Implementation of Product Lifecycle Management in Small Scale Foundry in the Area of Product Design-A Case Study

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Abstract **Product design is one of the primary functional areas of Product life cycle management (PLM). PLM cater and encompasses all the significant areas of Product design and development data management. This allows the firms to address the core area of strong Product development without which the firms would not be able to secure a front position and create a position themselves in the market. Computer-aided design (CAD), Computer Aided Engineering (CAE) and Computer Aided Manufacturing (CAM) are integral part of product lifecycle management.This Paper explains in detail the benefits of implementing the PLM in small scale foundry in the area of product design. A case study is carried out on designing of the high pressure die casting (HPDC) product using a PLM tool i.e., CAX software. Initially the 3D modelling of the product was done using CATIA V5 and Z-CAST PRO software is used for simulation and the results obtained were analyzed.**

Keywords* — *CAX software, High Pressure Die Casting, Product Life cycle Management, Product design, Small Scale Foundry

I. Introduction

The main Product lifecycle management (PLM) is a software facilitated approach to perk up processes to develop a thought, design, develop and handle products to coerce elevated levels of manufactured goods profitability [1]. PLM is an incorporated suite of applications that facilitate companies look up product novelty, product improvement and engineering performance. PLM affiances to develop the design environment by providing an incorporated sight of manufacturing engineering and the resources available in the firm. PLM superimposes an unswerving set of business solutions in maintaining of joint conception, use of product definition information and management [2]. The heart of PLM is the conception and innermost administration of all manufactured goods statistics and the technology used to contact this information and acquaintance [3]. The challenges like increasingly superior spotlight on modernization and time-to-market suppleness, that were once stumbling blocks for the largest manufacturers are now bearing down on Small scale manufacturers as they seek to optimize product development and manufacturing processes in an effort to gain a gung ho edge [4]. In many companies the Operational management getting improve with PLM because groups all across the value chain can work quicker and more efficiently from side to side advanced information retrieval, electronic information sharing, dealing with large variety of processes, product scrutinizing, the supervision of change orders, bill of materials, and trait regulation. With all the functionality that is available, it is significant to decide shrewdly. PLM as a subject materialized from paraphernalia such as CAD, CAM, CAE and PDM, but can be out looked as the assimilation of these tools with techniques, groups, and the processes from side to side all phases of a product's life [6]. It is not only concerning to software expertise but it is also a trading approach. When, developing High Pressure Die Casting the casting arrangement the design should be considered based on the connection among introduction of molten metal into the die, casting condition, gating system, and cooling system [11]. In current casting companies, the design and development of a casting layout is a trial-and-error method based on heuristic know-how. The solution achieved in such a way lacks scientific calculation and analysis. CAD and CAE simulation technology helps practitioners generate, verify, confirm and optimize the design clarifications [5]. Modelling and simulation are most well-organized and cost effective technologies incorporated in PLM casing for effective communication, analysis, prediction, and evaluation of casting product quality defects [10]. Foundries depending on simulation tool can have the benefit of the newest casting process design technology that calculates residual stresses, time for solidification [8]. To

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achieve the desired casting quality depending on the casting process, from the simulation one can anticipate the design and make slight process changes & make sure production ready cost- effective designs [7]. In today's manufacturing environment the process of casting simulation is the imperative tool that allows foundries to obtain steadfast and high-quality cast parts. With PLM software, one can achieve cutting-edge solutions that meet the needs of casting producers [9]. In this work at a small scale foundry Karnataka Castings PVT Ltd., Bangalore the PLM was implemented in the area of Product design and the benefits gained by executing were noted by a case study. A case study was carried out on the high pressure die casting component called Cylinder shell. The PLM tools i.e., CAX software CATIA V5 and Z-CAST PRO were utilized for modelling and simulation respectively for the required casting. The simulation results were studied and analyzed to apply them into the production die-casting mould. During the mould filling, internal porosities caused by air entrap were predicted and reduced significantly by the alteration of the gating structure, and the configuration of flow junction zone. With the solidification examination, internal porosities caused by solidification shrinkage were predicted and reduced by bringing the changes in the gating system.

