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Design Of Automatic System For Opening And Closing Of Mould And Core In Gravity Die Casting Machine

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ABSTRACT

Gravity Die Casting (GDC) process is capable of making complicated components, such as wheels, cylinder heads, engine blocks, brake callipers etc. at lower cost than most other casting processes. A hydraulic system is designed for controlling the opening and closing movements of casting dies and release and fitting of core/punch to the die, easy removal of punches from die for cleaning purpose. Guiding system has been designed for smooth movement of dies and punches. The proposed system would improve the production rate. Different components of the system have been designed analytically and static analysis of the designed components have been carried out using FEA software ANSYS. Static analysis results for total deformation and equivalent (von Mises) stresses are compared with standard values. Due to high temperature of die, machine components near die are subjected to heat. Therefore, these components are analysed using coupled thermal and structural analysis. The results for directional heat flux and total deformation are compared with standard values and found within the safe limit. Designed system would reduce the dependence on skill of labour and reduce heat loss.

Keywords: Gravity Die Casting (GDC), Hydraulic system, Guiding system, FE Analysis.

I. INTRODUCTION

Die casting is performed to manufacture of various products namely wheels, cylinder heads, engine blocks, brake callipers. Die casting is adequate for mass production and has the advantage of being able to yield complicated shapes accurately with a smooth casting surface. It is also possible to save materials in comparison with sandbox casting. Die casting is an important industrial process used for the production of large quantities of intricate components. The quality of the castings produced, in terms of surface finish, depends on a number of interrelated factors including temperature and fill pattern [1].

II. LITERATURE REVIEW

2.1 Die casting moulding cycle and hydraulic system

Die casting machine have horizontal movement of dies. There are eight significant actions occur in Gravity Die Casting (GDC). These are punch fitting, mould closing, clamping, idle-1 (for pouring/ holding), release punch, mould open, idle-2 (removing casting, cleaning). The following discussion will explain the purpose of each machine action and requirement of the hydraulic system for the same have been explained in the nest section.

- Punch fitting

During this stage punch/core is moved in to die for producing hollow portion in casting.

- Mould close

During this stage mould/die havles are closed for pouring purpose, necessary clamp pressure is generated using hydraulic cylinder and power pack,

- Clamping

After closing of die, clamp pressure is generated by hydraulic system for preventing molten metal leakage,

- Idle-1 (for pouring/ holding)

During this stage main machine components are remain in idle condition for pouring and solidification of molten metal, the duration of this stage depends on part characteristic such as wall thickness and total size,

- Release punch

During this stage punch/core is moved out from dies or mould for removing casting from dies,

- Mould open

During this stage, mould or die halves are opende for allowing casting to remove form GDC machine,

- Idle-2 (removing casting, cleaning)

During this stage, machine stays in idle waiting for the casting removal manually, once the casting is removed, the mould is sprayed with a mixture of die lubricant and water. This is done to ensure easy part release from the mould, to limit the wear on the dies halves, Duration of this period vary depending upon process parameters and method of part removal [2].

2.2 Die plates

Die plates are the important components in a GDC machine. For horizontal movement of dies, machine usually have three plates; a stationary, a movable and a real plate. These are usually made of mild steel, cast steel or ductile iron and they are designed for maximum stress as per application.

2.2.1 Stationary plate

The stationary plate is the closest to the injection unit and having provision for the punches or core to pass through it. It is the part of an automation system which provides horizontal movements to the dies halves and punches. The stationary plate may be either stress or deflection limited depending on the size of the mould. The plate is usually deflection limited for a large mould and stress limited for a small mould.

2.2.2 Movable plate

Punch or core is usually stopped or guided using movable plate. Tie rod bushings are provided for smooth movements of the moving plate. Tie rod bushings are usually not used to support the weight of the moving plate and mould except in small machines, instead, shoes are provided for that purpose. These shoes usually ride on a smooth and lubricated surface way made of high carbon spring steel attached to the machine base; most of the manufactures provide adjustable shoes with replaceable wear pads.

2.2.3 Rear plate

Rear plate is remain stationary and it is attached with the structure. Hydraulic cylinders are mounted with rear plate [3].

