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Design and fabrication of Impact Die for Powder Metallurgy☆

C.Parswajinan[a]*, B.Vijaya Ramnath[b], M.Vetrivel[c], A.Riyaz Ahmed[d], A.S.A.Syed Mohamed Buhari[e], C.Muthukumaaran[f], I.Anish Hilary[g]

[a]*Research Scholar, Department of Mechanical Engineering, SCSVMV University, Kancheepuram, Tamil Nadu – 631561, India and Asst. Prof., Department of Mechanical Engineering, Sri Sai Ram Engineering College, Chennai, Tamil nadu – 600044, India*
[b]*Professor, Department of Mechanical Engineering, Sri Sai Ram Engineering College, Chennai, Tamil nadu – 600044, India*
[c]*Professor, Department of Mechanical Engineering, SCSVMV University, Kancheepuram, Tamil Nadu – 631561, India*
[d, e, f, g]*Department of Mechanical Engineering, Sri Sai Ram Engineering College, Chennai, Tamil nadu – 600044, India*

Abstract

Die design is one of the most important steps in Powder Metallurgy process because the shape and attributes of the die will directly affect the final component. Die design has a number of steps and considerations to be made before fabrication. This project is an attempt to design and fabricate a die for cold compaction process used in the powder metallurgy process. This project includes design and fabrication of a die for the fabrication of a rectangular specimen, which used to test the impact strength of the specimen using Izod impact test and Charpy impact test. The die is designed according to the standards of ASTM B925 with the die being made of AISI D3 tool steel with the punch material being AISI D2 steel. This project also includes the design considerations, calculations, 2-D drawings, 3-D model and processes involved in fabrication of the die.

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Keywords: Die, P/M, Impact

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: parswajinan@gmail.com

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1. Introduction

Powder metallurgy is the process of blending fine powdered materials, pressing them into a desired shape or form, and then heating the compressed material in a controlled atmosphere to bond the material. Powder Metallurgy is a continually and rapidly evolving technology embracing most metallic and alloy materials, and a wide variety of shapes. Al-Qureshi et.al [1] achieved full densification by several routes and often involves the simultaneous application of stress and temperature to close residual pores. This is achieved through cold and hot forging or extrusion processes. Hofmann & Bowen [2] research have investigated the cold forming of ferrous and nonferrous powder preforms and have reported the merits of the process such as good surface finish, higher accuracy, and superior strength due to work hardening and geometric hardening. Some of the limitations of hot forging are oxidation and decarburization of the surface of billets; excessive die wear, poor surface finishing & dimensional accuracy, and the induction of thermal stresses. Powder types, characterization, powder fabrication, alloying and mixing for the P/M steels have been analyzed by various researchers. Jhavar et.al and Mauricio Barrera et.al [3-4] conclude that low-alloy P/M steels containing Cr, Mo, Si, Ferro Si, Cu and Mn, manufactured from elemental powders are suitable for precision parts of automotive engines and transmissions. Hence, in the present research work admixed elemental metal powders such as Cr, Ni and Mo subjected to single pressing and sintering operation is considered. During cold and hot forging, the plastic deformation and densification characteristics of sintered powder materials are not same compared to conventional materials. Hence, detailed studies are required for the plastic deformation of the sintered P/M steels. Strengthening of sintered P/M low alloy steels can be achieved through densification, alloying and heat treatment [5-6]. The new yield function developed taking into account the hydrostatic stress, is considered in their work. Numerical integration has been carried out in order to compute the yield stress. William R. Blumenthal et.al [7] research concludes that the ratio of the yield stress of the P/M porous material to the yield stress of the fully dense material is found to increase with increase in densification due to plastic deformation. Scientists introduced a non-associated flow rule to characterize the yield and subsequent plastic deformation of porous solids by FEM analysis on the axisymmetric unit cell. Vijayaramanath et.al [8] observed that the composites reinforced with CNT showed with improved mechanical properties which can be utilised for various practical applications. Some challenges faced in areas like uniform dispersion of CNTs in matrix phase, reduction of carbide formation etc., limits the utilization of these composites on macro scale. Vijayaramanath et.al [9] found that the addition of CNT did not have any significant improvement in hardness value. The compressive strength of the composite was increased by 143.58 MPa. Parswajinan et.al [10] concluded that there was no improvement in hardness of the composite on addition of CNT while there was an increase in compressive strength. Kesavan and Vijaya Ramnath [11, 12] dealt with the applications of machines and press tools for various applications.

Nomenclature

P/M	Powder Metallurgy
2-D	2 Dimensional
3-D	3-Dimensional
ASTM	American Society for Testing and Materials
AISI D3	High Carbon/High Chrome Tool Steel

2. Material used

AISI D3 tool steel was used as die material and AISI D2 tool steel was used as punch material and the die dimensions were selected according to American Society for Testing and Materials (ASTM) standards.

2.1 2D Drawing of Die

The 2D drawings of die block are shown in figure 1. This diagram is taken from the ASTM B925-08 standards. The actual die submitted as project does not include the carbide liner as it was found to exceed our cost estimation. The

2D drawings of the punches were drawn using Auto Cad 2010 separately with the required dimension and geometry for the Die given as per the ASTM standards.

