

Linking design and manufacturing on a PLM platform

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Abstract: One of the means to quick and scalable manufacture in industrial environment is to employ software packages that allow for an “end-to-end design” and manufacturing. PLM or Product Lifecycle Management is used to realize these requirements. However little literature is available on this topic. In this work, a typical automotive fuel tank cap was modelled and an injection mould was developed for the part. The complete design data was then integrated into a commercial PLM software, for data and process management. It is expected that this paper which showcases design to manufacture linkage on a PLM platform will not only encourage industries/manufacturing units to plan for and employ this approach to their products but also add to the available information to the academic community on this highly practical/applied topic.

Keywords: Creo Parametric, Windchill, Injection moulding, Modelling, Product Lifecycle Management (PLM).

I. Introduction

Plastics are now touching every aspect of our lives - from automobile parts to computers. One of the key methods of manufacture of plastics is the injection moulding process. More applicable to thermoplastics, e.g., ABS or Acrylonitrile Butadiene Styrene, Polyamide, Polyethylene, Polypropylene, Polystyrene, Polyvinyl Chloride (PVC) etc., [1] the major advantages presented by this process are manufacturing ease and speed. In this method, hot plastic is injected under pressure into a suitably designed die to form the required components upon cooling.

On the design front, Computer-Aided-Design (CAD) has revolutionized the manufacturing process by allowing right from creating simple geometries to complex assemblies, [2] running functional simulations and thereby allowing for necessary optimization. Similarly Computer-Aided Manufacture (CAM) is well known for tool design and machine shop operations. We are now in a position to link CAD, CAM with the entire materials (inventory) and manufacture domain. This can lead to an improved productivity via machine and work-force management, understanding material utilization to control scrap etc. Interestingly, one can integrate aspects related to machine utilization and maintenance, quality control etc. also in the above system which then would be called Product Lifecycle Management (PLM).

PLM software assists manufacturing companies to manage the various aspects of the product by serving as a common platform to house and work with all information associated with a product throughout its life cycle - the key being design and manufacturing data [3]. On the other hand, Product Data Management (PDM) refers to another tool that is usually embedded into PLM software and is used to manage the “process and product history” [4]. Together, software of this nature lends the various parties (management, engineering and sales departments, and customers) to interact with the product during the course of its development, thereby bringing out improved quality and performance yet allowing for quick release of products with lower risk [5].

PLM is already used in automotive and other industries, however, unlike the standard CAD/CAM processes; both conceptual and illustrative literature on PLM is limited. The objective of this paper is to showcase some abilities and advantages of PLM software, by linking design and manufacture via a practical example: Automobile fuel tank cap. For this, the fuel tank cap was designed according to the required dimensions, and subsequently the design data was integrated into the PLM software for data and process management.

II. Methodology

1.1 Study of the component

The manufacturing design for a component is arrived after a systematic study of the following information: Specifications, appearance, quality and service. For this paper, the considered information was limited to the mechanical functionality of the cap i.e., closing and opening the fuel tank.

1.2 Modelling of the component

Modelling, in simple words, is the process of generating a precise geometry for a component at hand so as to allow for its manufacture. In this work, the solid model of the component was modelled considering all the

required dimensions in Creo Parametric 3.0. For modelling of the component, different options like *revolve*, *pattern*, *extrude*, *mirror*, and *round* were performed.

1.3 Tool design

Solid modelling of tool design was done by extracting the core and cavity in Creo Parametric 3.0. For the extraction of core and cavity, the parameters like shrinkage, tolerance, size of core and cavity have to be considered [6]. Here, these parameters were assumed. The amount of shrinkage to be considered is chosen by the type of material that is used for injection moulding. Thicker pieces shrink more than thin ones. Similarly, cores and cavities are sensitive to shrinkage and necessary tolerance must be provided to achieve the intended shapes and sizes of the components. The shape of core and cavity is considered according to the component. A flow chart for general process of tool design for a plastic component in Creo Parametric 3.0 is shown in the following Fig. 1.

