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MANUFACTURING TECHNOLOGY OF COMPLICATED SHAPE PARTS OF SINTERED METAL POWDERS

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Summary. The technologies of powder metallurgy (PM) provide vast possibilities of manufacturing various powder products with forming of required mechanical, physical and service properties. New technologies of manufacturing metal powder parts developed by EUNU are presented in the paper. The technologies allow for manufacturing parts with desired mechanical properties, complex shape and intended for severe service conditions. The separate stages of forming details have been presented, as well as the effect of technological parameters on the properties of the finished product.

Key words: metal powder, compaction die, solid lubricant, stress, density, load-displacement**.**

INTRODUCTION

During 80-90th the development of new iron and steel powders and processes has led to a considerable expansion of PM applications. The high performance sintered components demand powder materials with improved mechanical properties at reduced costs. An important advantage of PM technologies is resource-saving characterized by low specific energy consumption in serial and mass production, as well as lesser-waste production process.

Density of powder components is the basic factor that influences mechanical properties in general and dynamic properties in particular. So PM components with densities higher than 7.2 $g{\cdot}cm^{-3}$ are being required in many fields of industry. Both methods such as double pressing and sintering and powder forging (PF) provide higher densities than traditional single pressing and sintering but in many cases their use for manufacturing structural parts is constrained by final cost and geometrical considerations. Therefore to extend the use of PM in future, the industry has to develop cost effective materials and PF methods and as a result further improve density and performance of the parts.

Density, alloying elements, alloying method and sintering conditions together determine the structure features and mechanical properties of sintered steels. Today, through advanced alloying technology and higher density levels, the mechanical properties and performance of PM steels has reached levels close to that of wrought high strength steel. During the last 30 years the density of PM components has increased from a level of 6.6 to 7.4 g·cm^{-3}. It has been obtained mainly as a result of continuous improvement in compressibility of pure iron powders [Engstrom 2000] and in alloyed powders, lubricants and their powder mixtures. Also, compaction presses and tooling facilities have been developed enabling higher compaction pressures. However, further developments to increase the compressibility of either pure iron or low alloyed steel powders will only result in marginal improvements at an increased cost that is undesirable. Therefore future developments and investigations to increase density have to be found in the lubricant systems and the processing conditions used. A fundamental question to answer is at which density level the material properties are good enough to meet the demands from the applications.

For many parts with complicated shapes, compaction pressures higher than 600 MPa are not applicable. Increasing the pressure can increase the density substantially, providing that the lubricant does not occupy too large a volume as an excess of the lubricant is worsening metal powder densification.

The strong influence of lubricant content on density was shown in the work [Ohdar 2003]. Even though pressures above 800 MPa at present can be only be used for a limited number of parts, the data [Ohdar 2003] clearly demonstrate that the amount of lubricant has to be reduced from present content levels of 0.8-1.0 % in order to achieve densities above 7.40 g·cm^{-3}.

The combination of warm compaction and sinter hardening is another interesting process route. Warm compaction helps to achieve higher density and green strength, allowing for that accurate machining of green components eliminates the need for costly post sintering heat treatment and machining [Vidarsson 2004]. Tensile strengths up to 1250 MPa and hardness levels close to 50 HRC can be achieved in a single operation at sinter hardening of warm compacted materials like Astaloy CrMo or Distaloy DH-1. A compaction – sintering – forging technology has a real capability to increase density up to 7.7 g·cm^{-3} [Stojanov 2002, Weinert 2001, Leszczynski 2000]. So far this method has not been used to any large extent in ferrous PM because of its high operation costs. However, the components subjected to heavy fatigue loading are attracting increasing attention for this technology. The examples of components operating in heavy conditions can be highly stressed synchronizing hubs, rings and cones, different types of gears and cam lobes. The most prominent are transmission gears and various pinions [Stojanov 2002, Weinert 2001]. The possibility of manufacturing these components by usage of a modified cold powder forging process is becoming closer as the mechanical properties of PM steels are close to those of wrought high strength steels. So, the task of manufacturing full density parts by modified PF methods remains important. The paper presents results of examination of forging technology of steel powder parts. An optimization of friction conditions during forging operation allows achieve the high density of powder parts at the relatively low contact pressures.