II. IMPLEMENTATION OF PLM IN FOUNDRY

The flow chart in Fig.1 below shows that the method followed by Karnataka castings pvt. Ltd., a small scale foundry before implementation of PLM in the area of Product design initially. The foundry design and manufactures aluminium castings in high pressure die casting method. The development of the casting was based on trials carried out in shop floor of the foundry.

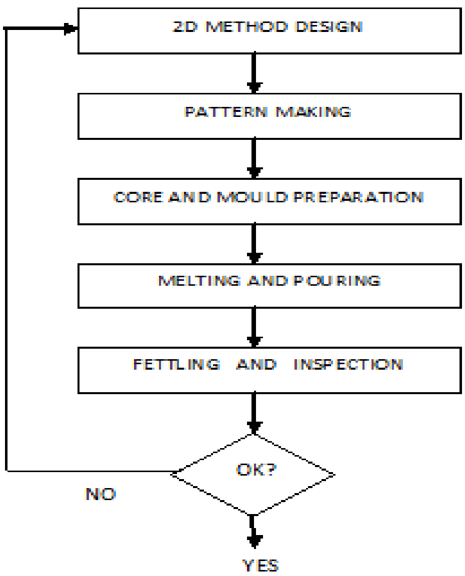

Figure 1: Conventional method of product design and development.

The flow chart in Fig 2. Shows that the method followed in design and development of the product after implementation of PLM in the foundry.

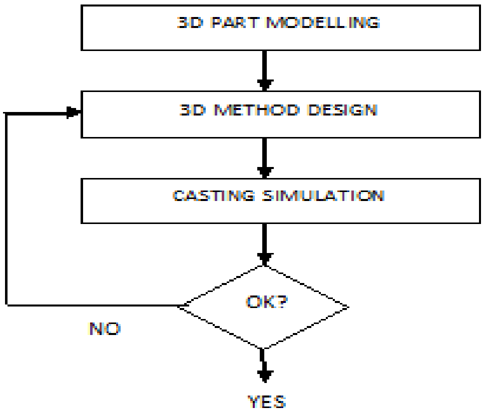

Figure 2: PLM approach of product design and development.

After PLM implementation, it helped the organization to transform from the 2D-centric design of the past to a 3D, model-based enterprise, or digital tapestry. 3D CAD and simulation tools which are part of PLM are utilized to improve the system design of the casting.

III. MODELING AND SIMULATION

A. Solid Modeling

The three dimensional model and sectional views as shown in Fig.3, Fig.4 and Fig.5 respectively of Cylinder shell was done using CATIA V5 software which is a multi-platform software suite for CAD, CAM, PLM developed by Dassault System. Initially the small scale foundry was not using any software for 3D model creation, instead it was following the 2D method design, and later on the same was installed.

