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Design Optimization of Automobile Wiper Motor Casting Die

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ABSTRACT: This paper deals with elimination of defects in aluminium alloy castings of automobile wiper motor produced by pressure die casting process by optimizing die design. The main intention of work is to investigate the defects and improve quality of a pressure die cast component. Pressure die casting process involves producing accurately dimensioned parts, by forcing molten metal under pressure in to split metal dies, which are later on opened to allow the casing to be ejected. The main goal of project involves modelling of aluminium castings and to compare with old model and also developing the Die Design for “Automobile Wiper Motor” using NX 12.0.

KEYWORDS: PDC, Casting Defects, NX 12.0, Catching, Core and Cavity etc.

I. INTRODUCTION

Die-casting is a fast, versatile and cost-effective manufacturing process for producing complex-shape metal components by injecting liquid metal at a high pressure in a steel mould called a die. Die-castings are among the highest volume, mass-produced items manufactured by the metalworking industry, and they can be found in thousands of consumer, commercial and industrial products. The die-casting process typically uses a non-ferrous alloy, such as aluminium and zinc, which is melted in the furnace and then injected into the die; the die is installed on a die-casting machine.

Computer-aided design (CAD) can be defined as the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. Computer aided manufacturing (CAM) can be defined as the use of computer system to plan, manage, and control the operations of a manufacturing plant through either direct or indirect computer interface with the plant’s production resources.

The design of a die-casting die is a crucial step in between the design of a part and its subsequent manufacturing. The research focus of the thesis, computer-aided design of multi-cavity die-casting dies from part product model, constructs a valuable bridge for achieving design-manufacturing integration for the die-casting process. Important steps of the die-casting die-design and manufacturing with role of CAD/CAM tools at each step are shown in below Figure, which are briefly explained in the following paragraphs.

- The die-design activities instantiates from the design of part, where CAD tools are used to make its part product model.
- Various die-design steps such as layout design, gating system design, parting design, side-core design, cooling design and ejection system design require CAD and CAE tools.
- When the design of a die-casting die is ready, CAE tools, such as filling simulation are used for its validation.

A validated die-design is ready for manufacturing, and CAM tools are employed for process planning and die manufacturing activities.

Design consideration:

Moulds:-

- Material used for the component, its applications.
- Shrinkage of the material.
- Calculate the weight of the component.
- Study the detail of the component, projected area of component.
- Type of mould required for the component to be produced.
- Machine available for the component.
- Injection pressure required

- Runner system & gate required.
- Ejection system weather blade, stripper etc.
- Split and side core considerations
- Cycle time required for the component for complete fill.
- Efficient cooling in a short duration is required.
- Cooling channels must be lick proof.
- Selection of better material for core & cavity.
- Additional shrinkage required for core & cavity dimensions.
- Parts in the assembly must not foul with each other in operation.

Gating System Design:-

Gating systems normally are classified according to where the metal is allowed to enter the mold cavity. Patterns can be top, bottom or side gated.

Top gates have the fastest filling times and actually require the fastest pouring to avoid collapse. Side gates results in the slowest filling while bottom gates are somewhere in between. It is difficult to control the flow of falling metal in top or side gating to avoid the entrainment of some plastic residue. Bottom gating gives the most control over filling the mold cavity with liquid metal during pouring. The metal falls in the most controlled way in the sprue and then rises in a regular fashion in the mold cavity. The flow of the metal into the mold cavity must displace the form pattern. Head pressure can help reduce porosity in the casting. At least one process uses 3-10 bar pressure on the flask during solidification to improve soundness during pouring and solidification.

Multiple castings can be assembled on one gating system. Care must be taken to ensure that each casting will fill as expected, especially as the head pressure and the resulting flow rates in the higher castings decrease. Also castings must be so close to each other as to cause excessive gas pressure, which can result in sand fluidization and ruin the cluster.

II. PROBLEM IDENTIFICATION

Due to its large volume production, it is only logical that optimization of the PDC Die for wiper motor for its weight or volume will result in large-scale savings. It can also achieve the objective of reducing the weight of the vehicle component and also make easy and defects free part with smooth production.

During the discussion with managers and supervisors staff following issue was reviled:

1. Catching issue in Core insert.
2. Heavy weight of Die.
3. Sharp corners inside the cavity.
4. More Filling time to cavity.

III. OBJECTIVE OF WORK

The objectives of the work are:

1. To Model new PDC Die for automobile wiper motor using NX 12.0 after changes consider in design.
2. To Manufacturing new modified wiper motor component.
3. To Change gate position for reduce filling time.

IV. MODIFICATION PROPOSAL

Casting 2D:

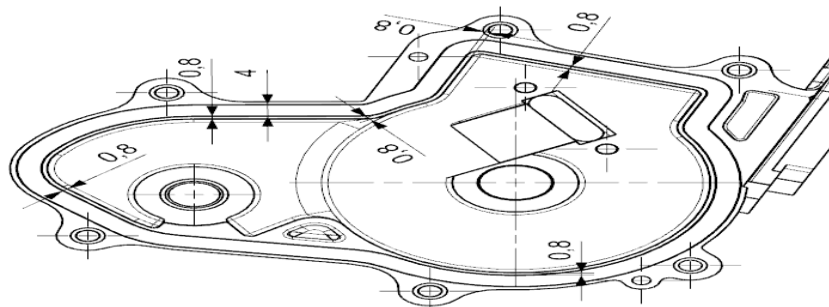


Fig.5.1: Modification Proposal Casting 2D

Casting 3D:-

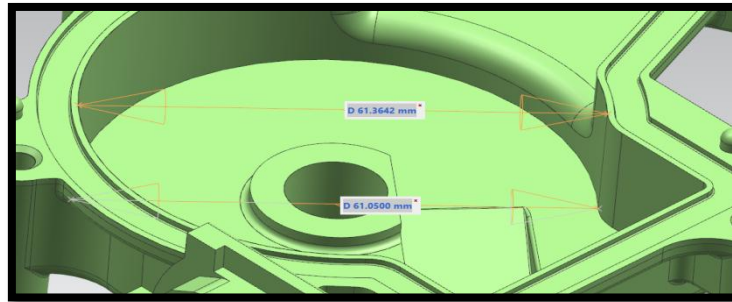


Fig.3.2:Modification Proposal Casting 3D

Note:- \varnothing 61.05 maintained at bottom with 0.5° plus draft. Top edge will be \varnothing 61.36mm. In this condition we can achieve the rib width as 0.8mm

