

Redesign and Thermal Analysis of Rubber Compression Mould

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Abstract-This paper presents the redesign of a rubber compression tool for producing rubber sleeve moulded component for marine engine valve and performing thermal analysis for the mould to access deformation of tool, stress and strain. The guiding elements plays important role in damage free production of rubber specimens for mechanical and structural characterization. Defined the amount of preform needed for production and cure time. Selected compression tool material is cold work tool D2 steel. The technique, theory, methods as well as consideration needed in redesigning of compression moulded tool are presented. The model for redesign is done in NX 8.0 and the model for thermal deformation and thermal stresses due to working of tool at a high temperature and pressure is solved using commercial finite element analysis software called ANSYS WORKBENCH.

Keywords: Rubber compression mould tool, Thermal analysis, Preform, cure time.

I. INTRODUCTION

Compression moulding is a technique in which thermoset plastic or rubber compound (generally preheated) is placed in the heated open mould cavity, mould is closed under pressure, causing the material to flow and completely fill the cavity, pressure being held until the thermoset material has cured. The melting temperature of rubber is 150°C. Heat is then applied to the platen and by convection to the mould and elastomer. The elastomeric material spreads to fill the cavity because of the flow of the elastomer resulting from the applied pressure. After the suitable time the mould containing elastomer is cooled, either naturally or through forced convection of air or water in suitable drilled channels in the pressed panel. The mould is then opened to remove the component.

Davide S.A.et al. [1], designed interlocking metal parts that produce appropriately shaped cavities in which polymer specimens are moulded, and that are easily dismantled after moulding to allow removal of the specimens from the moulds. Several proposed designs have been manufactured and successfully employed in the production of rectangular specimens for characterization of a range of polymer.

Antoine Rios et al. [2], Computer added engineering tools allow at early stages of product design to predict and optimize mould filling, residual stress, and structural response and post processing shrinkage and war page of the final part. The use of these tools has been used to solve design problems at early stages and avoid expensive and time consuming trial-and-error procedures.

Abdulrahman El Labban et al. [3], and the vulcanization of rubber moulded parts is dependent upon the temperature history undergone any rubber points during the moulding process. Moon-Sun Kim et al. [4], Precharge location and dimensions that gives the significant effects on the mechanical performance of composite structure manufactured by the compression moulding. Controlling the material condition can eliminate flash, reduce the time difference between cavities, improve part quality, and widen the process window to ensure the mould runs at peak manufacturing efficiency.

S.H.Tang et al.[5] conducted the thermal analysis due to uneven cooling of the specimen was developed

solved using FEA software this gives temperature distribution for the model and also temperature variation through the plastic injection moulding cycle by plotting time response curve. The results shows shrinkage is occur in the region near the cooling channels compared to other region.

SooHong Kim. [6] Did the induction heating analysis to detect temperature distribution on mould surface. The analysis showed results of surface temperature distribution with different number of coils. This leads to the concluded that increasing the number of coils and input current would be able to get uniform surface temperature distribution as well as rapid temperature increase.

Above all papers explained about moulding, mould filling and orientation of fibers here we are maintaining uniform thickness of flash produced around the mould, flash reduction and curing time required for the elastomer. And some papers explained the thermal residual stress due to uneven cooling, temperature distribution on surface by induction heating, temperature control during moulding, temperature distribution between the tool and mould, cooling channels and residual stresses. Here we have considered the thermal deformation of tool under temperature and uniform surface pressure.

II. MODELING

2.1 Modeling

Modelling is done according to the positive horizontal flash type; here mould produces a vertical flash in the direction of moulding pressure. The clearance between the plunger and the cavity is 0.2-0.3 mm. 2° taper on core (plunger) side. There are some flash grooves of 0.2 mm deep, 2.5 mm wide space provided to facilitate the removal of excess material. Guide pillars and bushes are introduced as per the standard available. The modeling is done in NX8, MOLD WIZARD with reference of CIPET data handbook Chennai.