OBJECTS AND PROBLEMS

The innovativeness of method [Stojanov 2002, Weinert 2001] lies in joining in one technological cycle the operations of forging and sizing of compact sintered at an optimal temperature. During forging operations an increase in density occurs. Finally, this method permits the attainment of 98 % density of the solid material. The same density may only be obtained by the process of powder hot forging, however a great accuracy of execution is not obtained in such a process. Final hardness enhancement may be obtained during thermo-chemical processing. The hardness obtained depends on the density of the product and on the chemical composition of the powder mixture used. The PM technology with nanoparticle impregnation is applied to parts for which high wear resistance and low friction coefficient are required. The appropriate selection of technological process parameters allows manufacturing structural parts with a wide range of density, hardness as well as with low coefficient of friction. This technology envisages different variants of the impregnation process and a wide range of impregnation mixtures. The mixtures on a base of micro or nano particle solid lubricant are applied. The offered technology enables successfully to manufacture the following structural parts with controlled porosity such as bearing and chain rings and self-lubricating bushings.

The experiments were conducted using Astalloy Mo and Astalloy CrMo powders, the characteristics of which are given in Table 1. The powder compaction and forging experiments were carried out using special tooling which is installed on the test machine. After the compaction and forging-repressing the density of compact was measured by Archimedes' method. The operations were performed on INSTRON test machine with load capacity of 200 kN. The scheme of the forging tool set up on INSTRON press is shown on Fig. 1.

Table 1. **Characteristics of Astalloy Mo and Astalloy CrM powders**

Name of the powder	Composition				Apparent density, g/cm^3
	Fe	Mo	Cr	C	
Astaloy Mo	base	1.5%	-	< 0.01	3.10
Astaloy CrM	base	0.5%	3%	< 0.01	2.85

The load-displacement diagrams were computer recorded, processed and corrected to take into account an elastic deformation of tooling. Density of compact measured after each densification was used as final point of pressure-density curve which was calculated on the base of computer recorded load-displacement diagram.

The normal load applied to upper and lower punches as well as the radial stresses were recorded during forging operation. The powder rings made of Astalloy powders were used as the parts for subsequent forging operation.

Friction forces prevent complete densification because of the contact between the powder compact and the die wall. It is obvious, that the friction increases with the geometric complexity of the PM part. In this work, the geometry selected is a cylinder ring (d_{outer} = 22.0 mm; d_{inner} = 18.0 mm; h =10 mm).

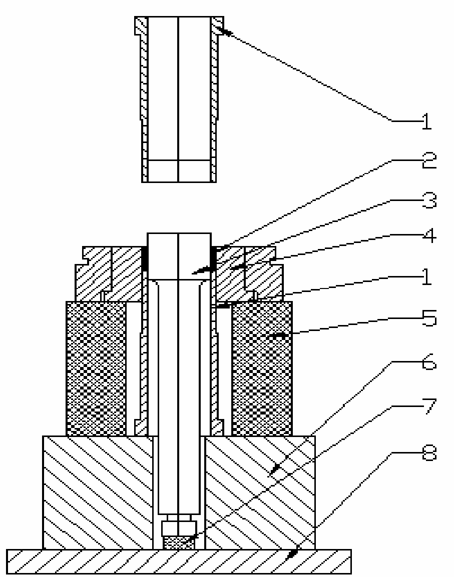

Fig. 1. The scheme of the forging tools set up on INSTRON press:
1 - punch, 2 - forging element, 3 - rod , 4 - die with radial load cell,
5 - matrix plate of the die, 6 - distance sleeve, 7 - load sell of the rod, 8 - base plate

The lower punch force (F_i) is lower than the compaction force (F_s) which is recorded by upper punch load cell, because of the friction acting on the surface of the compact at the length h. The simple analysis assumes that the displacement of the ring element takes place only along the axial direction. That is why the density distribution in the radial direction can be considered as uniform. It can be shown as:

$$F_s - F_i = F_t \, , \tag{1}$$

and

$$(\sigma_s - \sigma_i) \cdot A_f = \tau \cdot A_t \, , \tag{2}$$

where: F_s - the applied force, F_i - the lower punch force, A_f - the ring cross section area, A_t - the side wall area, and σ_s, σ_i, τ are the applied, transmitted and tangential stresses of the compact, respectively.