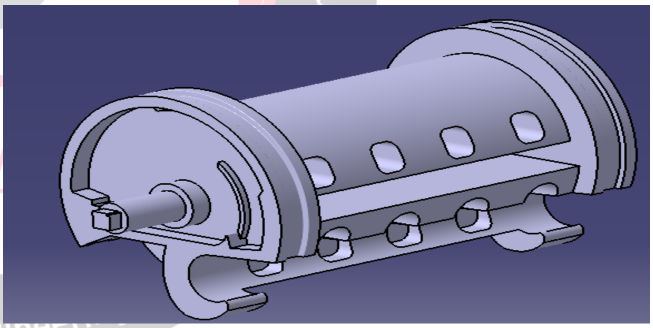

Figure 3: 3D model of Cylinder shell

Figure 4: Longitudinal Sectional view of Cylinder shell

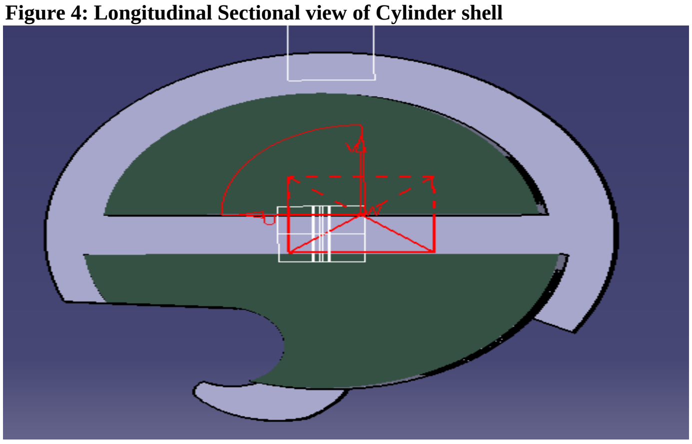

Figure 5: Transverse Sectional view of Cylinder shell

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B. Simulation

The Z CAST PRO Casting Simulation Software .That is used for simulating end-to-end casting process, filling, solidification, heat-stress and heat treatment simulation was utilized for simulation of cylinder shell component.

Fig.6 shows the gating system considered during simulation The various input parameters applied during simulation are as mentioned below

Input Parameters

Process: High pressure Die casting process

Material: Aluminium (ADC 12)

Pouring temperature: 680^0c

Shrinkage allowance of material: 0.6**%**

Die material: H13 steel

Die temperature: 180^0c

Element size: 0.5 mm

Total number of elements: 1522612

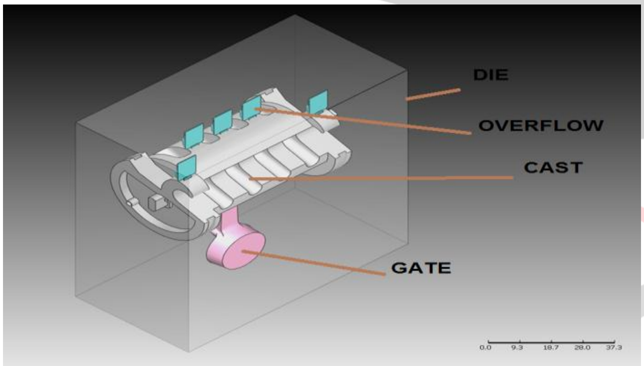

Figure 6: Position of gating system

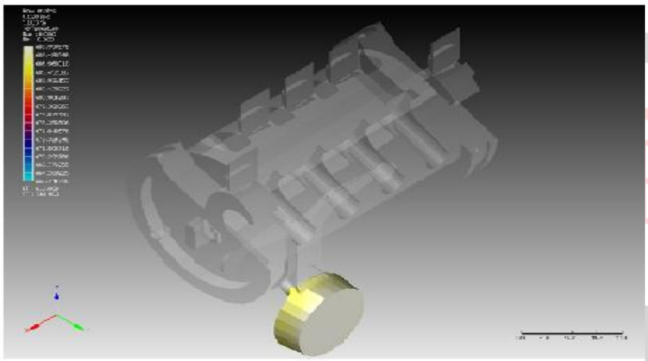

Figure 7: Flow simulation shows filling percentage and flow time with respective temperature plots at the beginning of the flow

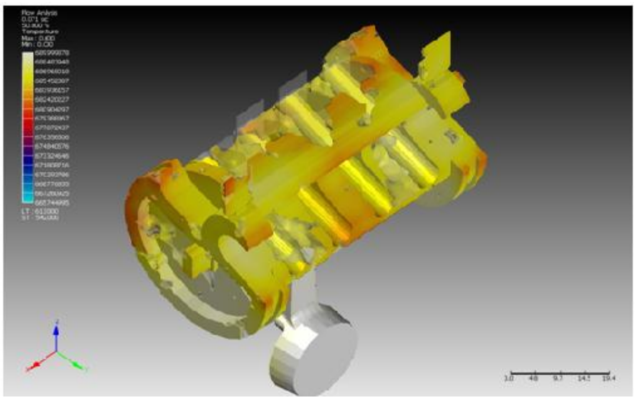

Figure 8: Flow simulation shows filling percentage and flow time with respective temperature plots at 50% filling