2.3 Tie rod bushing

Bushes are generally provided in the moving plate. These bushes help in guiding the moving plate laterally as it opens and closes the mould. A loose running fit is used between the rod and bushing. A loose running fit is used in the tie rod bushes to allow for tolerance stack-up that occurs during gravity die casting. Allowance must be made for tolerance in the tie rod hole location, tie rod diameter, lack of tie rod straightness and sag in the tie rod due to its own weight. Bronze bushes with oil or grease lubrication are the most common design. Parallelism between the moving platen and the stationary plate is important to reduce wear on the mould leader pins and to insure proper tie rod loading [4].

2.4 Vibration analysis of horizontal beams

Treyssede [5] developed an analytical model for the vibration analysis of horizontal beams that is self-weighted and thermally stressed. Geometrical nonlinearities were taken into account on the basis of large displacement and small rotation. Natural frequencies were obtained from a liberalization of equilibrium equations. Thermal force and thermal bending moment both were included in the analysis. Torsional and axial springs were considered at beam ends, allowing various boundary conditions. For thin structures such as beams, the effect of prestress was enhanced by the slenderness ratio, so that even low pressurised states far from the buckling stage may have a significant impact on dynamics. For self weighted vertical beams, the load was also purely axial, though non-constant, and some linear analysis can be found. The effects of temperature on the modal behaviour of horizontal beams taking into account self-weight, as well as cables taking into account bending stiffness was investigated [5].

III. DESIGN AND ANALYSIS

3.1 Analytical design

In this work die plates are designed and selection of hydraulic cylinder has been made for the proposed system. The die plates are analytically analysed for bending stress and deflection. It is found that both bending stress and deflection are well below the permissible values. Result of analytical design for die palates are shown below.

Table 1, Analytical design of machine components

Sr.No.	Components	Bending stress (N/mm^2)	Deflection (mm)
1	Big punch side die plate	73.57	0.0077
2	Small punch side die plate	65.23	0.0069

3D model of hydraulic system has been prepared incorporating casting die's closing and opening motions, easy removal of punches from die for cleaning purpose and guide way system for smooth motion. The proposed model reduces labours required for the die casting and improves production.

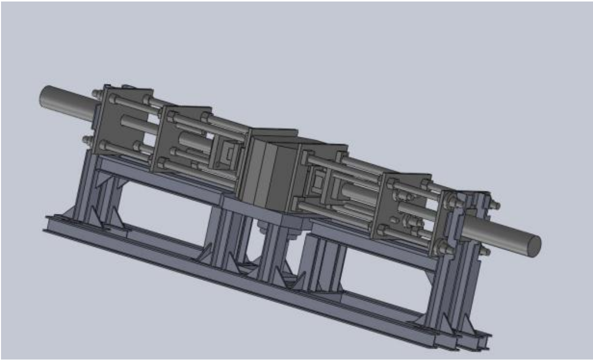

Fig. 1 Propose model for GDC machine

Static analysis of different components of the proposed system namely die plates, base structure, punch arrangement are carried out and same is explained in the next section for comparing analytical values with FE analysis.

3.2 Linear static stress analysis

Linear static stress analysis has been carried out to look into the stress and deformation pattern of the plates under static loading condition. For static analysis, the fixed boundary condition is applied to the suspension mounting surface area of the plate since the locations do not allow any translation and rotation. When the assembly is stationary, the weight of components and payload are applied to the surface of the plate as a force.

3.2.1 Die plates

For the ease of meshing fine fillets and chamfers are deleted. For the die plate, total deformation and equivalent (von Mises) stress are shown in the Figs. 2 and 3 respectively.

