Journal for Technology of Plasticity, Vol. 36 (2011), Number 2

DOI: 10.2478/v10211-011-0007-y

WEAR RESISTANCE OF THE DEEP DRAWING METAL MATRIX DIE

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ABSTRACT

The aim of this paper is to present the experimental research that has been realized for improving the strength and high temperature properties of Metal matrix composite material (iron- Alumina (Al_2O_3) - iron powder added by 0-8 Wgt % Al_2O_3 powder.
Powder were mixed, compacted and subsequently sintered at 1150^oC in laboratory tube furnace, under an endo gas atmosphere.
The outcome result of this research is the fact that 4 vol % Al_2O_3 is the optimal percentage of the Alumina in the composite material structure to obtain superior properties.
The composite material which was created, after all was used as material for designing the deep drawing die and punch. The results of experimental testing of the deep drawing tool elements shows that the above mentioned composite material could be succesfull replacement of the standard steel for desining deep drawing tool's elements .

***Key words**: sintering, compressing, strength, hardness, tools,*

1. INTRODUCTION

Sintered iron components are used for various commercial applications. However, inferior strength is a limitation of sintered conventional iron powder metallurgy products in many applications. Therefore, the chalange of the science is to realize research which will be directed toward improvement of the strength of conventional iron powder metallurgy products, as it is prsented in the references [1÷4] for sintered iron and iron-carbon premixes.

However, sintering often is carried out in the relatively higher temperature. The aim of this research 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.

2. EXPERIMENTAL PROCEDURE

In order to define a composite material which will be most suitable for desigining working elements of the tool for **deep drawing (die and punch)**, metal matrix composite iron – alumina (Fe-Al_2O_3) were examined .
The aim of the experimental research was to desing composite with sufficient strength to withstand the pressure as well as good properties of friction between tool elements.

Iron powder, which was used is produced by Swedish company Hoganas.
Since the fact that research was directed toward determination of the optimal material's composition for sintering technique and to obtain the maximal deformation strengthening behaviours of sintered iron-alumina composites, different mixtures were prepared for the experimental research.
Alumina and iron powder have been mixed by using a rotary mill and small portions of mixture (100 gr mixture). The mixed powders were additionaly improved by adding a certain quantity of polyvinyl chloride as a means of lubrication 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 of 12 mm and height of 15 mm by onsite uniaxial compressing in pressings tool (Fig.1).
Five mixture are prepared for designing test pieces by using four different compaction pressures of 200, 400, 600 and 800 Mpa. This was done with aim to determine the influence of pressure to green and sintered density and to optimise properties of tool elements.
When the compressing and receiving process have been finished, compacts were placed in the furnace, for a very slow warm up to 100^{o}C, and hold 5 hours on this temperature. After that they have been warm up to 200^{o}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.
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 of 1150°C and hold time of 1 hour and 40 minutes at this temperature.
The cooling process was carried out gradually in the protective atmosphere of gases. When the temperature decreasses to a temperature of 400°C, test pieces were left to cool to room temperature in the furnace, without the circulation of gases. After sintering, dimensional and weight measurement was made again.

Fig.1 - Tool for compacting of test pieces

Fig.2 - Sintering furnace

3. DEEP DRAWING TOOL'S ELEMENTS DESIGN

Since the fact that the aim of this research is to define the most suitable metal matrix composite for designing the deep drawing tool's elements, the experimental research outcome is that the optimal metal matrix composite properties are as following:

Fe	Al_2O_3	Compressing pressure	Sintering temperature	Sintering time
96 %	4 %	600 MPa	1150^{o}C	40 minutes

This metal matrix composite has the following mechanical properties:

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

Therefore, two deep drawing tool's elements were produced: die (fig.3) and blank holder for second deep drawing operation (Fig. 4) for cylindrical deep drawn parts

Fig. 3 - Compressing tool for die

a) b)

Fig.4 - Blank holder (a) and die (b) manufactured by metal matrix composite material (96%Fe and 4% Al_2O_3) compressed at pressure of 600 MPa and sintered on temperature of 1150^0C

The deep drawing tool with elements made of iron composite Fe-Al_2O_3 is used for deep drawing of low carbon sheet metal with 1 mm thickness. The drawn pieces are shown on figure 5.
The research shows that there is a difference in the strenght of deep drawing s it is shown on figure 6. It is a result of the non-homogeneous structure of the cold rolled sheet metal.
The Force 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. 6). It is a result of self-polishing the surface due to the wear of the radius of the die.