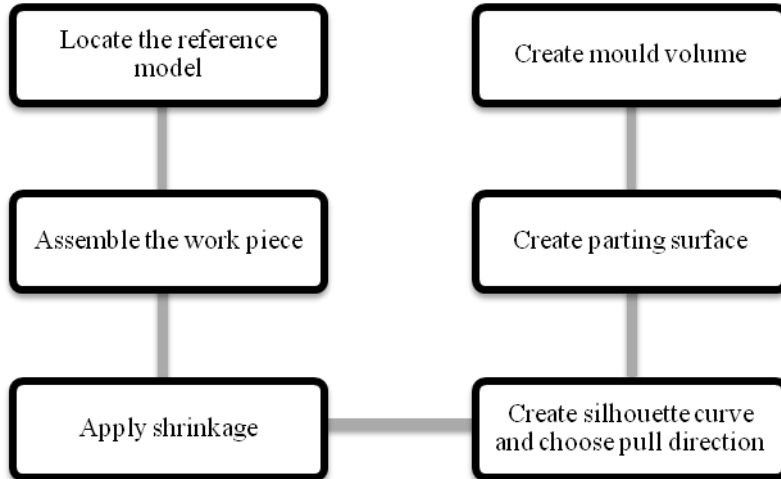


Figure 1 Process for tool design under manufacturing type and mold cavity sub-type

2.4 Tool manufacturing

In this work, the tool manufacturing was done by considering all the required parameters and NC program was generated using Creo Parametric 3.0 [7]. Here NC programs for core and cavity were generated separately. A flow chart for general process of tool manufacturing for a plastic component in Creo Parametric 3.0 is shown in the following Fig. 2.

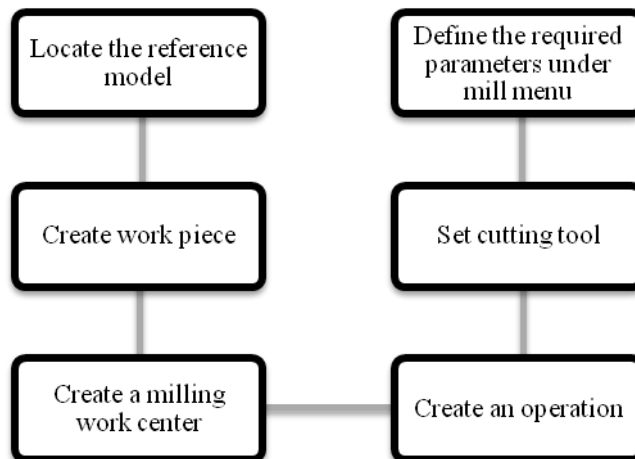


Figure 2 Process for tool manufacturing under manufacturing type and NC assembly sub-type

III. Results and Discussion

3.1 Design of the Fuel Cap

The different details of the part and its design are shown in TABLE 1 and 2. Fuel tank cap was modelled and the result is shown in the following Fig. 3.

Table 1 Part details of the component

Name of the component	Fuel tank cap
Surface area of the component	1.9508325e+04 mm ²
Volume of the component	1.4433408e+04 mm ³
Number of cavities	One

Table 2 Design details of the component

Outer diameter of cap	71 mm
Inner diameter of cap	67.5 mm
Length of holder	41.26 mm
Height of holder	9.42 mm
Width of holder	8.09 mm
Length of rib	17.12 mm
Diameter of hole on the holder	6.2 mm

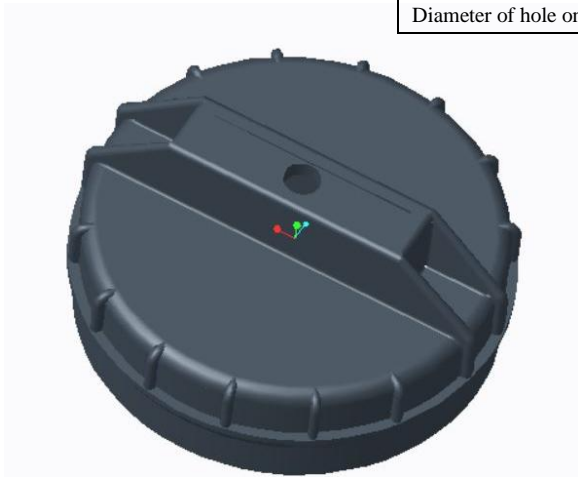


Figure 3 Model of fuel tank cap

3.2 Design details of the mould

Silhouette curve, the curve passing through the extreme points of the component has to be selected carefully, as this curve helps to select the parting line. Parting line helps to split up the mould into two half's, i.e. core and cavity. For the extraction of core and cavity, the parameters like shrinkage, draft should also be considered. Here, all these parameters were assumed accordingly. Fig. 4 shows the extraction of core and cavity designed using Creo Parametric 3.0. In case the runner and gate design have to be considered, the diameter of the gate should be according to the type of the gate that is being chosen [8], whereas the location of the gate has to be selected by running the moldflow advisor analysis [9].