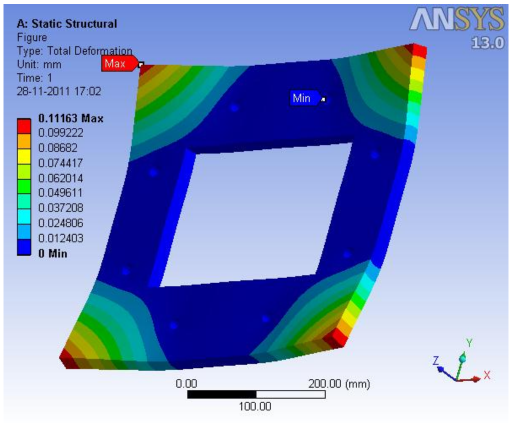

Fig. 2 Total deformation of die plate

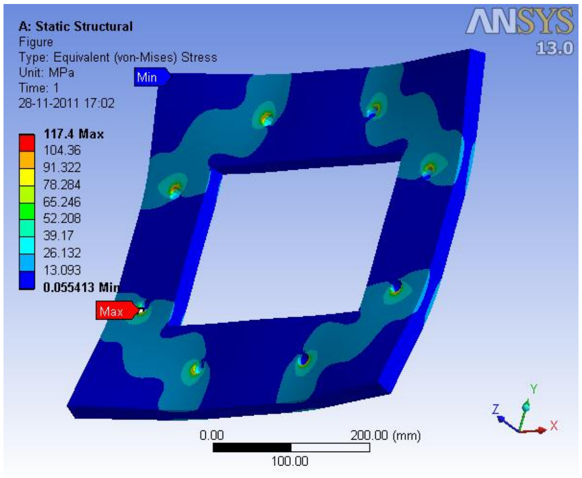

Fig. 3 Equivalent (von Mises) stress for big punch side die plate

3.2.2 Base structure

Base structure is one of the important parts in GDC machine, because forces applied by all hydraulic cylinder and also total weight of the machine are finally transferred on the base structure. For the ease of meshing fine fillets and chamfers are deleted. The constraints and loads, total deformation and equivalent (von Mises) stresses produced on the base structure are shown in Figs. 4, 5 and 6 respectively.