V. METHODOLOGY

The methodology of the work is:

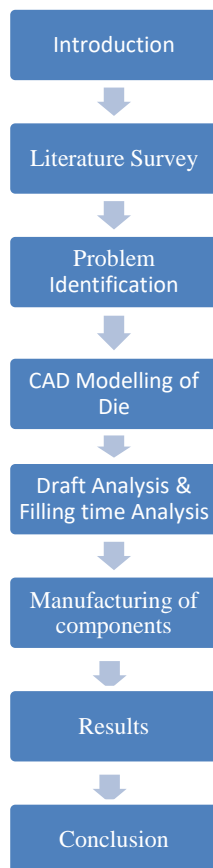


Fig.6.1: Flowchart of Methodology

VI. COMPONENT STUDY

Component name = Wiper Motor

Volume of component = 67599.1934mm³

Density = 0.000007831 kg/mm³

Projected area = 41118.02411mm²

Side Core Projected area = 32172.7681mm²

Weight of comp = 5.191100638 N

Average Wall Thickness = 4mm

Radius of gyration = 45.399232777 mm

Factor of safety = 25 %

Maximum thickness = 2.9 mm

Optimal Filling Time:

The Optimal Filling Time is nothing but the time required to cast or mold a product. The efficiency of the casting is normally affected by two scenarios.

Slow Filling: If the velocity of the fill is very slow, it leads to cold shuts and misruns. The slow filling is avoided because of the early freezing in thin sections before the complete filling.

Fast Filling: The fast filling is governed by the onset of surface instability. The optimal filling time lies in-between this fast & slow filling. It also depends on the following factors like:

- Cast metal
- Weight
- Pouring temperature
- Minimum section thickness.

With the help of various experimental methods, researchers have developed different empirical equations, for determining the Optimal Filling Time for major metals.

A casting fills too slowly can have discontinuities such as cold shuts and misruns. Too fast filling leads to solid and gaseous inclusions. The higher limit of filling time (slowest filling) is governed to avoid premature freezing in thin sections before complete filling. The lower limit of the filling time (fastest filling) is governed by the onset of surface turbulence. The correct filling time lies between fast and slow filling. It is a function of cast metal, weight, minimum section thickness and pouring temperature. Several empirical equations to determine the correct filling time for metals are developed by casting researchers based on experimental investigations. The filling time t is expressed as a function of casting weight W in Kg, section thickness T in mm. A generalized equation for filling time for casting less than 450kgs can be written as:

$$t = (0.95 + T/0.853) \sqrt{w} \text{Sec}$$

Where

K = Fluidity factor dependent on equivalent carbon

T = Average casting thickness (inches)

w = Weight of casting (Ibs), (maximum 450 kg or 1000 Ibs)

For 4.0 eq. carbon, $K=0.70$ to be taken

$T = 3.0\text{mm}$

$w = 0.529344948 \text{ kg}$



$$t=0.70 (0.95+3/0.853) \sqrt{0.529344948}$$

$$t=2.275 \text{ Sec}$$

Gate design:

$$\text{Fill rate (Q)} = \frac{\text{volume of metal through gate}}{\text{Filltime}}$$

Volume of metal through gate = volume of component + volume of over flows

V = volume of component + 15 % volume of component

$$V = 67599.1934\text{mm}^3 + 10139.87901 \text{ mm}^3$$

$$V = 77739.07241\text{mm}^3$$

$$\text{Volume of metal through gate (V)} = 77739.07241\text{mm}^3$$

$$\text{Fill rate (Q)} = V/t$$

$$Q = 77739.07241\text{mm}^3 / 2.275\text{sec} = 34171.02084 \text{ mm}^3/\text{sec}$$

$$\text{Fill rate (Q)} = 34171.02084 \text{ mm}^3/\text{sec}$$

Assuming Gate velocity (Vg) = 10m/sec

$$\text{Gate area (Ag)} = Q / (Vg \times 100) = 34171.02084 / (10 \times 1000) = 3.4171\text{mm}^2$$

$$\text{Gate area (Ag)} = 3.4171\text{mm}^2$$

Runner design:

$$\text{Runner area (Ar)} = 1.45 \text{ Ag}$$

$$\text{Ar} = 1.45 \times 3.4171$$

$$= 4.9548\text{mm}^2$$

$$\text{Runner area (Ar)} = 4.9548\text{mm}^2$$

$$\text{Runner depth (D)} = (\text{Ar}/1.8)^{1/2}$$

$$D = (4.9548/1.8)^{1/2}$$

$$= 1.659\text{mm}$$

$$\text{Runner depth (D)} = 1.659\text{mm}$$

$$\text{Runner width (W)} = 2 \text{ D}$$

$$W = 2 \times 1.659\text{mm} = 3.318 \text{ mm}$$

$$\text{Runner width (W)} = 3.318 \text{ mm}$$

Wiper Motor Shot Model:-

Its material is Carbon steel. It is a replica model of components with all gating system which helps to create cavity and core.