The friction is assumed to follow a Coulomb law:

$$\tau = \mu \cdot \sigma_\rho \, , \tag{3}$$

where: μ - the friction coefficient and σ_ρ - the radial pressure.

The main relationship can be derived by combining equations (2) and (3):

$$\frac{(R_{outer} - R_{inner})}{2} \cdot (\sigma_s - \sigma_i) = \mu \cdot \int_0^h \sigma_{\rho} \cdot dy \;, \qquad (4)$$

where: R - the cylinder radiuses.

Equation (4) shows the general relationship between the friction coefficient and the stress components. If the parameters $\sigma_\rho, \sigma_s, \sigma_i$ will be measured (Fig.1), it is easy to calculate the friction coefficient on the base of equation (4). We assume a uniform distribution of radial stress σ_ρ over the height of the ring during forging a relatively short ring. Thus, we can calculate the friction coefficient on the base of the equation (4):

$$\mu = \frac{(R_{outer} - R_{inner})}{2 \cdot \sigma_\rho} \cdot \frac{(\sigma_s - \sigma_i)}{h} \,. \qquad (5)$$

RESULTS AND DISCUSSION

The combined effect of lubrication type and the sintering temperature on compressibility of steel powder compacts is shown on Fig. 2. The friction conditions are shown to be strongly dependant on the type of lubricant and value of contact stresses and, therefore, radial stress σ_ρ.

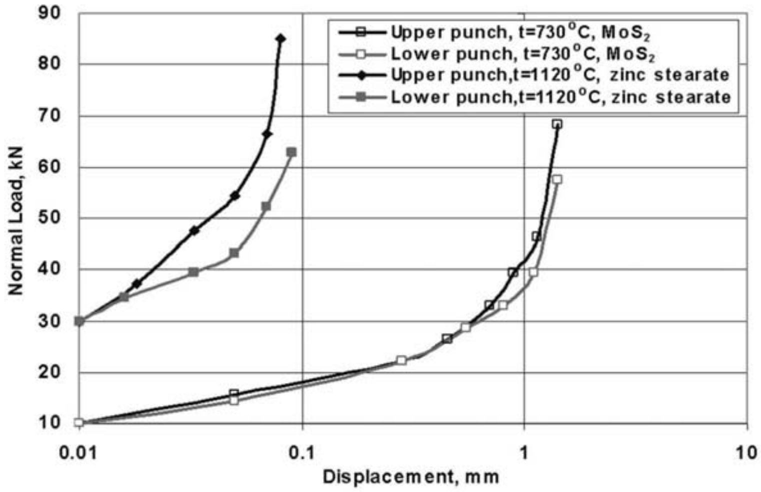

Fig. 2. Load displacement curves made with correction of elastic strains: closed die compression of rings sintered with temperatures 1120°C and 730°C; two types of ring lubrication - zinc stearate and MoS_2

The dependences of friction coefficients and radial pressure are shown in Fig. 3, 4. The results of the friction coefficient calculation reveal a possibility of contact conditions management by the control of regime of lubrication with solid lubricant. This opportunity is important in particular in the range of normal contact stresses of 400-700 MPa. The function $\mu = \mu(\sigma_\rho)$ has a minimum that reveals effectiveness of lubricant film at the interface. Indeed the thickness and robustness of lubricant film depend on the type of lubricant and method of lubricant deposition. Die wall lubrication is less effective then part lubrication.

