

# Tools and Strategies for Product Life Cycle Management – A Case Study in Foundry

Rajashekar Patil<sup>1</sup>, S. Mohan Kumar<sup>2</sup> and E. Abhilash<sup>3</sup>

<sup>1</sup> Assistant Professor, Department of Mechanical Engineering; <sup>2</sup> Professor & Director; <sup>3</sup> Associate Professor, Department of Mechanical Engineering; Sri Dharmasthala Manjunatheswara College of Engineering and Technology, Dharwad, Karnataka, India  
Email: eashan123@gmail.com, dr.s.m.kumar@gmail.com, abhilash.e@gmail.com

## ABSTRACT

Advances in information and communication technology (ICT) have opened new possibilities of collaborations among the customers, suppliers, manufactures and partners to effectively tackle various business challenges. Product Life Cycle Management (PLM) has been a proven approach for Original Equipment Manufacturers (OEMs) to increase their productivity, improve their product quality, speed up delivery, and increase their profit and to become more efficient. However, their Tier 2 and Tier 3 suppliers like foundry industries are still in their infancy without adopting PLM. Hence to enhance their understanding, the basic concepts, the tools and strategies for PLM are presented in this paper. By selecting and implementing appropriate PLM strategies in a small foundry, an attempt was also made to understand the immediate benefits of using PLM tools (commercial PLM software and digital manufacturing tools). This study indicated a reduction in lead time and improved utilization of organizational resources in the production of automobile impeller. These observations may be further extrapolated to other multi-product, multi-discipline and multi-customer companies to realize the advantages of using PLM technology

**Keywords :** PLM; Tools; Strategy; Foundry; Digital Manufacturing; Master Pattern; Rapid Prototyping

## 1 INTRODUCTION

As a next generation of lean thinking, a philosophy to eliminate waste and inefficiency across all aspects of product life, PLM has emerged as a newest strategic approach to increase the productivity of an organization [1]. Over the years many concepts and technological threads have gone into PLM. This includes various functional areas Computer Aided Design (CAD), Engineering Data Management (EDM), Product Data Management (PDM), Computer Integrated Manufacturing (CIM), Sales & Service and Disposal & Recycling, and various domains of knowledge or enterprise application systems such as Materials Resource Planning (MRP), Enterprise Resources Planning (ERP), Customer Relationship Management (CRM), and Supply Chain Management (SCM). The Design for Environment, a recent philosophy, has gained attention to many international companies as it introduced Disposal and Recycling as a major functional area and redefined the PLM concept “cradle to grave” to “cradle to cradle”. In this regard, inverse manufacturing [2] and digital manufacturing [3] concepts were also introduced to contribute in PLM. Valuable learning contents on PLM can be referred in various books [1], [4] and research publications [5],[6],[7],[8].

PLM has been a proven approach for OEMs to increase their productivity, improve their product quality, speed up delivery, and increase the profit and to become more efficient. However, small and medium enterprises (SMEs) like foundries, who are suppliers to OEMs, are still in their infancy without adopting this strategic business approach. Hence to enhance their understanding the basic concepts, the tools and

strategies for PLM are presented in this paper. By selecting and implementing appropriate PLM strategies in a small foundry, an attempt was made to assess the immediate performance outcomes following the implementation of PLM tools (commercial PLM software and digital manufacturing tools).

## 2 PRODUCT LIFECYCLE MANAGEMENT (PLM)

Manufacturing companies are compounded with many business challenges such as global competition, increasing labor costs, increasing product complexity and engineering product data, and more governmental and organizational standards and regulations. In order to pursue a more competitive business model, they have been keen to utilize the new quality of ICT to enhance the collaboration among their customers, suppliers and shareholders. The conception “collaboration” is frequently associated with conceptions like cooperation, coordination and communication, and is often used in different contexts without any consistent and precise definition. Hence Fig.1 is provided here to illustrate the characterization of these conceptions and their interrelations. These conceptions can be defined by two factors: the level of interaction/ interoperation and the level of integration. As shown in vertical axis, integration is accumulative. “The communication implies integration of information; coordination requires the integration of information as well as the integration of goals. Cooperation involves the integration of information, of goals and in addition the integration of performances. Finally, collaboration implies the full integration of information, of goals, of performances and the integration of actions in terms of operations as well.

Integration is accompanied or achieved, respectively by different levels of interaction/interoperation of actors or of systems. Interactions include the exchange of reciprocal information, the joint arrangements of goals, the systematic matching of performances and synchronization of actions” [9]. PLM helps fast integration of systems by providing a platform for intense interactions using latest technologies.