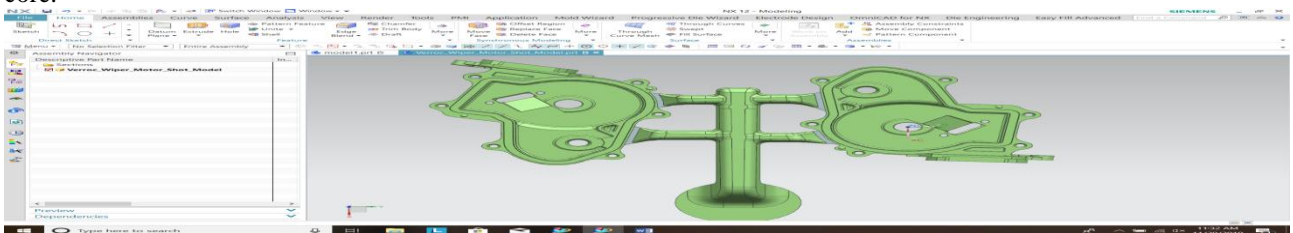


Fig.7.16: Shot Model

VII. COMPONENT ANALYSIS

Previous gate location:-

NX EasyFill helps designers explore the filling pattern of the mold by simulating melt front time. It checks for potentially incomplete filling and unbalanced flow flashing problems, identifies weld line and air trap locations, and much more. With the prediction of melt front time from the field plot, users can check the filling dynamics with the animation function to understand how well the filling process is working. Facing Problem-Filling timing more so solidification problem will be create before spread full material in impression.

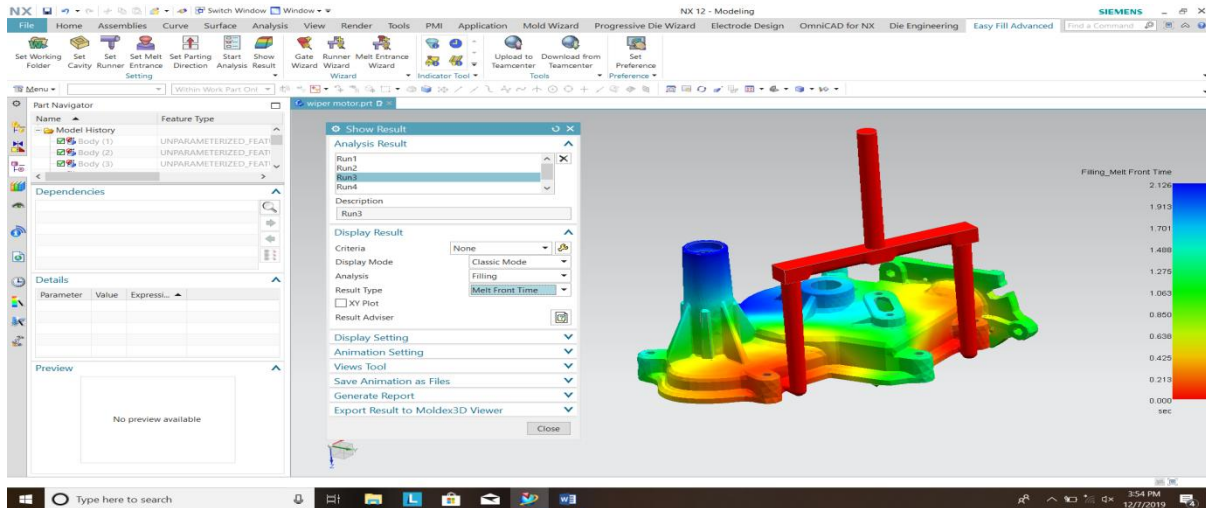


Fig.7.17: Previous gate location filling analysis

Check wall Thickness:-

Analyze and view the wall thickness of any area or all areas in a solid model. Need to check wall thickness for placing the gate at proper location.

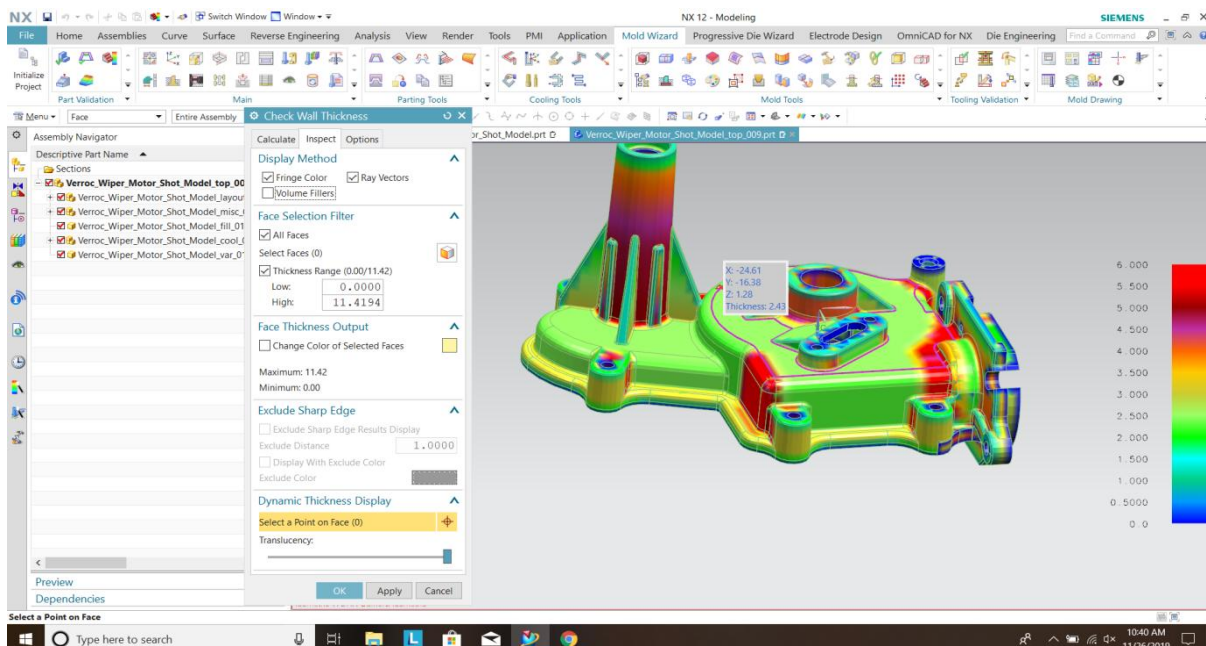


Fig.7.18: Check wall thickness analysis

Draft Analysis:-Draft analysis is the analyzing command which lets you know if your model or design have draft angle in a given tool direction. Required Draft Analysis for extract core and cavity safely without damage the rib.