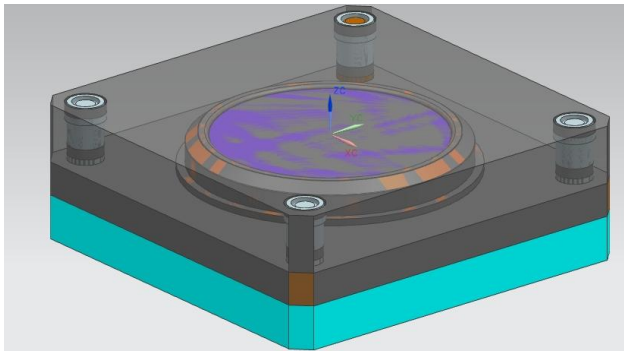


Fig.2.1 3d model of tool

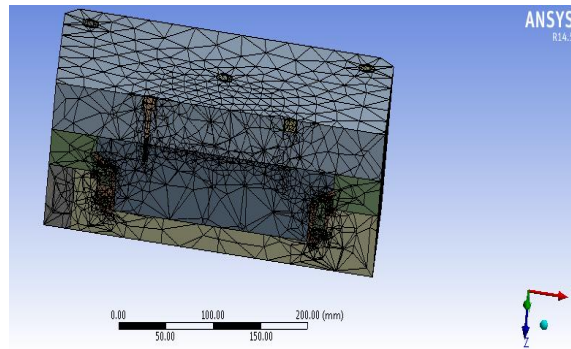


Fig.2.1 Tool geometry mesh

2.2 Preform

Preforming is a method of cold pressing granular moulding compound into cavity. The preform provides an easy way to handle the mould charge both for preheating and for charging the mould. The preform can be round, square or rectangular edge. In order to achieve void free moulding specimen between 15% to 20% excess polymer is typically loaded into the cavities. This intern reduces the amount flash. The removal of specimens after the moulding is aided by gently cutting through the around the edge of the specimens with a sharp blade.

Weight of the preform (shot weight) = weight of component + 10 to 15% of weight of component.

2.3 Wall thickness of core / cavity inserts:

Criterion - strength of materials;

$$\text{Insert wall thickness } t = \sqrt[3]{\frac{CPD^4}{Ey}} \quad (1)$$

C = Constant based on ratio of cavity length to depth, = 0.111

P = Cavity pressure = 93 kg/cm²

D = Depth of cavity wall = 3.766 cm

E = Modulus of elasticity = 2.1 × 10⁶ kg/cm²

y = Permissible deflection for the insert, = 0.005 cm

$$t = \sqrt[3]{\frac{0.111 \times 93 \times 3.77^4}{2.1 \times 10^6 \times 0.013}} \text{ cm}$$

$$= 0.45 \text{ cm}$$

$$= 5 \text{ mm}$$

Taken **10 mm** as minimum

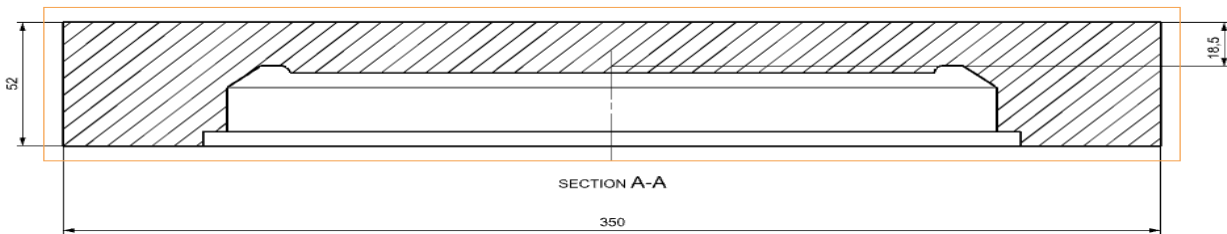


Fig. 2.4 cavity plate

2.4 Cure Time

$$\begin{aligned} \text{Total cure time} &= \text{maximum thickness of the component} \times \text{curing time of neoprene per mm} \\ &= (22 \times 60) \\ &= 1320 \\ &= 22 \text{ minutes} \end{aligned}$$

So curing time is completely depends on maximum thickness of component and curing time of the elastomer per mm if it is more that effects the electrical and physical properties of the material.

III. ANALYSIS

The finite element analysis was carried out observe the deformation, stress and strain development in tool. Ansys 14.5 workbench was used to analyze the behaviour of the d2 material under surface pressure and 150°C operating temperature. Observation of results gives the idea where we need to concentrate while designing the compression mould tool.

3.1 Material Properties

The following table shows the Tool Steel (D2) and Mild Steel material properties.