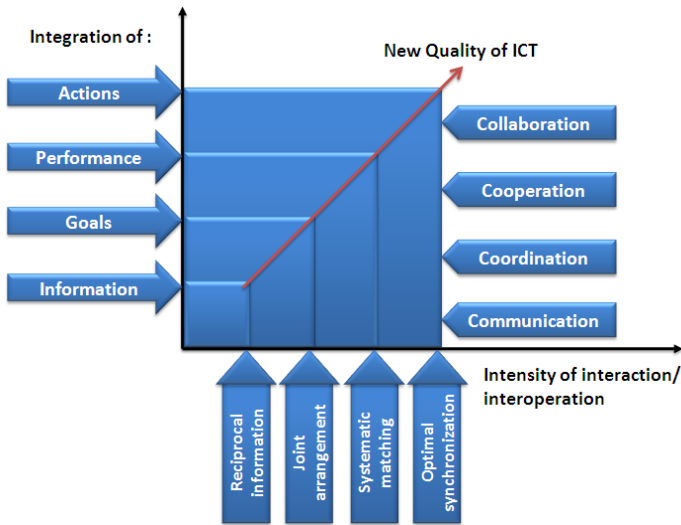


Fig.1. Collaboration ability enabled by advanced technology [9].

Structure of a few collaborations in a PLM portal configured with four major functional areas or departments (concepts & design, analysis & planning, manufacturing & production and sales & support) in an organization is shown in Fig.2. The collaborations include intra- organizational activities such as checking the configurations, manufacturability, quality and serviceability of the product, and inter-organizational activities or customer interactions with various departments such as part customization, part replacement, delivery schedule, spare part requirements etc. Appropriate system integrations and use of PLM tools (software and hardware) in modern manufacturing companies will help enhance their collaborations and decrease their inefficiency by accurate and prompt usage of information. The cumulative gains (growth in revenue and profit) in an organization can be assured by increasing the efficiency through continuous improvements in PLM technology adopting new strategies and by using new tools.

PLM can largely be considered as an informational core which can be accessed through user-friendly interfaces (Graphical User Interfaces or Application Programming Interfaces) configured with various functional areas in such a way that information is shared and secured among each area through some collaboration protocols. Most of the enterprises system applications such as CRM, ERP and SCM are also embedded in PLM. The tools in PLM may include CAD/CAE/CAM or (CAX) software, DFA/DFM or (DFX) software, tools for Computer Aided Process Planning (CAPP), e-commerce tools, office tools for documentation, encryption software for security

and storage, and other user interfaces for hardware tools, multimedia tools and digital manufacturing tools such as Computer Numerical Control (CNC) machines, RP machines etc. All this applications or interfaces may be accessed either through intranet or internet facilities. The available PLM software tools can be clustered in three groups [8]:

1. Information management (e.g. methods for identifying, structuring, classifying, modeling, retrieving, sharing, disseminating, visualizing and archiving product, process and project related data).
2. Process management (e.g. methods for modeling, structuring, planning, operating and controlling formal or semi-formal processes like engineering release processes, review processes, change processes or notification processes).
3. Application integration (e.g. methods for defining and managing interfaces between PLM and different authoring applications like CAD, CAM, CAE and integrated enterprise software such as ERP, SCM or CRM).

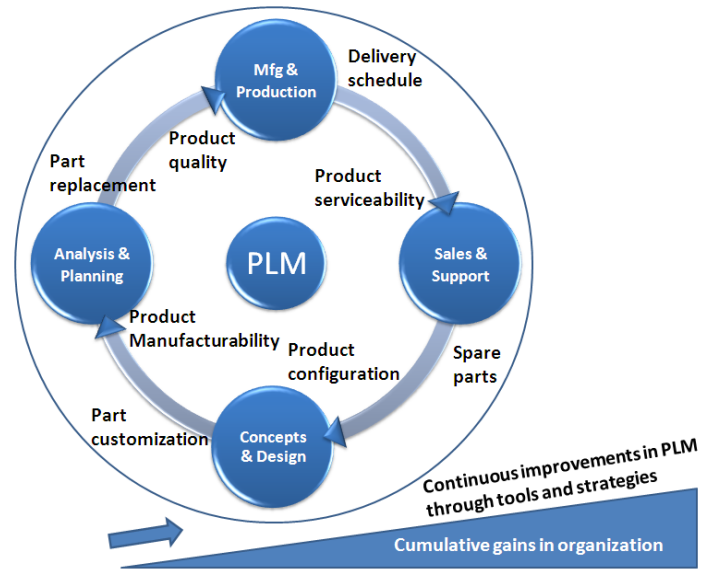


Fig. 2. Structure of collaborations in PLM portal for major inter and intra-organizational activities.

