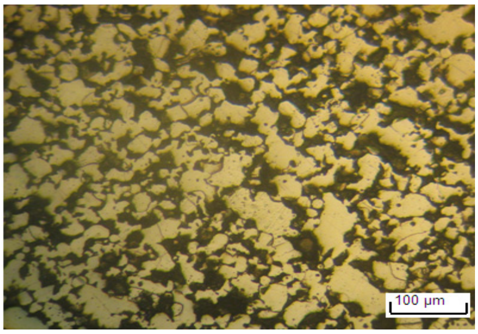

Fig.4 - Metallographic images of composite 100%Fe compressed by pressure of 200Mpa

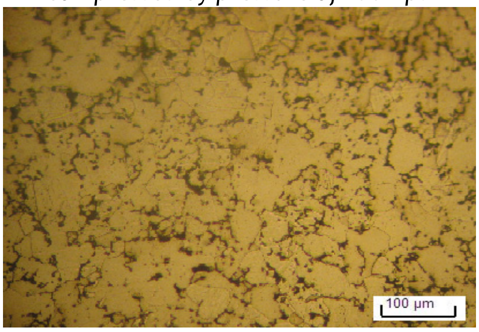

Fig.5 - Metallographic image of composite 100%Fe compressed by pressure of 600 MPa

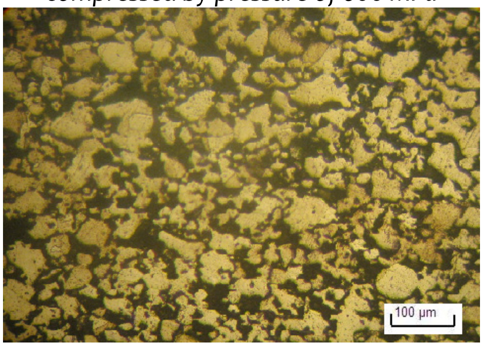

Fig.6 - 96%Fe-4% Al_2O_3, - 200 Mpa

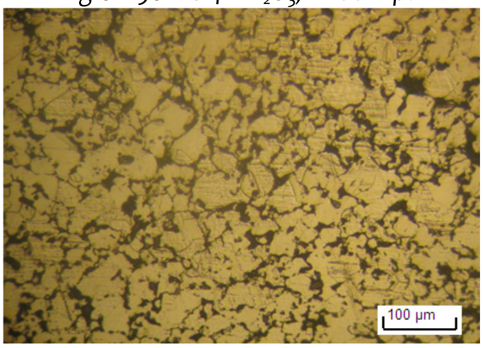

Fig.7 - 94% Fe- 4% Al_2O_3 – 600 Mpa

DEEP DRAWING DIE DESIGN

The goal of carry outer investigation, which same of results is presented in this paper, is to find the most suitable composite Fe-Al_2O_3, according to researches made and previously explained the optimal composite is presented below (Table 1).

Table 1. The most suitable composite Fe-Al_2O_3

Fe	Al_2O_3	Compressing pressure	Sintering temperature	Sintering time
96 %	4 %	600 MPa	1150°C	40 min.

This composite has the characteristics presented in Table 2.

Table 2. Characteristics of composite Fe-Al_2O_3

Green density	Sintered density	Strength during 10% strain	Hardness
6,03 g/cm^3	6,188 g/cm^3	200 N/mm^2	115-130 HRB

From this composite, two elements for deep drawing tool were made: die and blank holder for second draw (Fig. 9) for cylindrical deep drawn parts with a diameter of 50 mm in cylindrical part with diameter 35 mm.

For compressing of these parts from composite material, special tools are designed and manufactured. Images are shown on figure 8.

Fig. 8 - Compressing tool for die

a)

b)

Fig.9 - Blank holder (a) and die (b) manufactured by composite material 96%Fe and 4% Al_2O_3 compressed by pressure of 600MPa and sintered on temperature of 1150°C

The tool (the die and the blank holder) made of iron composite Fe-Al_2O_3 is used to deep drawn 105 pieces of low carbonic sheet metal. Figure 10 shows the drawn pieces including the die and the blank holder. The results are shown in form of a diagram in Figure 11.

The deep drawing was made of low carbonic sheet steel thick 1 mm. If we analyze the diagram in Figure 11 we can conclude that there is a difference in the strength of deep drawing. It is a result from the non-homogeneous structure of the cold rolled sheet metal. The strength at depth of deep drawing h_1=38 mm, which is the subject of the analysis is between the minimum 43 kN and the maximum 47 kN. If we consider the tendency of this strength we can state that it decreases by increasing the number of drawn pieces (Fig. 11). It is a result of self-polishing the surface due to the wear of the radius of the die.