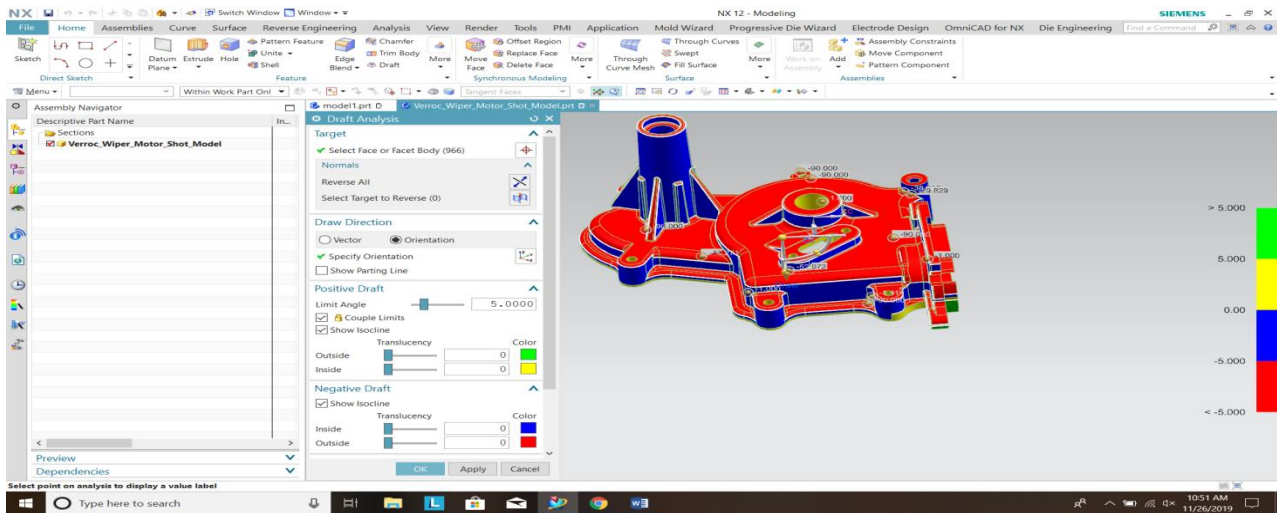
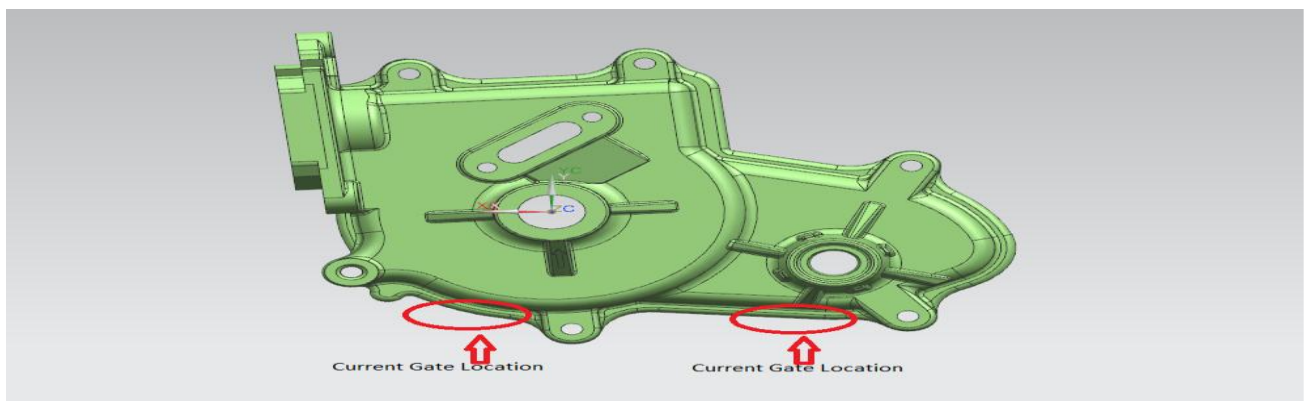
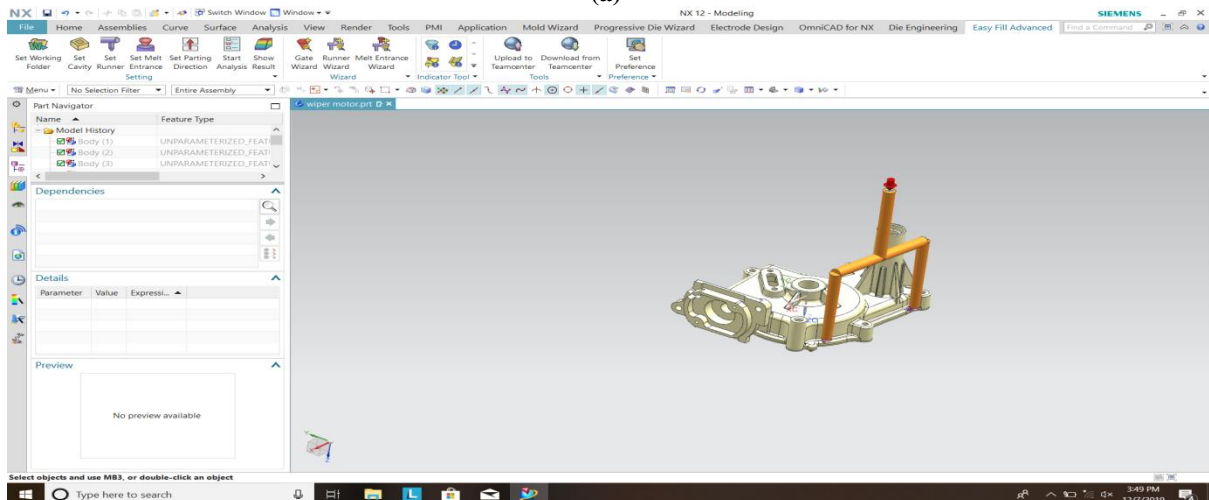


Fig.7.19: Draft analysis

Current location of gate:-



(a)



(b)

Fig.7.20: Current Gate Location

Filling time analysis as per current location of gate:-

NX EasyFill helps designers explore the filling pattern of the mold by simulating melt front time. It checks for potentially incomplete filling and unbalanced flow flashing problems, identifies weld line and air trap locations, and much more. With the prediction of melt front time from the field plot, users can check the filling dynamics with the animation function to understand how well the filling process is working. Reduce the filling timing through change the location of gate.

