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Design and Development of Clamping and Ejection systems for Mould used on Gravity Die Casting Machine

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Abstract: Die casting industry is under fierce competition around the world. Die casting Manufacturers have to compete not only with other die casting companies but also with plastics and composite materials processing industries. In order to survive and become competitive, manufacturers are forced to streamline and optimize their individual manufacturing processes. Gravity die casting process is labour intensive and expensive. Streamlining the process and automation helps in reducing the production cost and the process lead time. The key is identification of the areas that need automation and solutions to strategic as well operational issues need consideration. Manufacturing process also needs refinement to utilize the advantages of automation. In this paper authors describe an attempt has been made to obtain optimal setting of the gravity die casting process parameters on present system to increase the yield of the process. To improve the process, hydraulic clamping and ejection systems have been designed for the mould to replace manual operations. The newly designed system needs minimal resources in term of space, cost and maintenance. The system not only reduces the time but improves quality due to repeatability in casting process. It also reduces reliance upon skilled labour. Design of various components of hydraulic Clamping and ejection systems namely C clamp, couple shaft, Ejector rod, clamping pin, guide support have been carried out. Finite element analysis of critical components has been carried out using ANSYS. The work also includes design of Guide-bar fixture. 3D components, assembly and in addition 2D manufacturing drawing of Couple shaft, C Clamp, Supportive Guide have been prepared using Creo Element ProE 5.0 and Auto Cad software.

Keywords: *Gravity die casting, Hydraulic Ejection and Clamping system, Guide- bar fixture.*

1. INTRODUCTION

The increasing number of applications and of products is the best proof of the success of Aluminium alloys foundry. This is probably one of the most dynamic fields inside manufacturing and engineering industries. The well-known advantages associated to the use of Aluminium alloys (light weight, good mechanical behaviour, good corrosion resistance, etc.) constitute the driving force for the introduction of new applications and design and on the other hand, for the development of new processing solutions1. Various processes are now competing, to achieve both economically and technologically advantageous production of Aluminium alloys castings. The general scenario is described in a quite wide literatureand is schematically shown in Fig 1 (part-process-weight chart).

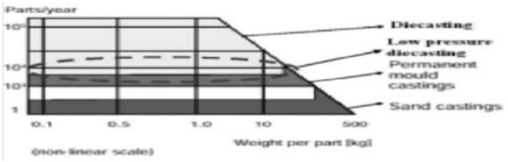

*Figure 1:*Field of convenience of foundry process as a function of production rate and casting weight

GDC is the main product of the firm where this project has been carried out. Total 12 number of workers including skilled and unskilled labour are required for the process. Rate of production and quality of production decrease significantly due to fatigue. Unskilled labours increase chances of rejection due to bending in casting during ejection from mould.

I. LITERATURE REVIEW

Two different ejection methods used, one uses conventional ejector pins and the other uses a conformal ejector pad**[1].**The tool surface roughness is measured before and after moulding to observe any change caused by ejection. Results show that ejector pins require a lower ejection force than a conformal ejector pad and this may contribute to longer tool life forthe AIM process. The forces recorded using ejector pins increased as expected with longer cooling times however, this was not the case with pad ejectors. Onepossible reason for the higher ejection forces using pads is that air is not able to fill the void between the mould and moulding at the early stages of ejection. An equation predicting the ejection force based on various material properties of the mould and moulding has been developed by Glanvill and Denton **[2].** The equation is based on ejecting a tube from a core. The use of a tube rather than a closed cylinder like the one used in this research is significant as the ejection force will not need to overcome a partial vacuum between the mould and moulding.

The equation is given as:

$$\mathrm{F_e} = \frac{\alpha(\mathrm{T_m} - \mathrm{T_e}).\,\mathrm{DEA}\mu}{\mathrm{D}[{}^{\mathrm{D}}/_{2\mathrm{t}} - ({}^{\mathrm{D}\gamma}/_{4\mathrm{t}})]}$$

…..[1]

Where:

F_e= Ejection Force
α=coefficient of thermal expansion of moulding
material
T_m= melting temperature of moulding material
T_e= ejection temperature of moulding material
D = diameter of core
E = Young's Modulus of moulding material at T_e
A = Area of contact between core and moulding in
direction of ejection
m = coefficient of friction between moulding
material and core
t = thickness of moulding
γ =Poisson's ratio for moulding material

The wrench torque required to develop the specified preload is estimated by using some methods such as the turn-of-the-nut, pneumatic-impact wrenching, and torque wrenching**[3].** Although the coefficients of friction may vary widely, there is a good estimate of the torque required to produce a given clamping force using an analytical formula presented by Eq. (2):

$$F_{cl} = \frac{T}{kd_{bolt}}$$

….[2]