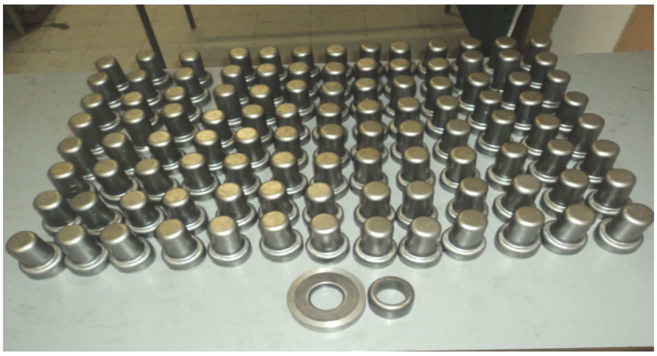

Fig. 10 - The die, the blank holder and deep drawn pieces

Fig.11 - The tendency of decrease of the deep drawing strength in the second operaiton of deep drawing wiht tool Fe-Al_2O_3

The tool has successfully endured all the deep drawings without any damages. In addition to the batch of 105 pieces around 10 pieces of galvanized low carbonic sheet metal have been deep drawn as well.

CONCLUSIONS

In this paper is made a substitution of classical tool steels (OCR12, Mat. No. 1.2080, DIN X210Cr12) with composite material for the deep drawing tool, presenting innovation and contribution to the development of tools production.

Moreover the composite material was made of working elements of the deep drawing tool, blank holder and die for drawing of cylindrical parts for the second operation. Manufacturing the tool elements for the second operation of deep drawing process were chosen with the reason that they are with smaller size compared with the tools for fist draw. The powder material, iron and alumina were supplied from the Swedish company Hoganes.

First of all researches were made in order to determine which composition from the powder materials will create composite materials with the best mechanical characteristics (pressure strength and hardness). Mixed material is compressed in samples with a diameter 12 mm and height about 15 mm by compressing in specially developed tool. The compressing is performed on Erichsen hydraulic machine owned by the laboratory of Faculty for Mechanical Engineering in Skopje. For all 5 groups of mixtures, 4 compressing were made with different pressure of 200,400,600 and 800 MPa. The manufactured samples were drying and sintering in the dryer and sintering furnace in the laboratory of Faculty for Technology and Metallurgy in Skopje. Sintering furnace has a tube chamber with diameter of 80 mm. Sintering is performing in protective atmosphere with nitrogen and hydrogen. Sintering time after reaching temperature of 1150°C for samples is 40 minutes and for parts of tool is 1 hour and 20 minutes. Thus the sintering of the samples is achieving hardness of 96 HRB, and working elements of the tool to 120 HRB.

Investigation showed that the best mechanical characteristics were achieved with the composition of 4% Al2O3 and 96% iron power. In a view of pressure, the best results are achieving under pressure of 800 MPa, but because it is very high pressure, it is adopt working pressure of 600 MPa.

The company MK Mold DOO manufactured two tools for compressing die and blank holder. With this tools are manufactured two pieces of die and two pieces of the blank holder for drawing of cylindrical parts.

Given the porosity of composite material have better hold on characteristics for the lubricant thereby it reduces the forces and the friction stresses. Besides that it does not damage the surface of the deep drawn parts.

The strength of the deep drawing, shows a slight tendency of decrease depending on the number of deep drawn parts. It is a result from the fact that the die and the blank holder have been used directly following the compacting and sintering, with no additional mechanical processing. During the work due to gliding and attrition, there is self-polishing the surface of die.

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REFERENCES

[1.] J. Caloska, I. Lazarev, J. Lazarev, J. Mickoski: Metalni matricni kompoziti za izrabotka na alati otporni na abenje. Razvojno istrazuvacki proekt sofinansiran od Ministerstvoto za obrazovanie i nauka. Skopje, 2009 godina

[2.] Lazarev, K.Kuzman J. Mickovski, J.Lazarev, J.Caloska: Sintered Iron-Alumina Composites as tools material for the deep drawing. 3rd International Conference "Advanced Composite Materials Engineering "COMAT 2010. 27- 29 October 2010, Brasov, Romania

[3.] J.K. Mickovski, I.J. Lazarev, J. Lazarev, D. Stoevska-Gogovska: Microstructure case study of LENStm processed cilinder from AISI H13 steel. Journal for Technology of Plasticity, No 1-2, 2010, Novi Sad

[4.] S. K. Mukherjee, B. Cotterell and Y. W. Mai: Sintered iron-ceramic composites. Journal of Materials Science, Springer Netherlands, Volume 28, Number 3/ February, 1993

[5.] J. H. Schneibel, C. A. Carmichael, E. D. Specht and R. Subramanian: Liquid-phase sintered iron aluminide-ceramic composites. Metals and Ceramics Division, Oak Ridge National Laboratory, PO Box 2008, Oak Ridge, Tennessee 37831-6115, USA, 1996