As mentioned, today’s PLM software include many concepts and technologies woven together to enable the users to access, share, manipulate, reason and update the product information. Alternatively, they help in converting the sequential information flow into parallel flow within functional areas and increasing the collaborations in an organization. Commercially available PLM software, their vendors and their client focus are presented in Table 1. Theoretically the concept of PLM is very elaborate and comprehensive. However, the very purpose of PLM software vendors is to transform all the tacit knowledge concerns to product life cycle into the tangible or virtual knowledge. Most of the PLM vendors targets SMEs. However, SAP, Dassault Systems, Siemens PLM Software and PTC have PLM software preferably for Medium and Large

Enterprises. Custom made industry solutions for OEMs (automobile, aerospace etc.) are also available in market.

- Environment-friendly products

Each of these strategies may be carefully implemented in the organization through appropriate actions by understanding global competition, complexity of products and standards and regulations posed by government or OEMs. For example, implementation of the strategy “fastest time to market” requires immediate commencement of projects, sharing of information, simulation rather than trial and error, and re-using and updating the information for continuous improvement. Based on a few selected PLM strategies, this case study discusses: (i) the ways to meet an objective of manufacturing the automobile impeller casting (ii) how well the resources such as equipments, materials and people are managed or used.

**TABLE 1**  
**COMMERCIALY AVAILABLE PLM SOFTWARE, THEIR VENDORS AND THEIR CLIENT FOCUS**

PLM Tool	Vendor	Client Focus
Accolade	Sopheon	Small-Medium
Agile Advantage	Oracle/Agile	Small-Medium
Aras Innovator	Aras Corp	Small-Medium
Arena PLM	Arena Solutions	Small-Medium
Enovia Matrix One	Dassault Systems	Medium-Large
Enovia SmarTeam	Dassault Systems	Small-Medium
BPMplus	Ingennus	Small-Medium
ProductCenter	SofTech	Small-Medium
SAP PLM	SAP	Medium-Large
TeamcenterEngg	Siemens PLM	Medium-Large
Teamcenter Express	Siemens PLM	Small-Medium
Think PLM	Think3	Small-Medium
Windchill	PTC	Medium-Large
Windchill On-Demand	PTC	Small-Medium

There are many modules developed to satisfy the activities in functional areas or domains of knowledge. Based on the strategy adopted by the foundry, these modules may be included or upgraded in the PLM tool. Proprietor/ foundry manager should ensure the PLM tool to be technologically state-of-the-art, open and harmonized with all applications, easily configurable and very user friendly in its application. Caution should also be made to check the computing capability, communication bandwidth and storage capacity as sufficient infrastructure.

To bridge the gap between the reality and the objectives of the organization, proper strategies should be implemented by the management. Since strategies depends on the market situations and the available resources within an organization, collecting proper information about the organization, identification and selection of appropriate strategies, communicating the same in the organization and its proper implementation are the major activities of a visionary management. There are many PLM strategies which can be adopted by the organization. Some of these strategies are as follows [4].

- Increased customer involvement
- Customization of products
- Highest functionality products and services
- Most robust product or services
- Widest range of products and services
- Best processes
- Standard product and services
- Fastest time to market
- Value adding life cycle
- Lowest cost competitor
- Longest life product

### 3 DESCRIPTION OF THE CASE STUDY

A small foundry in Belgaum foundry cluster (India) which manufactures impeller casting was chosen for the case study. The customer firm (Tier1 Supplier) is within 8 km from the foundry and was in demand of superior castings to meet the requirements of OEMs. However, these demands were highly fluctuating depending on the market conditions. Hence, the foundry firm (Tier 2 Supplier) was in great difficulty to meet the resources (men, material, machines) in order achieve the customer demands. Outsourcing the work due to the shortage of employees and machines was not a wise decision as per their management. Also, there were issues with shortage of materials since inventory control was not a healthy practice in the foundry. As a strategic decision, this foundry was interested to adopt PLM and check the benefit of using PLM tools. A few PLM strategies implemented were (i) shorter time to market (ii) automation (iii) best process and (v) minimization of production cost. To march towards this plan of actions, a few healthy practices and digital manufacturing concepts were also introduced to the foundry. Further, to understand the immediate advantages, a qualitative assessment was done on various activities in foundry in which manufacturing of impeller casting was done with and without the intervention of PLM tools.