In this equation, T is the torque (N-m), F_{cl} is the initial clamping force (kN), d_{bolt} is the bolt nominal diameter (mm), and K is the torque coefficient defined as the term which depends on friction coefficients, lead and thread angles, and mean diameter of the bolt. However, the coefficient of friction depends upon the surface smoothness, accuracy, and degree of lubrication **[3].** Therefore, it is needed to find out the precise coefficients to calculate K in order to use this formula for determining the clamping force in bolted connections. However, the torque coefficient of 0.20 is usually used when the bolt condition is not stated **[4].** It was also found that the mean coefficient of 0.208 is suitable for both lubricated and unlubricated bolts, according to the result of tests conducted by Blake and Kurtz **[5].**

J.Z. Luo and T.G. Liu presented three-dimensional analytical formulation for axially symmetrical homogeneous isotropic circular plates.The axially symmetrical homogeneous isotropic circular plate under uniform transverse as shown in fig 2 load is made of an isotropic material with Young's modulus E and Poisson's ratio m. U, V and W stand for the displacements in the radial, circumferential, and axial directions, respectivelyobtain solutions of the stresses

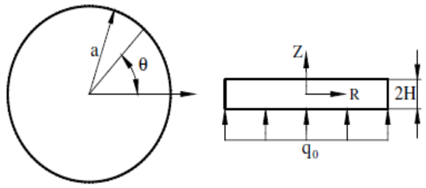

*Figure 2:*Geometry of a circular plate under uniform transverse load.

$$\sigma_r = q_0\Big[\frac{2+v}{8}\frac{Z^3}{h^3} - \frac{3(3+v)}{32}\frac{r^2Z}{h^3} + \frac{3Z}{32h^3}\left(1+v-\frac{8h^2}{1-nu}\right) - \frac{v}{2(1-v)}\Big] \quad \ldots [3]$$

$$\sigma_\theta = q_0\Big[\frac{2+v}{8}\frac{Z^3}{h^3} - \frac{3(1+3v)}{32}\frac{r^2Z}{h^3} + \frac{3Z}{32h^3}\left(1+v-\frac{8h^2}{1-u}\right) - \frac{v}{2(1-v)}\Big] \quad \ldots\ldots [4]$$

$$\sigma_z = q_0\left[\frac{-Z^3}{4h^3} + \frac{3Z}{4h} - \frac{1}{2}\right] \quad \ldots. [5]$$

$$\tau_{rz} = \frac{-3q_0r}{8h^3}(h^2 - Z^2) \quad \ldots\ldots [6]$$

Above equation are used for the design of circular plate for the guide fixture assembly.

II. PROCESS STUDY

An Ishikawa diagram (cause and effect diagram Fig. 3) has been constructed to identify the casting process parameters that may affect the casting quality. The process parameter can be listed in four major categories as follows:

- die machine related problem
- die design related problem
- labour related problem
- cast metal related problem

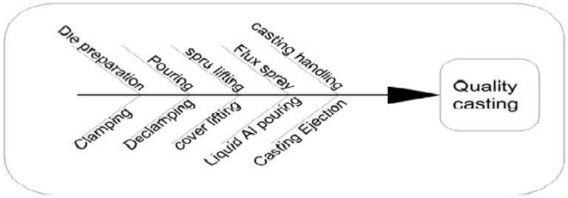

*Figure 3:*Ishikawa diagram for the various activity of GDC process

Timing of various activitiesof GDC process has been studied and graph has been prepared on the basis of average recording. Fig 4 shows the comparison graph between activities time vs. number of casting.

By observing process parameters, three activities i.e. clamping and declamping of die plate and ejection of casting take makeable time in whole production process.

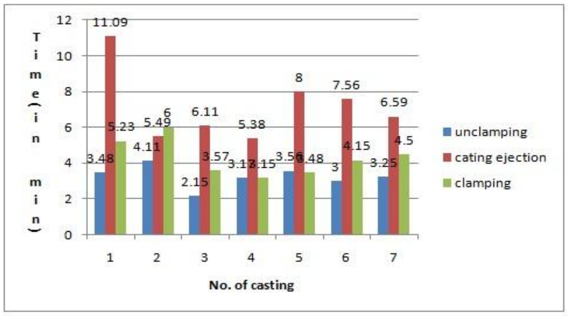

Figure 4: Graph chart between process parameters and number of Casting

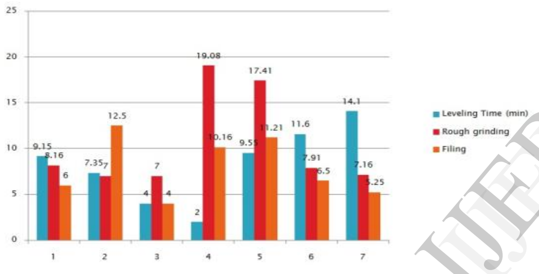

Figure 5: Bar graph chart between machining process parameters and number of casting