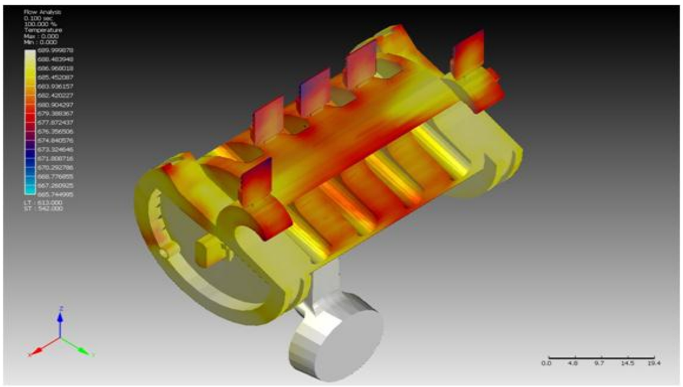

Figure 9: Flow simulation shows filling percentage and flow time with respective temperature plots at 100% filling.

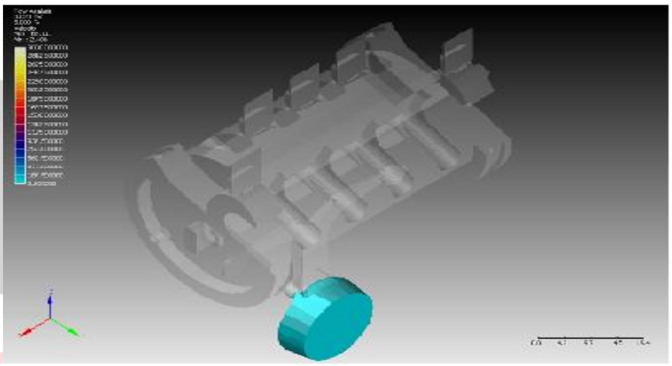

Figure 10: Flow velocity simulation shows filling percentage and velocity of molten flow inside the cavity

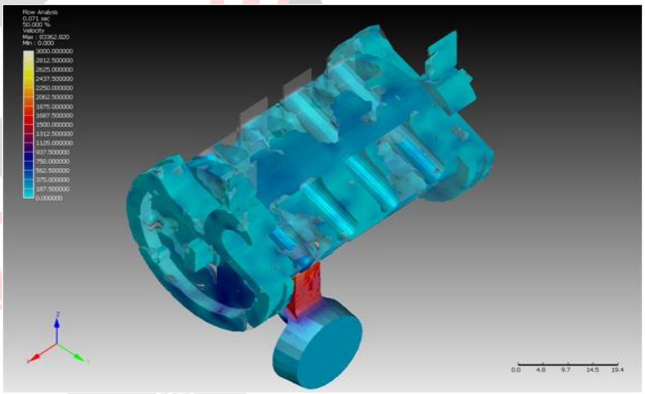

Figure 11: Flow velocity simulation shows filling percentage and velocity of molten flows inside the cavity at 50% flow rate.

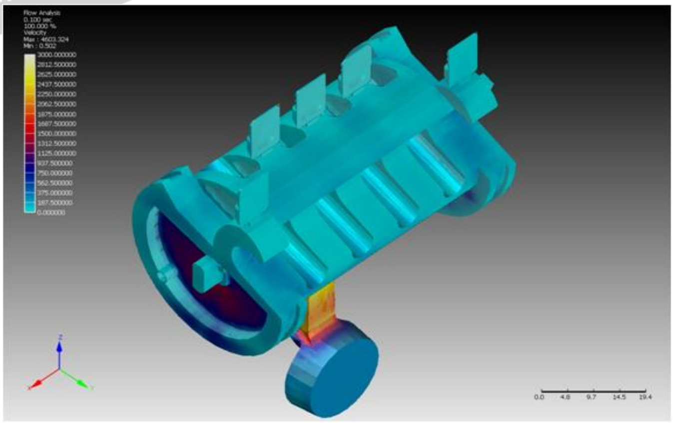

Figure 12: Flow velocity simulation shows filling percentage and velocity of molten flow inside the cavity at 100% flow rate.