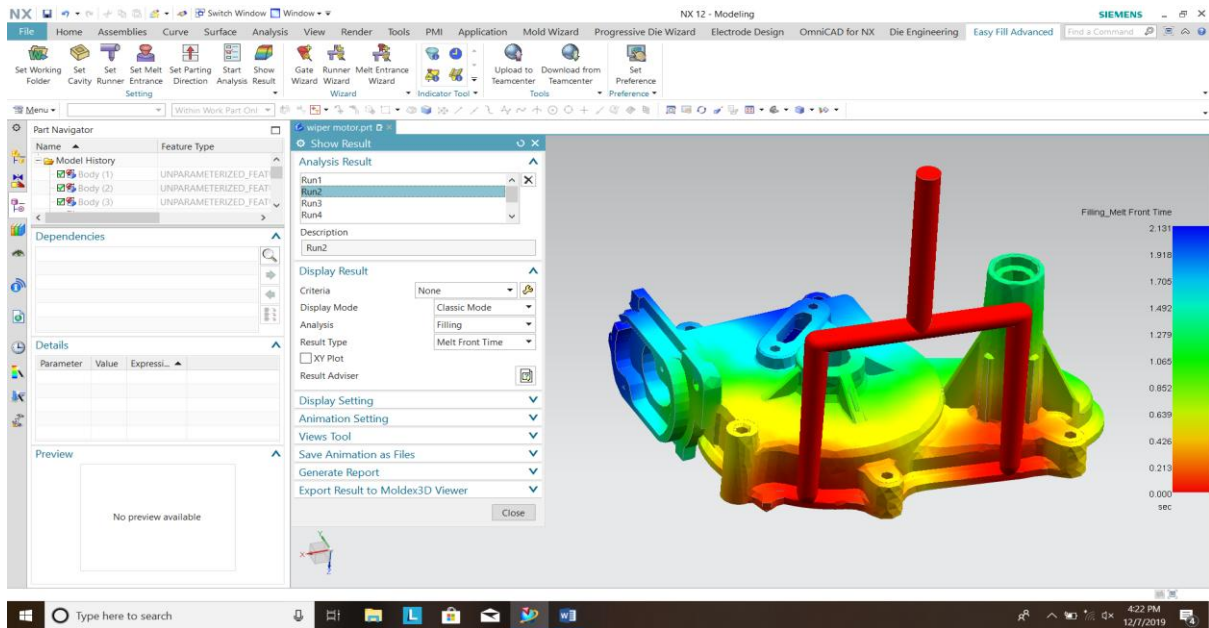


Fig.7.21: Current Gate Location filling Analysis

Current Gate Contribution:

Below Fig. Represent contribution of each gate to fill the cavity. EasyFill calculates each gate’s percentage of total molten metal flow into the cavity. Designers can use the result to achieve better flow balance for improved product and process quality.

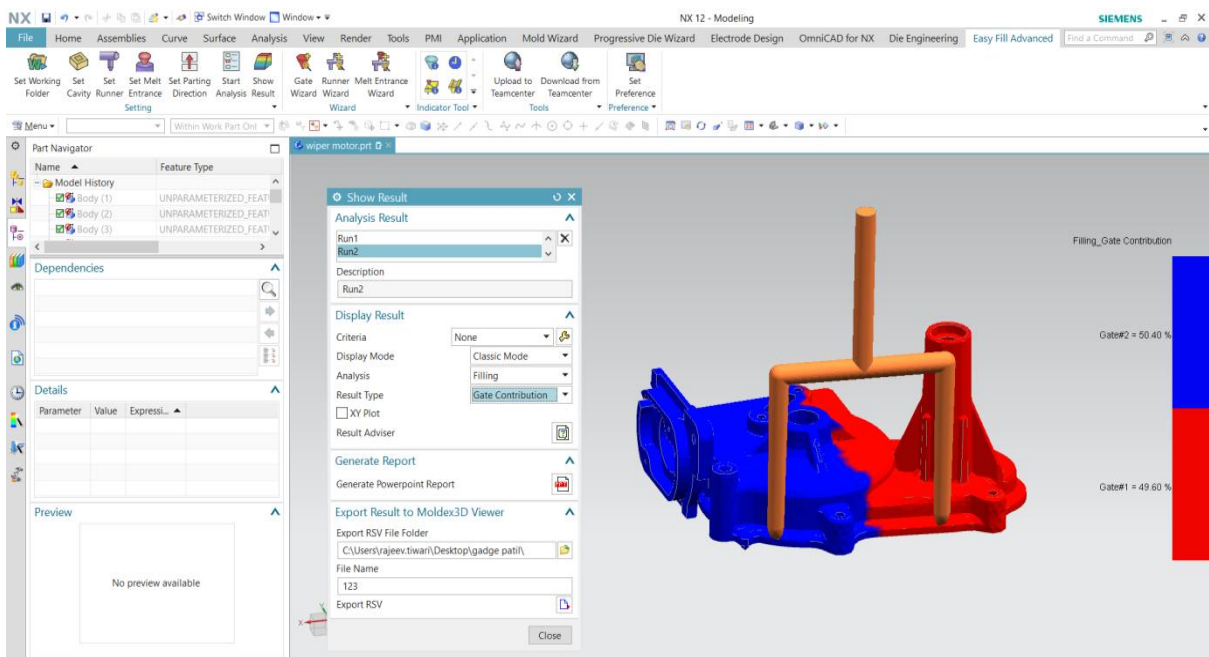


Fig.7.22: Current Gate contribution analysis

VIII. RESULTS & DISCUSSION

Result Obtained by NX Analysis:-

As we analyzed both type of gating system i.e. previous and current gate locations but we get the good results in current gate location. NX also gives Pressure distribution at each step. For using this pressure changes mentioned in Figures we can understand the rate of solidification.