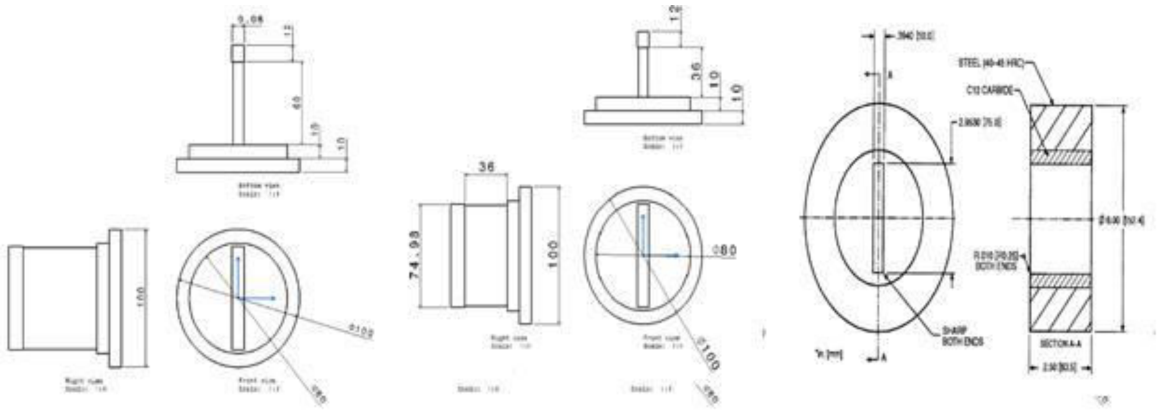

Fig.1 2D Design of Die and punches

2.2 *Die Safety Calculation*

Area, $A = b \times h = 75 \times 10 = 750\ mm^2$

Assuming a load of 200000 N,

Stress, σ = Load/Area = 200000 / 75 = 266.667 MPa.

The ultimate yield strength and ultimate tensile strength of D3 tool steel are 1034 MPa and 1158 MPa respectively. So, the die tends to withstand the given load with ease.

2.3 *Sample 3D Model*

A sample 3D model of the die and punch set with the above dimensions was prepared using Pro-Engineer Wildfire 5.0 modelling software. The sample models of lower punch, upper punch and die are shown in figures 2(a), 2(b) and 2(c) respectively. The relief given in the punch is usually given to reduce the area of contact between punch and wall of die cavity and thus minimizing friction and wear of both punch and die wall.

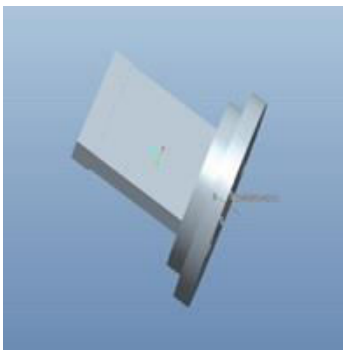

Fig. 2(a) 3D Model of Lower Punch

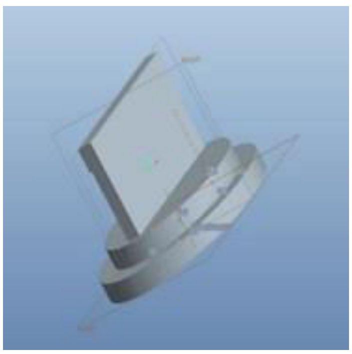

Fig. 2(b) 3D Model of Upper Punch

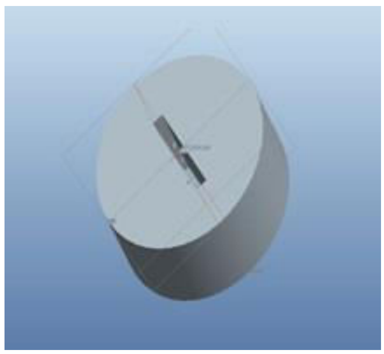

Fig. 2(c) 3D Model of Die

3. Fabrication

3.1 Turning

This operation is one of the most basic machining processes. That is, the part is rotated while a single point cutting tool is moved parallel to the axis of rotation. The starting material is 152.4 mm for the Die.

3.2 Facing

Facing in the context of turning work involves moving the cutting tool at right angles to the axis of rotation of the rotating work piece. This can be performed by the operation of the cross-slide, if one is fitted, as distinct from the longitudinal feed (turning).

3.3 Wire-cut EDM

Wire cut EDM is an unconventional machining process used to precise cutting of hardened metals by making the wire that passes through the material as cathode and work piece as anode in the presence of a dielectric. It is used to take the 75mm to 10mm slot in the die material as shown in the fig 3(b).