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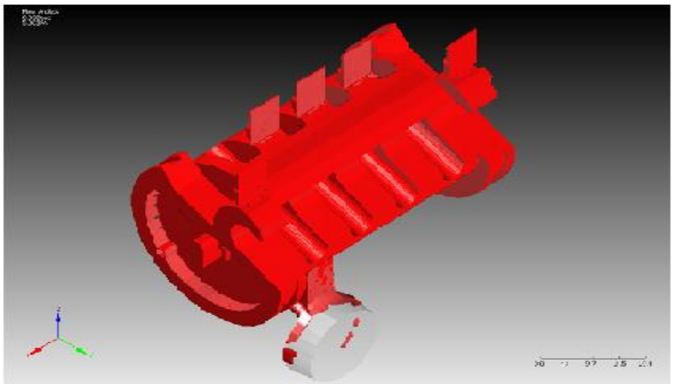

Figure 13: Simulation shows the Air escape from the mold, once material enters into the cavity. Here the red color indicates cavity yet to be fill and transparent area shows metal is filled.

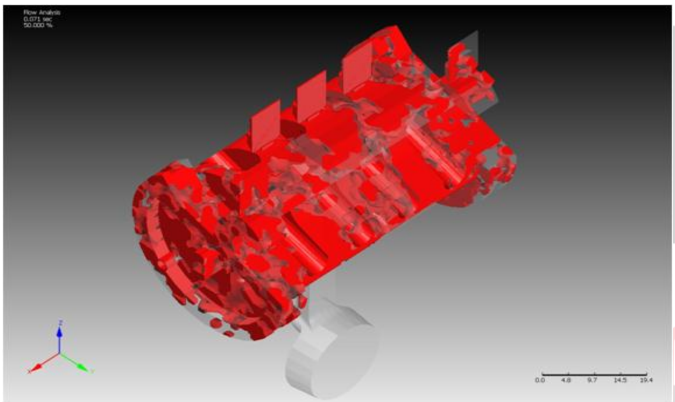

Figure 14: Simulation shows the Air escape from the mold at 50% filling of the molten metal.

Figure 15: Simulation shows the Air escape from the mold at 100% filling of the molten metal.

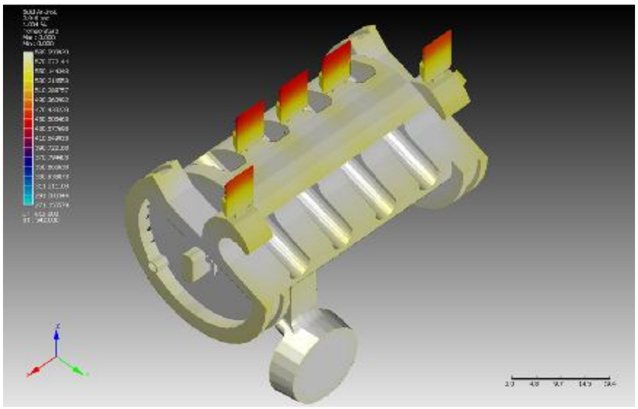

Figure 16: Solidification temperature pattern shows rate of solidification and time taken to solidify at the beginning of the flow

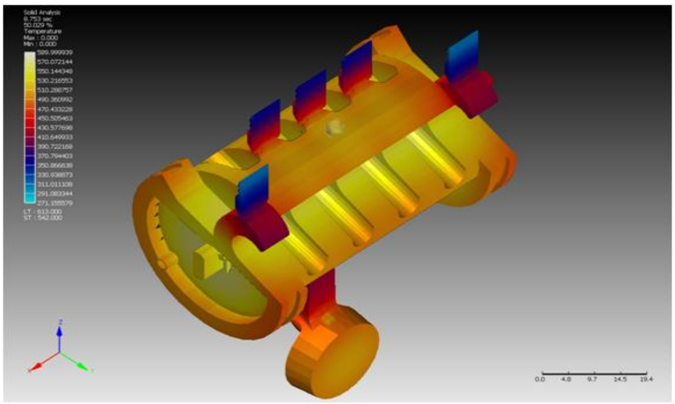

Figure 17: Solidification temperature pattern shows rate of solidification and time taken to solidify at the 50% filling