Result as per previous gate location:-

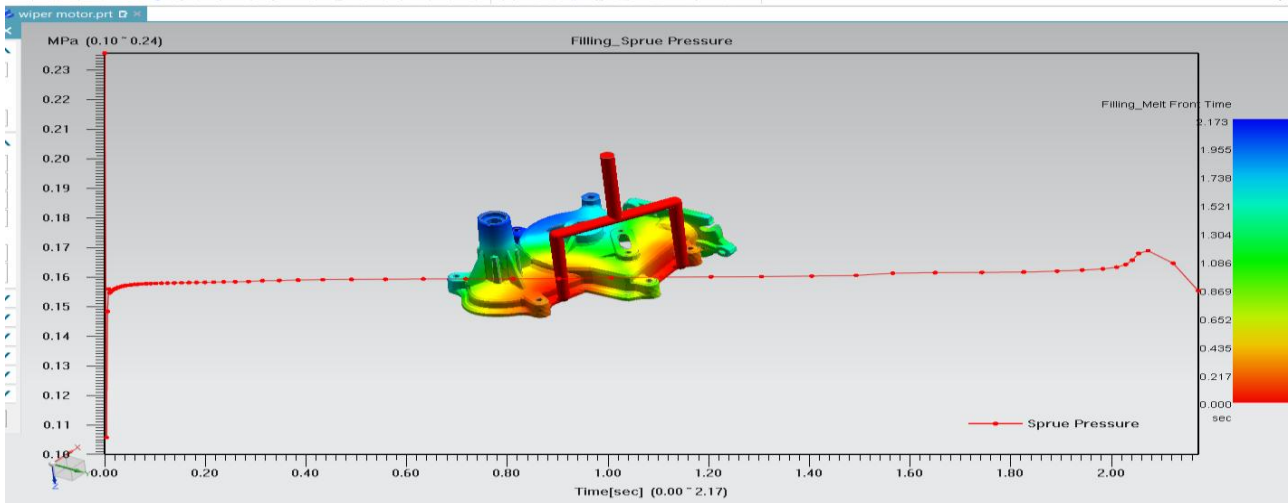


Fig.8.1: Filling time analysis

NX EasyFill helps designers explore the filling pattern of the mold by simulating melt front time. It checks for potentially incomplete filling and unbalanced flow flashing problems, identifies weld line and air trap locations, and much more. With the prediction of melt front time from the field plot, users can check the filling dynamics with the animation function to understand how well the filling process is working.

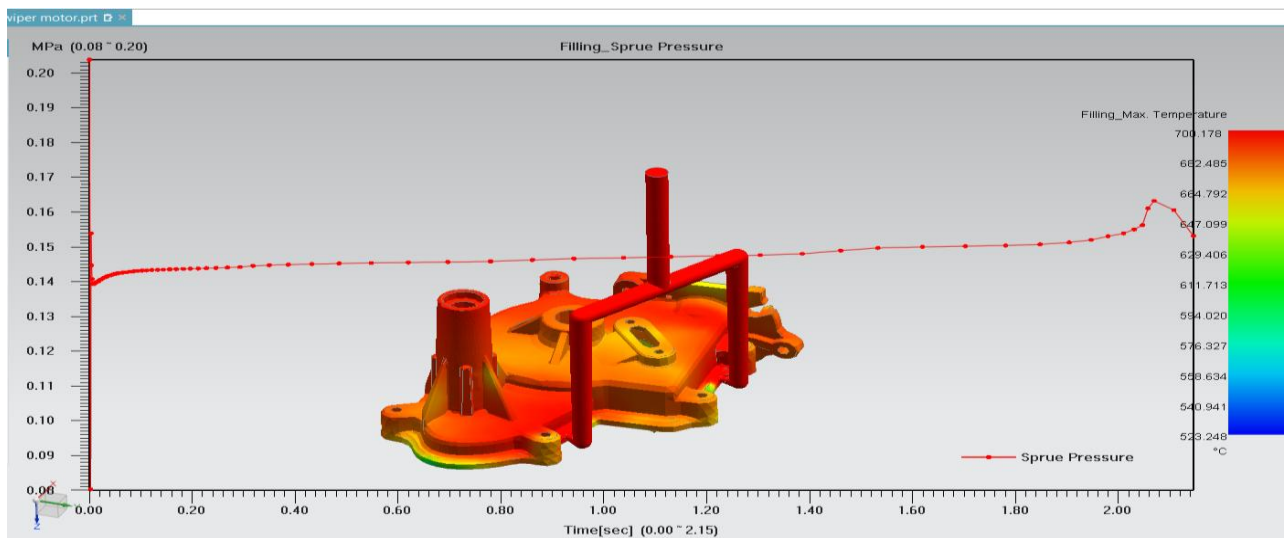


Fig.8.2: Filling Max Temperature Analysis

EasyFill calculates and displays the maximum temperature distribution during the filling process. Designers can readily assess the temperature distribution in three dimensions for the full cavity.