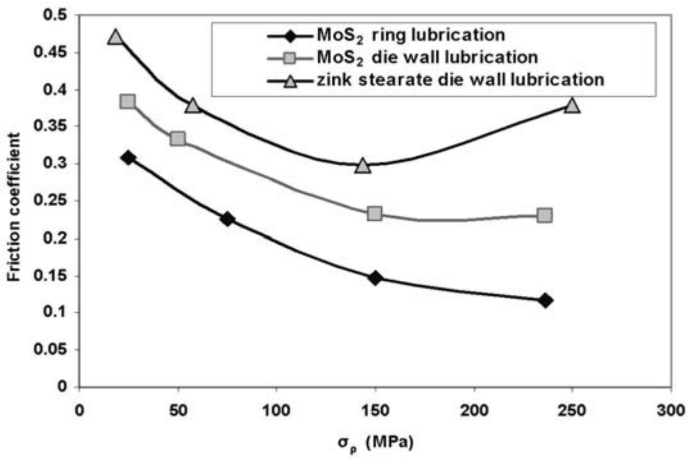

Fig. 3. Friction coefficient versus radial stress

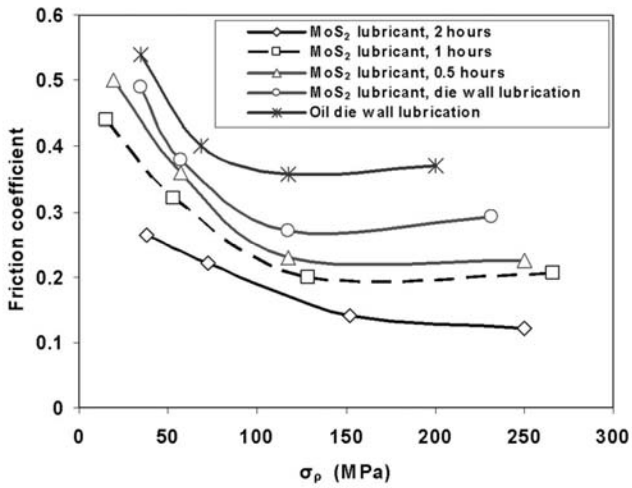

Fig. 4. Effect of lubrication parameters on friction coefficient

CONCLUSION

The cold forging process greatly depends on sintering temperature and lubrication technology. The management of these two factors enables to achieve a high density and accuracy of PM parts.

The offered technologies can be recommended for manufacturing structural responsible parts.

REFERENCES

1. Engstrom U., 2000. Challenges of high density. Met. Powder Report , vol.55, Sinter Revolution Suppl, p.8-9.
2. Leszczynski V., Cernozukova I., Weinert H., 2000. Modelling of Multioperational Cold Powder Die-forging. In: International conference on powder metallurgy & particulate materials 2000. Hilton New York, p.63.
3. Ohdar R.K., Pasha S., 2003. Prediction of the process parameters of metal powder perform forging using artificial neural network (ANN), J. Mater. Process. Technology, vol.132, no.1-3, p. 227-234.
4. Stojanov A., Leszczynski V., Weinert H., Lisowski J., 2002. Ksztaltowanie dokladne czesci ze stopowych proszkow zelaza // Obrobka plastyczna metali. nr. 3, t. XIII. – S. 33-39.
5. Stojanov A., Weinert H., Leszczynski V., 2002. High accuracy forming of parts made of powdered alloyed materials on iron matrix. In Archives of Mechanical Technology and Automation, p. 197-206.
6. Vidarsson H., Johansson B., Knutsson P., 2004. Performance and Capabilities of Powder Mixes during Warm Compaction. Materials of the Powder Metallurgy World Congress & Exhibition – Austria, Vienna. V1. – P.527-532.
7. Weinert H., Leszczynski V., Bubacz M., 2001. Precision multioperational cold die-forging of the powder rings. In: Powder Metallurgy Congress and Exhibition Proceeding. Conference Nice/France.

ТЕХНОЛОГИЯ ПРОИЗВОДСТВА СЛОЖНОПРОФИЛЬНЫХ ДЕТАЛЕЙ ИЗ СПЕЧЕННЫХ МЕТАЛЛИЧЕСКИХ ПОРОШКОВ

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Аннотация. Технологии порошковой металлургии (ПМ) обеспечивают широкие возможности изготовления разнообразных порошковых деталей с требуемыми механическими, физическими и эксплуатационными свойствами. В работе представлены новые технологии производства металлопорошковых деталей, разработанные в ВНУ. Эти технологии позволяют производить детали с желаемыми механическими свойствами, сложной формы для тяжелых условий работы. Рассмотрены отдельные операции производства деталей и влияние технологических параметров на свойства конечной продукции.

Ключевые слова: металлический порошок, штамп, твердая смазка, напряжение, плотность, деформация