The healthy practices introduced in the foundry include timely interaction among users through commercial PLM tool (Teamcenter), in-house computer aided design, structural analysis and casting process simulation, interaction with the customer for the finalization of product and delivery schedule, evaluation of man-hours and its appraisal, online monitoring of resources, and accounting. User logins were created in Teamcenter to carry out these responsibilities and to interact with users and customers.

A rapid prototyping (RP) machine of fused deposition modeling (FDM) type was introduced as a digital manufacturing tool to fabricate the complex master pattern. RP takes virtual designs from CAD modeling software, transforms them into thin, virtual, horizontal cross-sections (generally in STL file format standardized by rapid prototyping industries) and then creates successive layers of polymer materials until the

model is physically completed.

After structural and process simulations, the CAD model made using PLM tool was optimally (to approximate exact surfaces) converted to STL format (which represents a 3D surface to an assembly of planar triangles). The model in STL format was then pre-processed in INSIGHT program (user interface of RP machine) to adjust the size, location and orientation of the model within the RP machine. Slicing of the model (which can vary from 0.01 mm to 0.7 mm) was done to fix a deposition thickness of 0.124 mm to meet the desired quality of pattern. Tool path generation, support material (SR-30) generation, assigning of material (ABS-M30) for building, were other pre-processing steps done in INSIGHT. The time taken to build the parts and the amount of building material and the support material required for the parts could be obtained from the software.

#### 4 RESULTS AND DISCUSSIONS

There are many advantages of using PLM technology in foundry. Besides the PLM internal drivers such as productivity, quality, collaboration and new product development, the advantages include the reduction of human errors, the improved flexibility, the dissemination of product knowledge, and the continuous monitoring of their growth rates. By understanding the activities and the information flow in using PLM tools, some of these advantages were identified. Based on some identified characteristics of collaborative engineering, Table 2 presents the advantages of PLM technology compared to conventional technology.

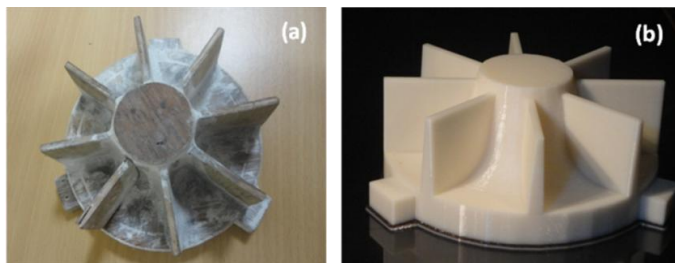


Fig. 3. Master Pattern of Impeller Casting (a) Wooden material (conventional manufacturing) (b) ABS material (digital manufacturing)

The introduction of RP machine as a digital manufacturing tool significantly decreased the time and energy involved in the production of master patterns. In addition to this, the usage of polymer/plastic patterns compared to wooden pattern have several advantages such as enhanced pattern life in product cycle, great dimensional accuracy, reduction in inspection and rework and also the reusability. Fig.3 shows the patterns made of Teak wood and ABS (Acrylonitrile-Butadiene-Styrene) through conventional and digital manufacturing respectively. Patterns made of ABS are dense, rigid, can serve at higher temperature and has lower shrinkage compared to that of Teak wood patterns. The cost, the size

limitation and the easiness in molding process are other advantages over other pattern materials. A microscopic observation was also made to understand the surface quality of the castings obtained using master patterns made of wood and ABS. The casting photo micrographs obtained at 4X magnification indicated better surface finish with ABS master pattern compared to that of wooden pattern.