By plotting various activities of production process, it has been concluded that most time consuming activities are ejection of casting, clamping and declamping of GDC cover plate(mould). Therefore, automation can be done for these three processes. By plotting graph between rough machining process parameters and number of casting, it has been concluded that levelling process take significant time, this is because casting will bend during ejection from mould. By using four cylinders for ejection of casting cause uneven lifting of ejection plate that will produce bending in casting. Therefore levelling process takes significant time. So new way has to be design by which one can eject casting by using single cylinder. If movement of ejection plate is carried out by single cylinder, uneven weight of casting made inclined of ejection plate which causes bending in cylinder which turns into wear-out of hydraulic seal.

III. DESIGN AND ANALYSIS

For the automation of clamping and ejection of die plate, clamping and ejection system has been designed which will operate on hydraulic actuator. Clamping and ejection assembly consist couple shaft, couple nut, guide shaft, clamping pin and clamp. For proper ejection of casting and the linear movement of ejector plate guiding fixture has been designed. Guiding fixture of hydraulic cylinder consist of six guide rods, six bushes, upper plate and lower plate. Table 4.1 show the diameter of shaft and rod calculated from analytical solution. Force of 2 T required for the clamping and force of 1.6 T for the ejection of plate which has been used for determination of size of hydraulic cylinder. Table 4.2 shows material selection of various parts of clamping and ejection assembly.

Table1: Derived Dimension of Ejection and Clamping Assembly

Part	**Safe Diameter**
Coupling Shaft	18 mm
Coupling Nut	18mm
Guide Rod	30mm
Clamping clip/ pin	13.58mm

Table 2: Material selection

Part	**Material**	**Indian Equivalent grade**
Coupling Shaft	Mild Steel (AISI 1018)	IS C14
Coupling Nut	Mild steel (AISI 1018)	IS C14
Clamp	Mild Steel (AISI 1018)	IS C14
Guiding Rod	EN-24	IS 40NiCr$_4$Mo$_3$
Clamping Clip	Silver Steel (BS 1407)	IS 4957

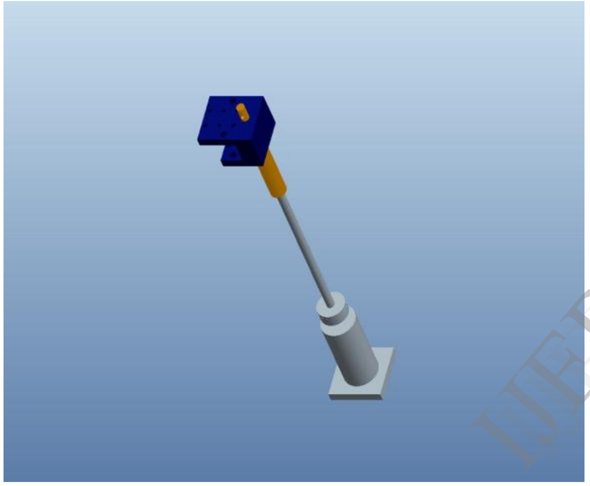

Figure 6: 3D model of clamping and ejection assembly

Linear static stress analysis has been carried out to look into the stress and deformation pattern produced in the shaft under static loading condition. For static analysis, the fixed boundary condition is applied to the suspension mounting surface area of the shaft since the locations do not allow any translation and rotation. When the assembly is stationary, the loads from the weight of components and pay load is applied to the top surface of the shaft as a force.