Fig 3(a) Programmed design for the slot

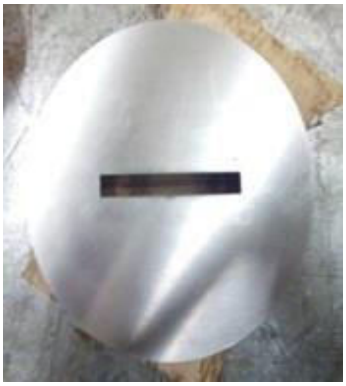

Fig 3(b) After EDM wire cut

Fig 3(c) After drilling and tapping

3.4 Drilling

Drilling is done on the punches in order to attach them to the collar using screws. It is shown in fig. 3(c)

3.5 Heat Treatment

Heat treating is a group of industrial and metalworking processes used to alter the physical, and sometimes chemical, properties of a material. Heat treatment involves the use of heating or chilling, normally to extreme temperatures, to achieve a desired result such as hardening or softening of a material. Heat treatment techniques include annealing, case hardening, precipitation strengthening, tempering and quenching. The die was hardened at 900˚C and soaked for 20 min and then oil quenched. The tempering was done for an average time of 45 min per inch of die thickness at 200˚C. The hardness of the die material after heat treatment was 62 HRC.

3.6 Surface Grinding

Surface Grinding is surface finishing process where a rotating abrasive wheel is made contact with the component. In this project it is used to differentiate the relief from the collar end in both the upper and lower punches is shown in the fig.4(a).The finished die and punches is shown in the fig. 4(b)

Fig 4(a) After Surface Grinding

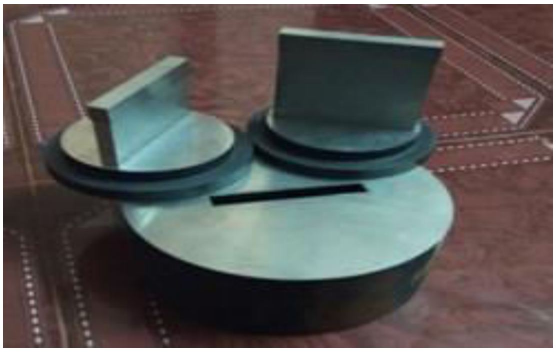

Fig 4(b) Finished Die and Punches

4. Analysis

4.1Finite Element Analysis using ANSYS

Thus designed die block was analysed for stress distribution using ANSYS 14.5.The analysis type was selected as structural with the element type as solid-concrete 65. The die block was exported as .igs file from Pro-Engineer and imported into ANSYS. The material properties given include Young's Modulus of $2.1 * 10^5$ MPa and Poisson's Ratio of 0.3. The model was meshed with SOLID65 tetrahedron with a size level of 4. The meshed solid is shown in figure 5(a). The die displacement was arrested in all directions outside the die and a pressure load of 700 MPa was applied on inside of the die. The stress distribution is showed in figure 5(b). The maximum intensity of stress was obtained to be 1091 MPa, which is less than the ultimate tensile stress of D3 tool steel (1158 MPa). The maximum deflection obtained is 0.19162 mm, which is acceptable.

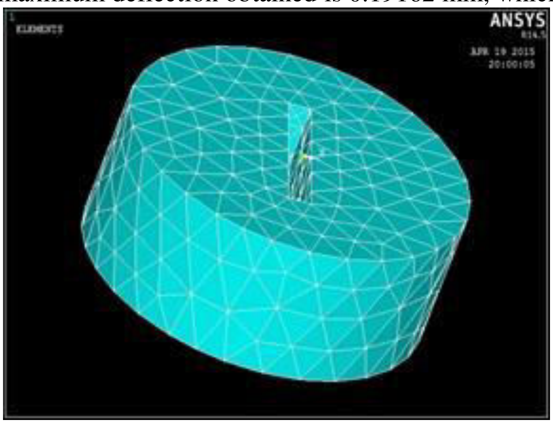

Fig 5(a) Meshed 3D model of Die Block.

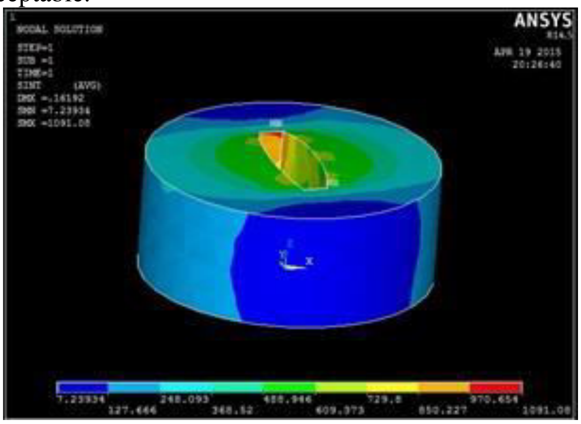

Fig 5(b) Displacement Analysis of the Die Block

5. Conclusion

In this project work, Design and fabrication of Impact die for powder metallurgy process was made according to the ASTM B925-08 standards. The failures such as bending of upper punch and lower punch during the application of load, and improper compaction of the powder materials were overcome. The die was made of higher grade material (AISI D3) which has better mechanical and thermal properties compared to die made up of other materials, chrome coating also reduced the friction between punch and die walls and made ejection of component easy.

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