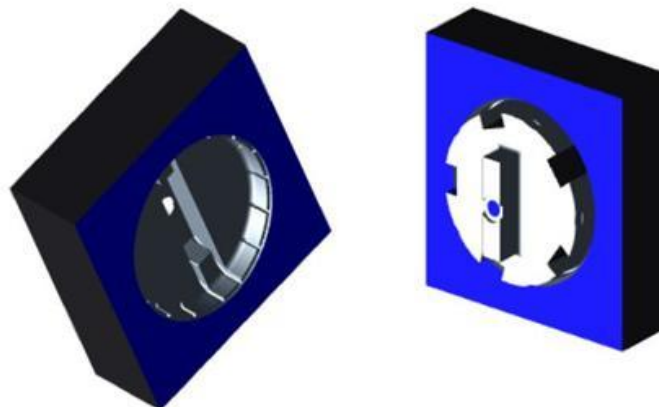


Figure 4 Cavity (left) and core (right) of fuel tank cap

3.3 Details for tool manufacturing

For manufacturing of the tool, NC programs are generated for core and cavity. The parameters for core and cavity should be considered separately. Therefore, the NC programs for both core and cavity were generated separately. The operations considered for manufacturing of the component depends upon the CAD model. In order to generate NC program for cavity, the operations shown in following Fig. 5 must be performed. The parameters considered for these operations are shown in TABLE 3.



Figure 5 Operations considered for generating NC program for cavity

Table 3 Parameters for cavity

Parameter	Roughing	Finishing for combined cuts	Finishing for profile cuts	Finishing for shallow cuts	Corner finishing
Cut speed	1500	1200	1200	1200	1000
Slope angle	---	45	45	45	0
Step over	5	---	---	---	---
Max. Step depth	0.5	---	---	---	---
Finish stock allow	---	0.05	0	0	0
Inside tolerance	0.06	0.025	0.025	0.025	0.025
Outside tolerance	0.06	0.025	0.025	0.025	0.025
Operation area scan	Type-spiral	---	---	---	---
Closed area scan	Follow-contour	---	---	---	---
Cut type	Climb	---	---	---	Climb
Lace option	---	Arc connect	Loop connect	Loop connect	Curve connect
Finish option	---	Combined cuts	Profile cuts	Shallow cuts	Combined cuts
Step area scan	---	---	---	---	Pencil cut
Shallow area scan	---	---	---	---	Pencil cut
Clear Dist	5	5	5	5	5
Coolant option	Off	Off	Off	Off	Off
Spindle speed	3000	3000	3000	3000	3000

In order to generate NC program for core, the following operations must be performed, which are shown in the following Fig. 6. The parameters considered for these operations are shown in TABLE 4.

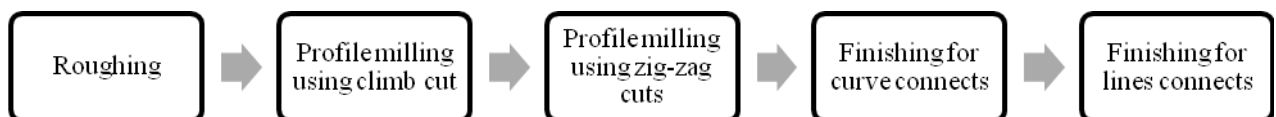


Figure 6 Operations considered for generating NC program for core

Table 4 Parameters for core

Parameter	Roughing	Profile milling using climb cuts	Profile milling using zig-zag cuts	Finishing for curve connects	Finishing for line connects
Cut speed	1500	1200	1500	2500	3500
Slope angle	5	---	---	45	45
Step over	0.5	---	---	0.1	0.1
Max. Step depth	0.06	---	---	0.1	0.1
Step depth	---	0.3	0.3	0.2	---
Inside tolerance	0.06	---	---	0.025	0.025
Outside tolerance	0.06	---	---	0.025	0.025
Tolerance	---	0.01	0.01	---	---
Operation area	Type-	---	---	---	---

scan	spiral				
Cut type	Climb	---	---	---	---
Lace option	---	---	---	Curve connect	Line connect
Finish option	---	---	---	Combined cuts	Profile cuts
Clear Dist	5	5	5	5	5
Coolant option	Off	Off	Off	Off	Off
Spindle speed	3000	3000	3500	3000	3000

Fig. 7 shows the manufacturing of the cavity and core to which the above mentioned operations were performed, according to the considered design parameters.