Fig. 5 - The die, the blank holder and deep drawn pieces

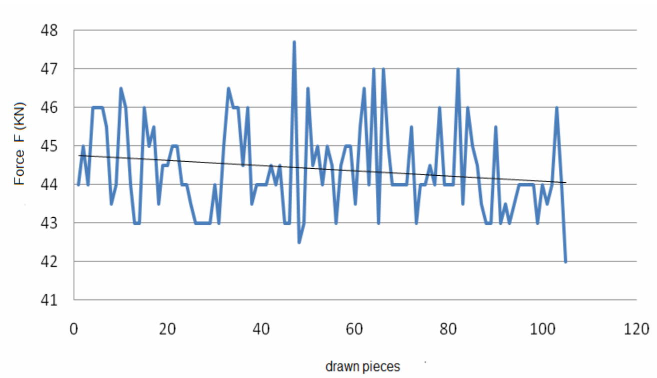

Fig.6 - The tendency of decrease of the deep drawing strength in the second operaiton of deep drawing wiht tool Fe-Al_2O_3

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.

4. WEAR OF THE DIE

There is no determined standard for testing or measuring the resistance to wear of the materials. and there is a great number of tests to define wear.

Most of such tests have been developed by different commissions, aiming to standardize the testing and so that it could be applied to different applications. One of those standard tests has been adopted by the sub-committee of ASTM G-Committee – 2 and according to it the wear is defined as loss of material during the operations. This, the loss of the material can be expressed through the loss of volume or the loss of weight.

The loss of volume gives more realistic image than the loss of weight especially when comparing the resistance to wear of materials with great difference in their density.
For example, loss of weight of 14 grams when dealing with a sample from wolfram carbide cobalt (density = 14000 kg/m^3) and loss of weight of 2.7 grams of a similar sample from aluminium alloy (density = 2700 kg/m^3) results in the same level of 1 m³ when expressed in form of volume loss.
The duration of each component of a composition or a machine shall end when the dimensional losses defined by the measure tolerances are exceeded.
The wear, together with the aging, fatigue, crawling, different types of fractures, causes progressive degrading og the materials in time, which leads to decrease of the duration of the element or the tool as a whole. The measuring was performed by a measurement machine TESA 3D, Micro-MS 454, (Fig. 7) in the toolfactory LONOSKI in Skopje, which shows the dimensions as one thousand part of the millimetre, that is in micrometers.

Fig. 7 - Measuring of the die

The measuring of the die was performed by measuring the diameter of the profile of the die at two levels of depth, 4.3 mm and 6 mm (Fig.8). The measuring of the dimensions of the die, as well as of the blank holder was performed in every 25 deep drawn pieces.
The measured variables of the die diameter are presented in Table 1, but also, these variables are shown in the diagrams on Figure 9 and figure 10. Both diagrams show that there is a slight difference in the character of the curve of the wear. But the one thing in common is that the increase of the number of deep drawn pieces increases the wear as well.