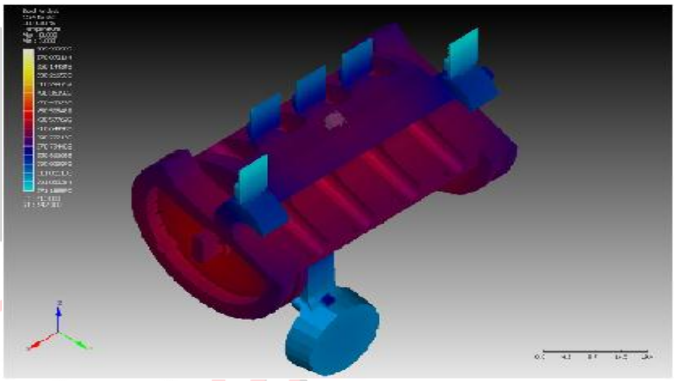

Figure 18: Solidification temperature pattern shows rate of solidification and time taken to solidify at the 100% filling

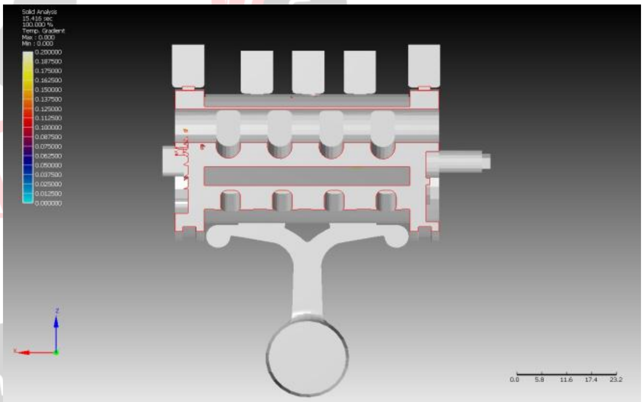

Figure 19: Solid Simulation, Niyama – Prediction of porosities

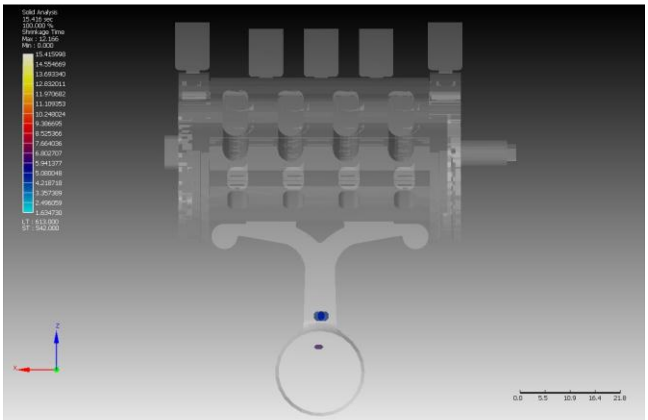

Figure 20: Solid Simulation depicts no shrinkage defects found

Observations:

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Fig. 7, Fig. 8 and Fig.9 depicts flow temperature simulation showing fill rate with respective time and temperature and can analyses different results,

- Time required to fill the cavity and riser is 0.1 sec
- Temperature drop during filling is about 678 ˚C.
- Thorough flow temperature analysis can test fluidity of molten material and Un-filling locations by analyzing temperature plots in thin sections of the cavity.

Fig.10, Fig. 11 and Fig.12 depicts Flow Velocity simulation shows,

- Flow velocity simulation shows filling percentage and velocity of molten flow inside the cavity.
- Can predict turbulent flow.

Fig.13, Fig.14 and Fig.15 depicts Flow – Un-filling simulation,

- Un-filling simulation shows the air escape from the mould, once material enters into the cavity. Here the red colour indicates cavity yet to be fill and transparent area shows metal is filled.
- Small dots indicate air entrapment in the cavity.
- Can predict unfilled locations in cavity.
- No air particles observed in cavity during filling.