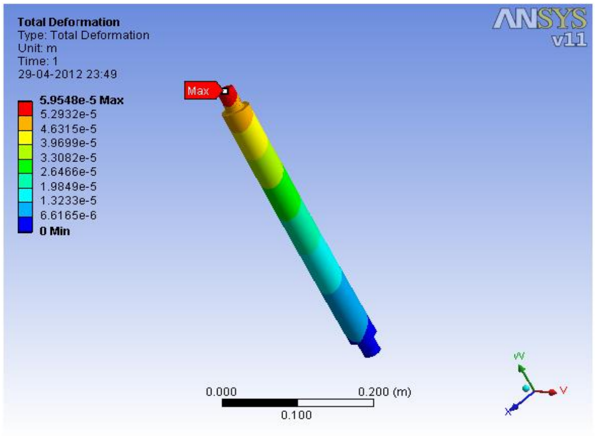

Figure 7: Total deformation of couple shaft

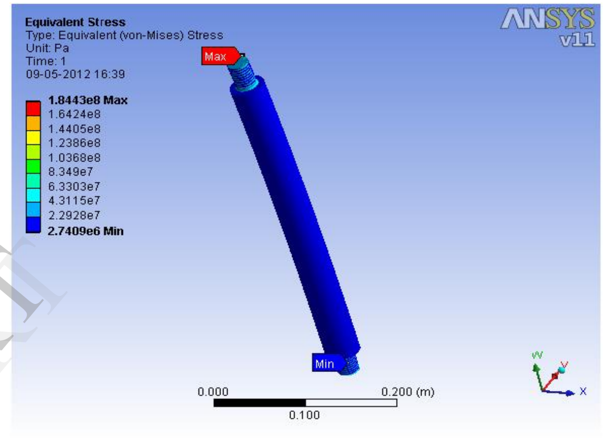

Figure 8: Von-Mises Stress of couple shaft

Since maximum displacement (Fig 7) is under allowable condition of motion of assembly i.e. couple shaft work without any error, therefore it is also validate from analytical solution. Maximum stress is (Fig 8) in less than the yield stress of Mild Steel i.e. under permissible limits, so derived dimension of design is in safe working condition. Clamp is in direct touch with the die cover plate, so there will be changed in dimension due to thermal effect and loading condition. Therefore clamp has been studied on the basis of thermal and structural couple analysis.

By going through the Finite element analysis, following results are obtain:

- Maximum displacement=0.084723 mm
- Minimum displacement= 0 mm

Since maximum displacement is of 0.084723 mm. So, guiding tolerance of 1 mm is added in clamp i.e. increase the dimension of hole by 1 mm, so there will no problem of interference arise due to thermal displacement.

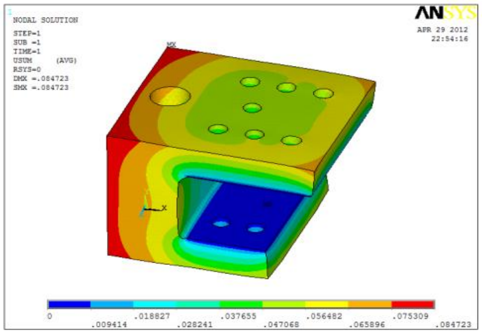

Figure 9: Thermal linear displacement

Linear static stress analysis is used to look into the stress and deformation pattern produced in the upper plate under static loading condition.

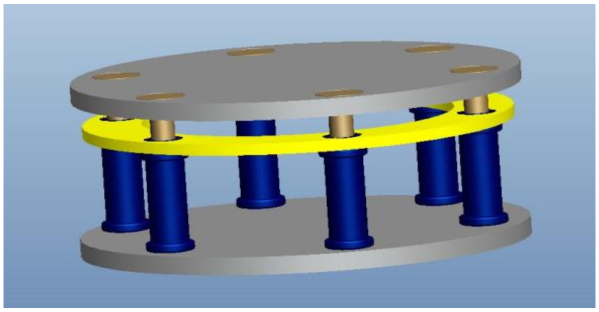

Figure 10: 3D model of guide fixture assembly

Since maximum displacement is under allowable condition of upper plate i.e. assembly will work without any error, and it is also validate from analytical solution. Maximum stress is in less then the yield stress of Mild Steel i.e. under permissible limits, so derived dimension of design is in safe working condition.

Maximum displacement=0.0483 mm (Fig. 11)

Minimum displacement= 0 mm

Minimum Von Mises Stress = 26641 Pa (Fig. 12)