TABLE 2  
ADVANTAGES OF PLM TECHNOLOGY COMPARED TO CONVENTIONAL TECHNOLOGY

Characteristics	Conventional Technology	PLM Technology
Singularity	Multiple versions of data for individual products, so difficult to identify and control data	Unique identification for each product, so easy to identify and control product data even after revisions
Correspondence	Limited because of non-availability of complete data and information about physical product	High because of availability of complete data and information about the physical product
Traceability	Risk of wasting time and energy since product data is not recorded digitally	Easy to track the product data and information and its updates because of digital storage
Reflectivity	Less fidelity to map information about real product to virtual product	High fidelity since all data and information about real product is recorded
Cued availability	Product and process data not available as and when required leading to wastage of time	Right product data and information at right time even without any search
Complexity	Difficulty due to incomplete representations and insufficient information	Easy to modify product data and information to include any complexity leading to mass customization
Security	Less security and difficulty in tracking the activities	Highly secured since each user is provided with login and password
Ownership	Difficult to track the ownership of product/ practices/processes and cost involved	Easy to track the ownership of product/practices/processes and cost involved
Education & Training	Difficulty in presentation of product data/ portfolio of company	Product data and information can be retrieved easily at any time to train a new comer/ next generation employee

The immediate benefits inferred by the introduction of PLM technology to foundry as compared to conventional technology is presented in Table 3. The approximate time taken to build the casting with conventional technology is found

around 25 hrs whereas with PLM technology is around 8 hrs 10 min. A one-third reduction in time is observed by this modernization. This reduction of time is noticeable because the activities also include new healthy practices such as computer aided design and analysis, and digital manufacturing using RP. Since CAD, CAE and RP can be done by a CAX Expert, there is an improvement in labor utilization too. Hence, it can be suggested that the introduction of healthy practices, its execution using a commercial PLM software, and use of digital manufacturing tools in foundry has greatly reduced the information inefficiency and execution inefficiency.

**TABLE 3**  
 THE IMMEDIATE BENEFITS INFERRED BY THE INTRODUCTION OF PLM TECHNOLOGY TO FOUNDRY AS COMPARED TO CONVENTIONAL TECHNOLOGY

Tasks/ Operations	Conventional Technology		PLM Technology	
	Rating	Remarks	Rating	Remarks
Placing the order	4 hrs	In person	10 min	E mail to manager
Defining the project	4 hrs	With proprietor	1 hr	As a team with an online discussion
Model generation	5 hrs	2D drawing in paper	1 hr	Using CAD tool within PLM
Product modifications	---	Not entertained by the company	30 min	Customer suggestions through oline interactions
Structural analysis and check	---	Based on heuristics and experience	2 hrs	Using analsis tool within PLM
Process simulation & planning	---	Based on heuristics and experience	1 hr	Using process simulation tool within PLM
Customer interactions	2 hrs	In person	10 min	Through on-line
Pattern production	10 hrs	High carpentry skill is required	2 hrs 30 min	Through RP technology
Pattern material	Not good	Made using wood/ply wood	Good	Made using Polymer (ABS) material (115 cm <sup>3</sup> )
Quality of the pattern	Low	As manually made	High and reliable	As digitally manufactured
Quality of the casting	Good	Surface finish and accuracy is not as desired	Very good	Surface finish and accuracy as desired
Labor utilization	7	Proprietor, Designer, pattern maker, Clerk, Foundry technician,	6	Proprietor, CAX Expert, Accountant, Foundry technician, Metallurgist, Helper

Metallurgist, Helper

## 5 CONCLUSIONS

New generation manufacturing companies have modified their views on performance evaluations not only based on their outputs but also based on their outcomes over a period. Here, the outputs refer to some measurable quantities, generally the number of products, whereas the outcomes refer to the achievements or deliverables attained during the product life cycle. PLM as a tool which helps to quantify the performance over a period also helps in meeting the customer expectations about both the product and the process (how they get, what they want, and what they actually get). It is high time to implement PLM tools in modern foundries to enhance their collaborations and decrease their inefficiency by accurate and prompt usage of information. In this regard, the basic concepts and the tools and strategies for PLM were presented in this paper. By selecting and implementing appropriate PLM strategies in a small foundry, an attempt was made to understand the immediate benefits of using PLM tools (PLM software and digital manufacturing tools). This study, which indicated the reduction in lead time and improvement in utilization of organizational resources in the production of automobile impeller, may be further extrapolated to other multi-product, multi-discipline and multi-customer companies to realize the advantages of using PLM technology. Being skeptical, most of the foundries often state that the huge capital cost, non-availability of skilled labors, installation time (appropriate system integration), insufficient training and support, reluctance towards participation and the financial risks involved are a few reasons for not adopting the PLM technology. However, it is advised that the foundries or their clusters who are the suppliers of multiple complex or value added products, especially those belongs to OEMs of automobile, medical and aerospace and defense sectors, should implement PLM technology so that they can develop new and innovative products in a very short period of time by meeting the demands of OEMs and hence reap great advantages over their global competitors.

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