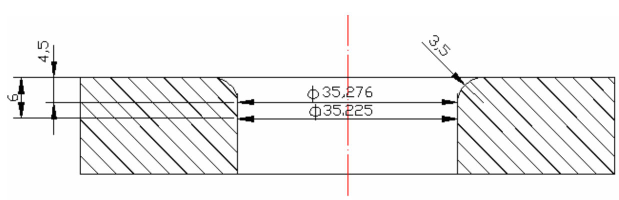

Fig.8 - Places for measuring the dimensions of the die with initial dimensions

Table 1. Variables of the dimensions of the die diameter and wear in case of deep drawing pieces

Measurment at depth of the die	Number of deep drawn pieces	Die diameter D mm	Radius R=D/2 mm	Wear mm
4,5 mm	0	35,276	17,638	0
	25	35,280	17,640	0,002
	50	35,296	17,648	0,010
	75	35,299	17,649	0,0115
	100	35,304	17,652	0,014
6,0 mm	0	35,255	17,6275	0
	25	35,272	17,636	0,0085
	50	35,280	17,640	0,0125
	75	35,280	17,640	0,0125
	100	35,294	17,647	0,0195

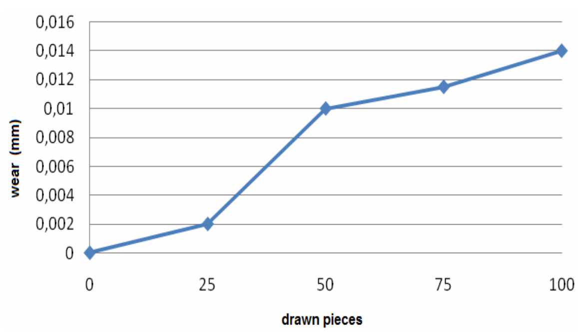

Fig.9 - Diagram of the wear measured on the profile of the die at depth of 4.5 mm, depending of the number of deep drawn pieces

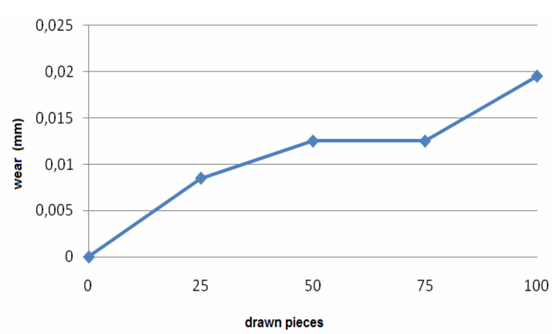

Fig.10 - Diagram of the wear measured on the profile of the die at depth of 6 mm, depending on the number of deep drawn pieces

5. CONCLUSIONS

The research presented in this paper shows that the classical tool steels (OCR12, Mat. No. 1.2080, DIN X210Cr12) used for designigning tool element's fro deep drawing could be replaced elements desing by using metal matrix composite material without any negative consequnces on the precision of the deep drawing process.
Also, the results show that there is a slight tendency of decrease of the deep drawing strength in the second operation . 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.
Experiments have confirmed that the criteria of wear of working elements of tools for deep drawing made of metal composite meet the requirements for quality of the surface of the working elements for tools for deep drawing parts in small production batches by deep drawing.

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OTPORNOST NA HABANJE MATRICE ZA DUBOKO IZVLAČENJE

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REZIME

U ovom radu prikazana su eksperimentalna istraživanja čiji je cilj bio poboljšanje čvrsoće i mehaničkih osobina na visokim temperaturama metal matrix kompozitnog materiala (železo – aluminijum oksid – Al_2O_3) – železni prah gde je dodat težinski 0-8% aluminijum oksida.
Prah je izmešan, sabijen i nakon toga sinterovan na 1150 °C u labolatorijskoj peći sa endo gas atmosferom.
Kao rezultat ovog istraživanja navodi se činjenica da je 4% Al_2O_3 optimalna količina aluminijum oksida u kompozitnoj strukturi da bi se dobile najbolje osobine materijala.
Kompozitni materijal koji je na ovaj način dobijen je kasnije bio upotrebljen kao material za izradu žiga i matrice za duboko izvlačenje. Eksperimentalno restiranje ovako dobijenih elemenata alata pokazuju da ovaj kompozit može uspešno zameniti standardni čelik koji se koristi u izradi alata za duboko izvlačenje.

Ključne reči: *Sinterovanje, komrecija, čvrstoća, tvrdoća, alati*