Maximum Von Mises Stress = 5.7×10^7 Pa

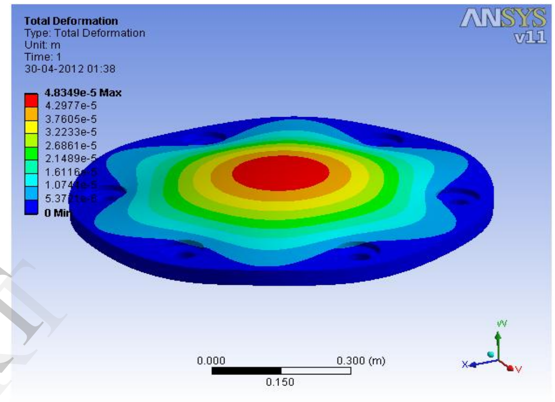

Figure 11: Total Deformation of upper plate of fixture

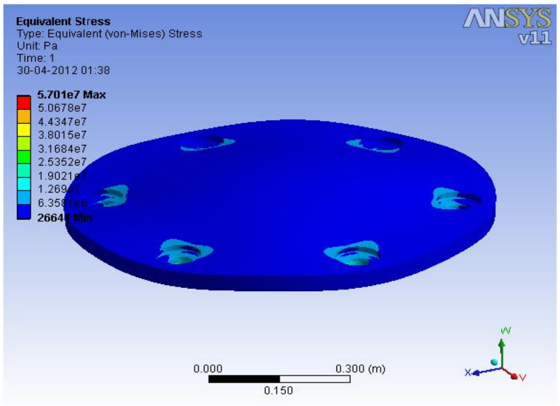

Figure 12: Von-Mises Stress of upper plate of fixture

IV. RESULTS AND DISCUSSION

Timing of activities of GDC process has been observed after the use of newly designed clamping and ejection assembly and guide fixture assembly.

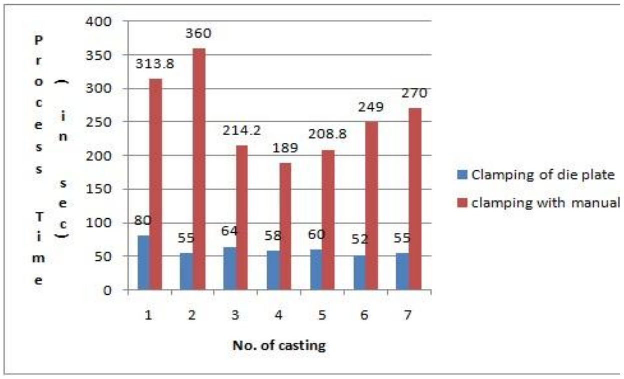

*Figure 13:*Graph showing process time of clamping of die plate

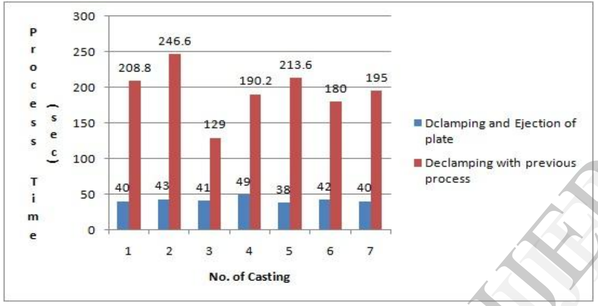

*Figure 14:*Graph showing process time of declamping of die plate

Fig 13 and Fig 14 shows compression between the timing of clamping and declamping of die plate before and after implementation of newly designed assembly. The implementation of new design shows that activities time has been reduced by significant percentage. Due to hydraulic arrangement of clamping and ejection of plate, process time and labours will save which increase in production. Due to automation repeatability of process has been increased, so there has been less chances of rejection in casting. Movement of ejector plate become smoothing in linear manner, so there are less chance of bending of casting during ejection process of casting from mould.

V. CONCLUSION

- From the various process parameters of production process, it has been observed that most time consuming activities are ejection of casting, clamping and declamping of GDC cover plate (mould). Therefore, automation has been carried out for these three processes.
- By plotting graph between rough machining process parameters and number of casting, it has been observed that levelling process take significant time, this is because casting will bend during ejection from mould.
- Hydraulic cylinder fixture with six guide bar, which will guide telescopic cylinder for linear movement and it will protect wear-out of cylinder seal.
- From FEA it has been observed that maximum displacement is under allowable condition of motion of assembly i.e. couple shaft work without any error, therefore it is also validate from analytical solution. Maximum stress is in less than the yield stress of Mild Steel i.e. under permissible limits, so derived dimension of design is in safe working condition.
- From thermal and structural couple FEA, maximum displacement is found under dimension of 0.084723 mm. So guiding tolerance of 1 mm is added in clamp i.e. increase the dimension of hole by 1 mm, so there will no problem of interference arise due to thermal displacement.
- Various activities timing has been observed after use of newly designed

clamping and ejection assembly and guide fixture assembly shows that, activities time has been reduced by significant percentage.

- Due to hydraulic arrangement of clamping and ejection of plate of die process time and labour will save which cause in increase in production.
- Due to automation repeatability of process activities has been occur, so there has been less chance of rejection in casting.
- Movement of ejector plate has been occurred in linear smooth manner, so there are less chance of bending of casting during ejection process of casting from mould.

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