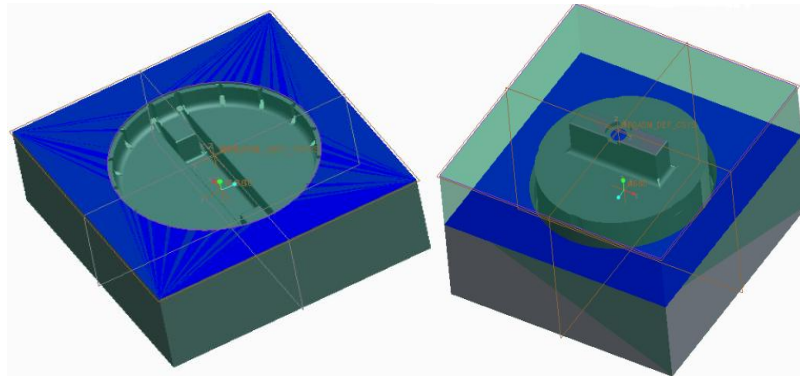


Figure 7 Manufacturing of the cavity (left) and core (right)

After assigning the above parameters for core and cavity, the NC programs for both were generated separately. The end-program is highly accurate and needs no further processing before commencing production with a CNC machine. With the implementation of the above steps, the production is deemed complete.

IV. Integration of fuel tank cap into the PLM software

The CAD data of fuel tank cap was imported into Windchill 10.2, PLM software. The data is stored in the central repository [10] which acts like a back-up. Data loss and data-overwrite are both protected against. Such data, for example, may be used for accreditation/audit purposes in some cases. The general procedure for importing the design data into Windchill is shown in the following Fig. 8, whereas Fig. 9 shows the CAD part of fuel tank cap in Windchill.

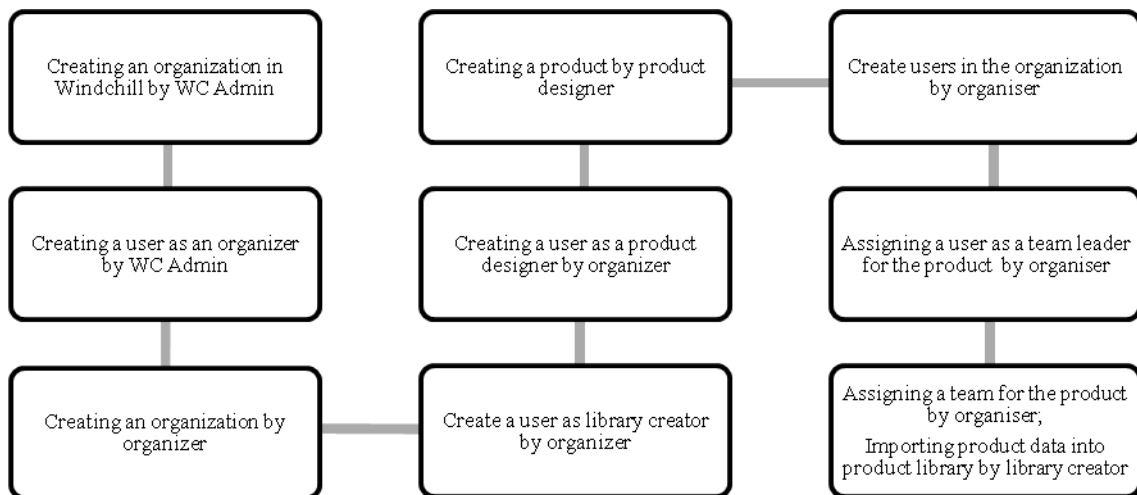


Figure 8 General procedure to import data into Windchill

In case the design engineer makes any modifications to the existing data in Windchill, a new version of that design/document is saved back to the central repository, maintaining the same part name. Every time a new version for a document is saved, a short description can be provided to understand the changes made in that particular version. This helps in locating the versioned document and reduces the time spent. As a result one can differentiate how the document is evolved between versions.