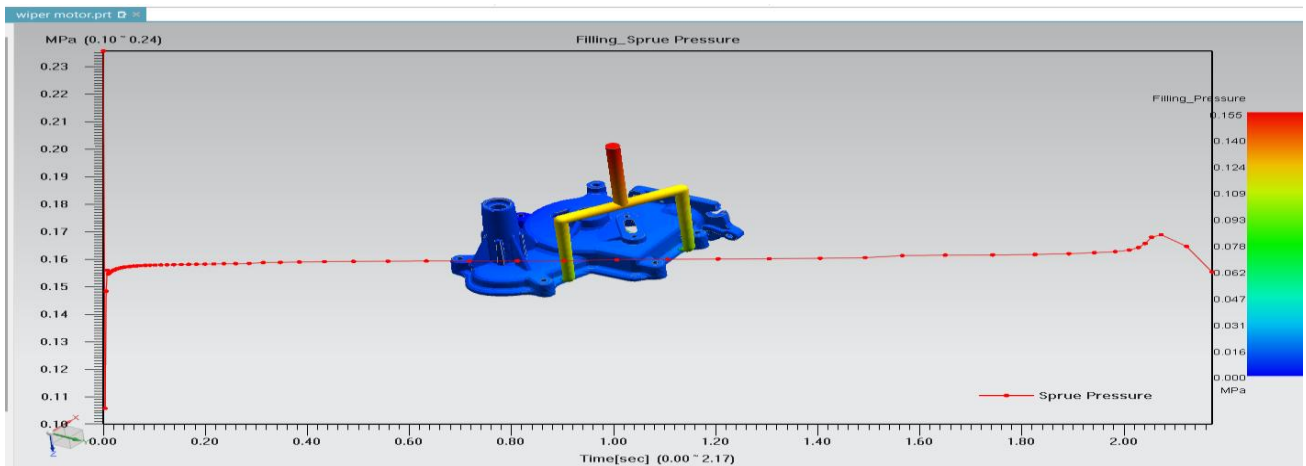


Fig.8.3: Filling Pressure Analysis

NX EasyFill Analysis simulates the drop in pressure at the flow front of the molten metal due to drag and frictional effects in the mold. The pressure drop simulation displays the pressure distribution of the part cavity at the end of filling (EOF) stage. From the pressure distribution, you can check the pressure transmission and evaluate the flow balance of the design.

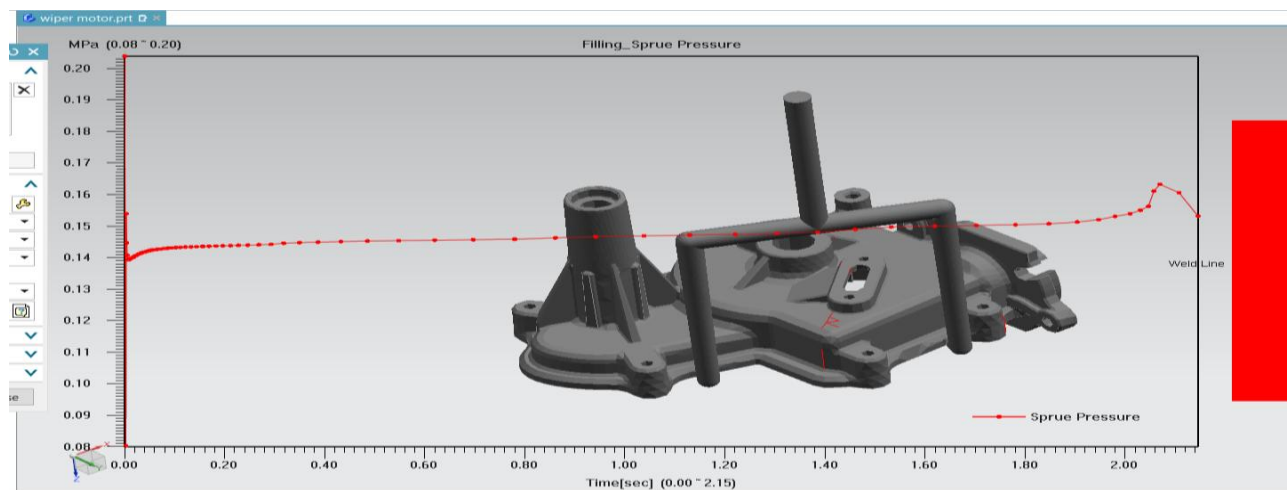


Fig.8.4: Weld Line Analysis

Different flow patterns also lead to a wide variety of weld line results, which can cause cosmetic blemishes or structural issues in parts. With NX EasyFill Analysis, you can observe the results and optimize gate locations.

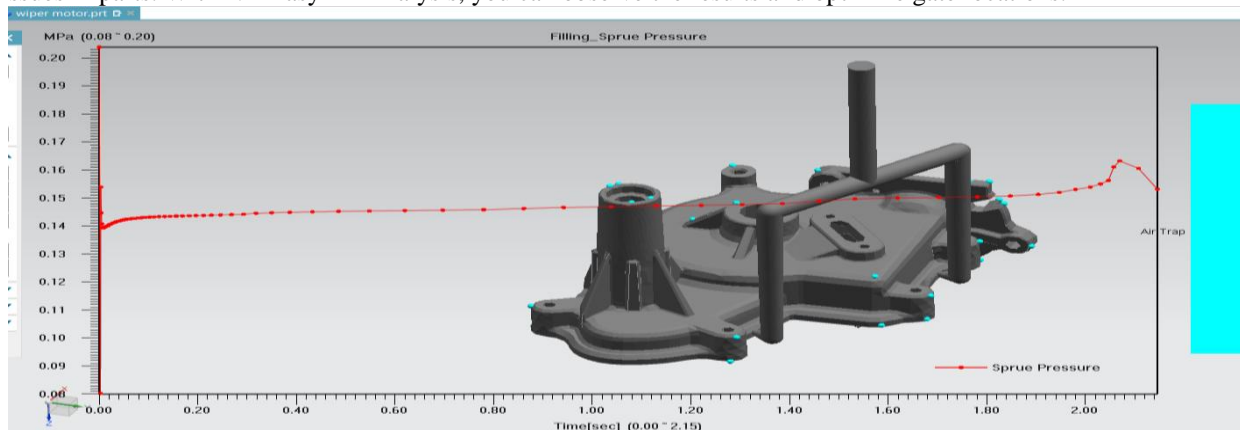


Fig.8.5: Air Trap Analysis

Designers can use NX EasyFill Analysis to visualize the position of air traps in the molding process. Different flow patterns cause a wide variety of air trap results, and EasyFill Analysis enables you to adjust venting designs to avoid such problems.