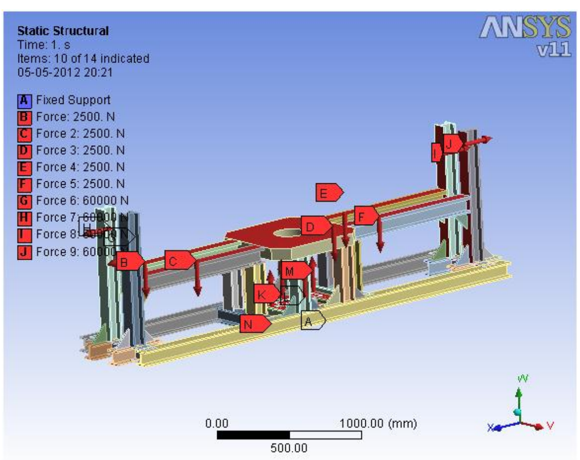

Fig. 4, Constraints and loads for base structure

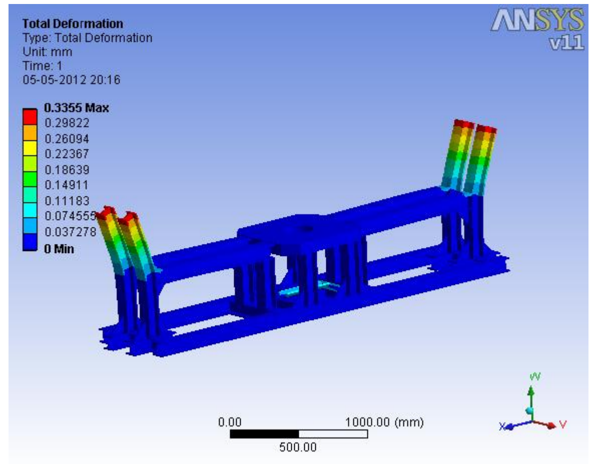

Fig. 5, Total deformation of base structure

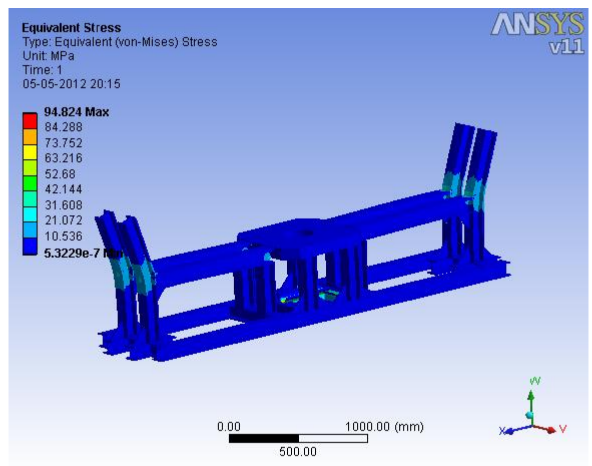

Fig. 6, Equivalent (von Mises) stress of base structure

3.3 Coupled thermal and structural analysis

Die plates are important components in GDC machine. Thermal analysis of die plates has been carried out to understand the effect of the heat. It has been observed that the die temperature is about 300 ºC. The total heat flux and total deformation for the die plates are shown in the Figs. 7 and 8 respectively.

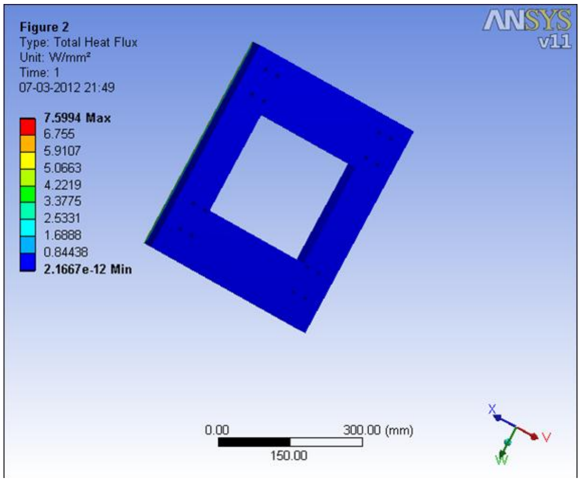

Fig. 7, Total heat flux for die plate

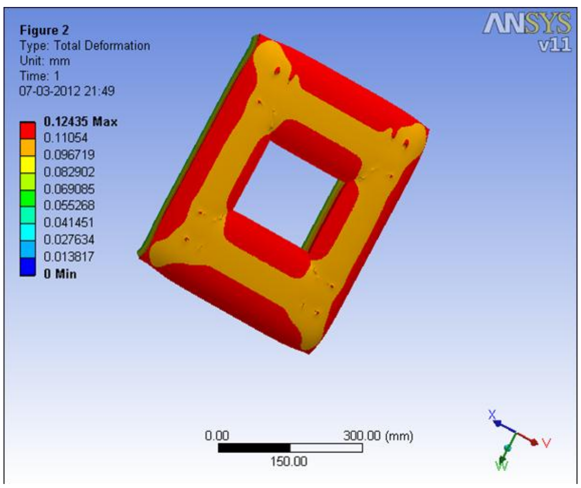

Fig. 8, Total deformation for die plat

Linear static stress analysis and coupled thermal and structural analysis of different components are carried out using FEA software ANSYS. Boundary conditions are applied in accordance to actual production condition observed on in GDC machine. Table 2 shows the static analysis results for total deformation and von Mises stresses values of various GDC machine components like big punch side plate, small punch side plate and base plate which are analyzed under the maximum loading condition.

Table 2, Static stress analysis results

Components	**Total defor - mation (mm)**	**Von Mises Stress (N/mm²)**
Big punch side plate	0.11	117.4
Small punch side plate	0.10	130.8
Base structure	0.33	52.95

Table 3 shows coupled thermal and structural analysis for total heat flux and total deformation of various GDC machine components.

Table 3, Coupled thermal and structural analysis result

Components	Total heat flux	Total deformation (mm)
Big punch side plate	7.59	0.12
Small punch side plate	6.93	0.12
Base plate	0.59	0.65

IV. CONCLUSION

3D model of hydraulic system has been prepared which provides opening and closing motion to the dies and punches. The proposed model also includes guide way system for providing parallelism in the movements of dies and punches.An important components of GDC machine have been designed analytically and analysed using FEA software ANSYS. It is found that results for total deformation and equivalent (von Mises) stresses values are well under permissible limits for these components. Due to high temperature of die, machine components near die are required to be thermally analyzed and it is found that results for directional heat flux and total deformation are well under permissible limit for these components.

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