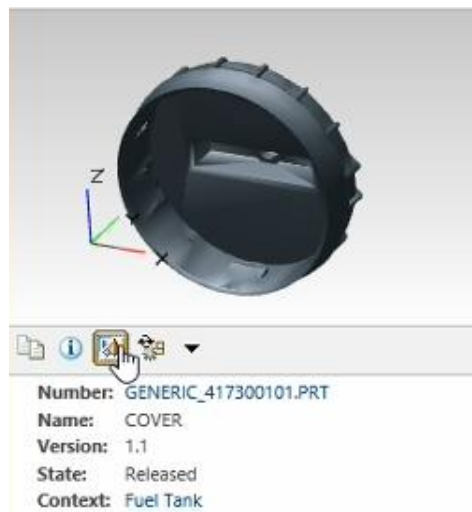


Figure 9 CAD part of fuel tank cap in Windchill

Apart from the team required for design and manufacturing of this component, a guest member was added to the team, who can read the data without acquiring membership in the organization. Considering the guest member as a customer, the CAD data of the fuel tank cap was given access to the guest member for reviewing. This reviewing was done on basis of the requirement of the design of the component. Comments on the design can be given by the customer, which is shown in the following Fig.10.

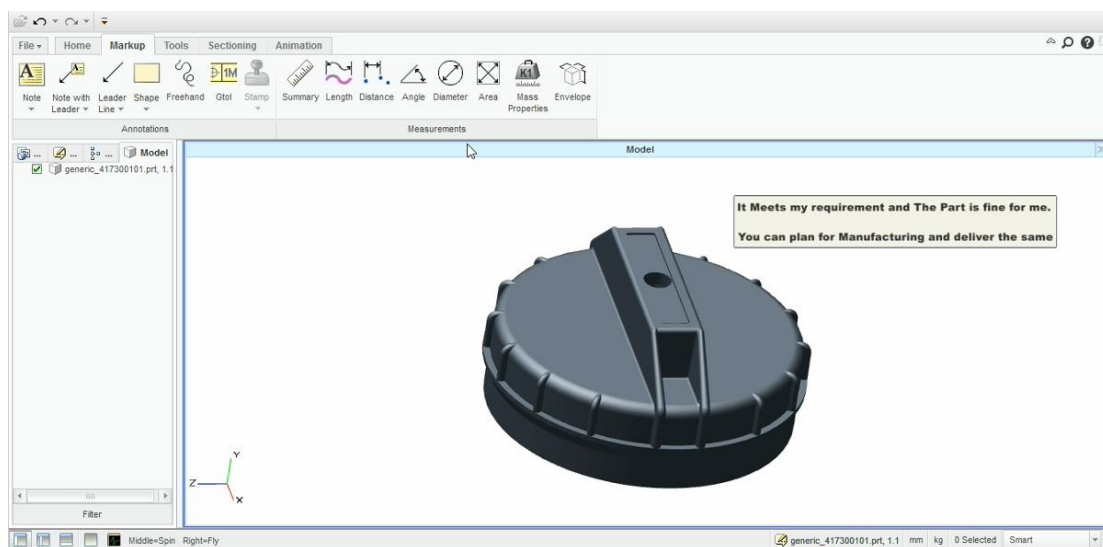


Figure 10 Note-up mentioned by the reviewer

In this specific example (Fig. 10), as the customer was satisfied with the design of the component, this design can now be sent to further stage i.e. manufacturing. In case the customer needs any modifications, the required modifications are commented in a note-up and sent back. Then, product manager initiates a change request with the approver of the product. The approver investigates the comments mentioned by the customer and if modifications are necessary, a change notice is issued to the product designer.

V. Conclusion

In order to showcase the linkage of design and manufacture on the PLM software, an automobile fuel tank cap was modelled and further the NC programs were generated for manufacturing of the cap. Subsequently, the complete data on modelling and manufacturing was integrated into the PLM software, which enables a smooth flow data from CAD systems, provide access only to authorized users, automatic updates when data is modified, data re-use and easy change management, etc. At any point of time, if the customer requires modifications to the existing model, the modifications can be easily applied, without causing any time delays.

This approach with PLM software could be of great help to the industries/manufacturing units as it has a high potential to draw and manage the process, product, service data efficiently.

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