Properties	Materials	
	Cold work tool steel (D2 material)	Mild Steel
Density (Kg/m ³)	7600	7850
Coeff. Of thermal expansion (C ⁻¹)	1.2E-5	1.13E-5
Reference Temperature (⁰ C)	30	30
Young's Modulus (Pa)	1.8E+11	2.1E+11
Poisson ratio	0.3	0.3
Thermal Conductivity (W/mc)	23	46
Tensile Yield Strength (Pa)	1.65E+09	2.5E+08
Compressive Yield Strength (Pa)	1.65E+09	2.5E+08
Tensile Ultimate Strength (Pa)	3E+09	4.6E+08

Table 2.4 Material properties

IV. RESULTS AND DISCUSSIONS:

Redesign of tool is done for proper alignment by introducing guide pillar and bush with screw and fit. Dimensions of bush and pillar are given according to Central Institute of Plastics Engineering and Technology, Ministry of Chemicals and Fertilizers, Chennai by considering plate thickness. Alignment gives the uniform thickness of the component as well controls the uniform flash thickness around the component.

Amount of perform is defined by considering various allowance like shrinkage and flash. 10 to 15% of extra material is added to achieve void free moulding specimen. If it is extra simply material will waste in the form of flash.

Deformation and stress distribution under pressure and temperature shown in below figure 4.1(a) and 4.2(b). Deformation is maximum at the edges near the centre is more so it is important to increase the strength of ring locator plate if you increases the thickness or margin of plate strength of the plate will increases. there is no problem with stress they are all below the below the maximum stress.

It is important to reduce the deformation, stress concentration in the plate to increase its life; it is done by two methods.

1. Changing the dimensions of plate like thickness and margin and selecting the appropriated one.
2. Change the material properties and check the results.

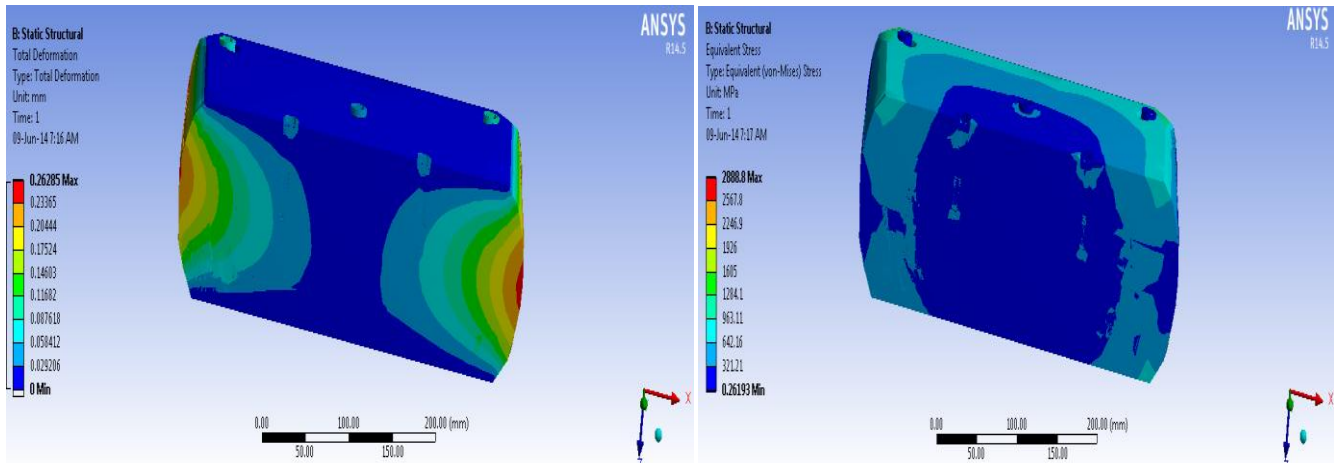


Fig 4.1(a) deformation

fig 4.1(b) stress

V. CONCLUSION

From the result it is necessary to redesign of the compression mould tool by introducing guide pillar and bush for proper arrangement. Wastage of material in the form of flash can be reduced by introducing definite amount of preform. Deformation of the tool plate is more at the guiding holes side so it is necessary to find the deformation at various thickness and margin. The thermal analysis of compression moulded tool has provided an understanding of thermal deformation and thermal stresses induced. Need to do thermal analysis for various thickness and margin of plate and choose the appropriate one and also need to check deformation for other material properties.

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