Fig.16, Fig.17 and Fig.18 depicts Solidification temperature

- Solidification temperature pattern shows rate of solidification and time taken to solidify with respective temperature drop during cooling.
- Total solidification time – 15.416 sec.

Fig. 19 depicts Solidification – Niyama (Porosity prediction) / Temperature gradients

- The value calculated by considering the cooling rate and temperature gradient.
- Higher value of Niyama shows porosity defect free and lower the Niyama value possibility to occur porosity defects.
- It's not absolute but shrinkage defects are likely to occur, where the smaller Niyama value also predicts possible locations of porosities.
- No porosity found in the casting.

Fig. 20 depicts Solidification –Shrinkage

- No shrinkage found in the casting.

After procuring simulation results and optimization the required casting that is Cylinder shell was manufactured by the following procedure i) Designing the suitable die with proper gating system ii) Fixing the die in High pressure die casting machine and pouring the molten metal into the die cavity by maintain all the parameters intact. Fig. 21 shows the cylinder shell as cast component

Figure 21: As cast of Cylinder shell produced from HPDC method

IV. RESULTS AND DISCUSSIONS

After implementation of PLM in the domain of Product design lot of improvements were observed within the small scale foundry. Fig. 22 shows the graph of improvement after implementation of PLM.

The changes observed were as listed below:

The design cycle was reduced to about 29% which has the greater accuracy provided by modelling and simulation, as well as the fewer errors was found on the shop floor.

The rejections of the castings was reduced from 40% to 19%

The yield was improved from 49% to 74%.

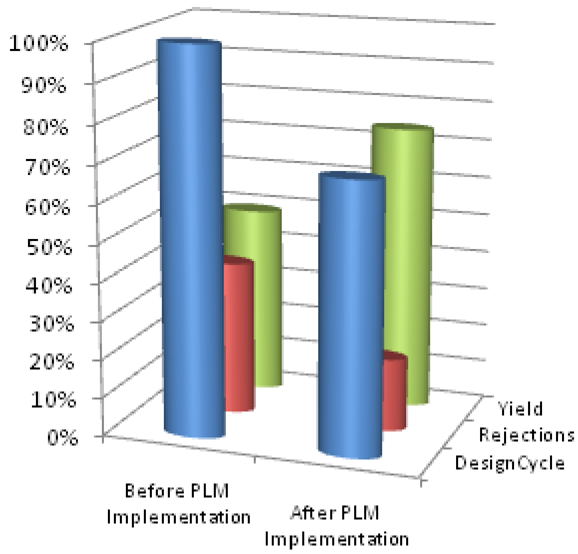

Figure 22: Improvements observed after PLM Implementation

Apart from the improvements observed after PLM implementation it was also noted that the healthy practices were established in the foundry which include timely communication among users through PLM tool, in-house computer aided design, casting process simulation which helped a lot for manufacturing the intricate aluminium casting, it was noted that by casting simulation the prediction of flaws in the casting was done thereby improving quality and eliminating internal flaws like air entrapment, porosity and shrinkage in the

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casting, swift development of novel casting was also developed by reducing many number of trials in the shop floor, effective communication with the customer for the finalization of product and delivery schedule was also observed.

V. CONCLUSION

From this study it can be concluded after implementation of PLM in the area of Product design the design cycle (especially in high pressure die casting industry) is reduced to a considerable level.3D modeling in the manufacturing of cylinder shell helped easy correction of design features before any physical structure of cylinder shell is made thereby reducing costs of producing inaccurate metal mould. The casting simulation models have been capable to reproduce properly the thermal performance of the mould and of the cast part, with considerable reduction in calculation times. Casting simulation which is an ingredient of PLM also helped the small scale foundry to reduce the percentage of rejections by predicting the air entrapments in mould cavity and chances of porosity. It can be recommended from this study that the small scale foundries which takes the order for multifarious shape castings (which has to be produced in high pressure die casting) particularly which are utilized in aerospace, automobile and medical applications should utilize PLM especially in the area of Product design, so that they can construct up novel goods like Cylinder shell (Aluminum castings) in a very diminutive time by meeting the demands from its customers and therefore reaping immense intrinsic worth over competing with large scale .

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