Result as per current location of gate:-

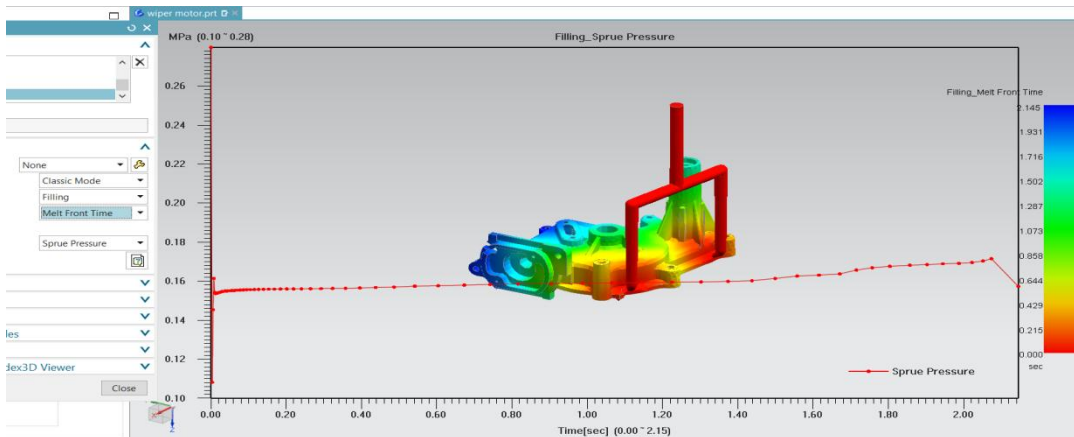


Fig.8.6: Filling time analysis result

NX EasyFill helps designers explore the filling pattern of the mold by simulating melt front time. It checks for potentially incomplete filling and unbalanced flow flashing problems, identifies weld line and air trap locations, and much more. With the prediction of melt front time from the field plot, users can check the filling dynamics with the animation function to understand how well the filling process is working.

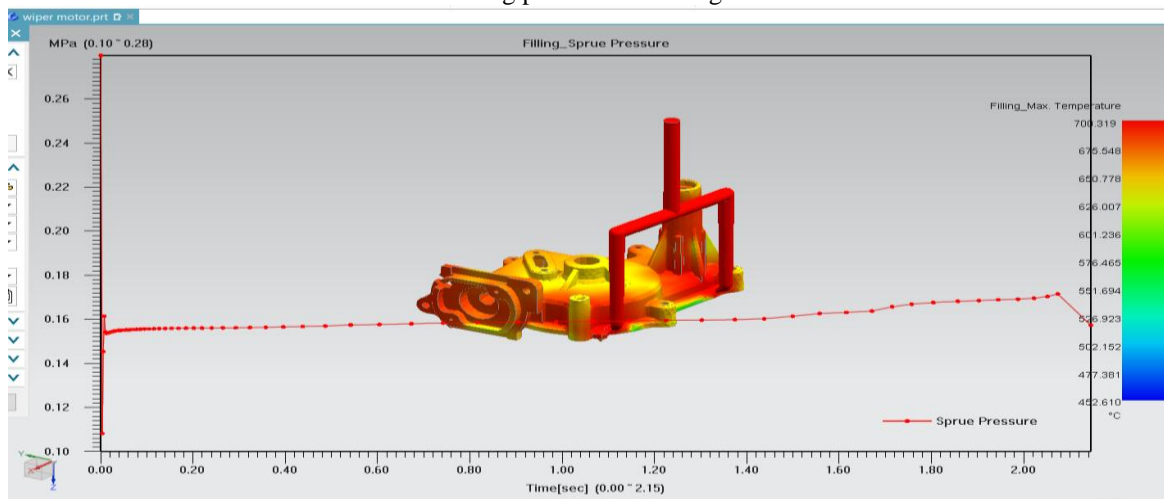


Fig.8.7: Filling Max Temperature analysis

EasyFill calculates and displays the maximum temperature distribution during the filling process. Designers can readily assess the temperature distribution in three dimensions for the full cavity.

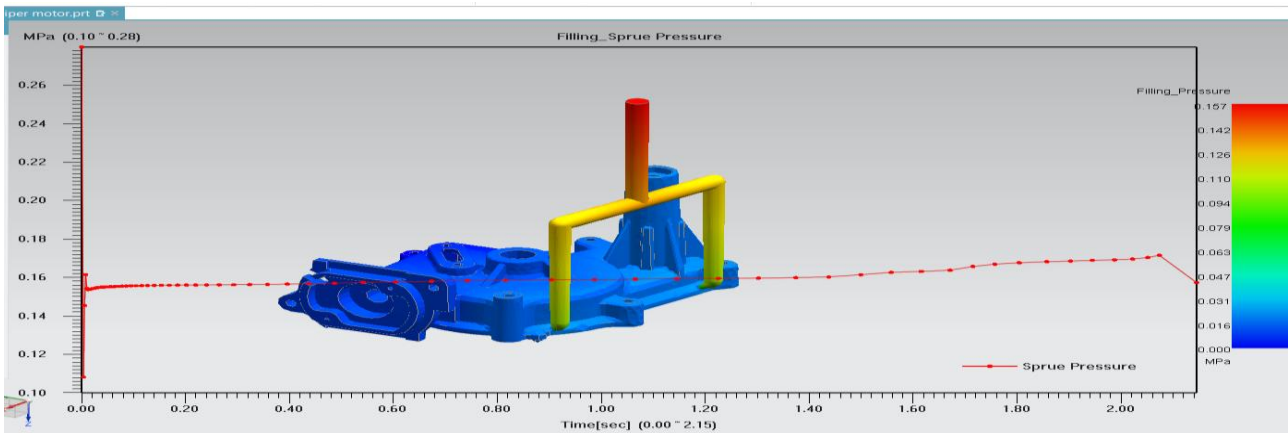


Fig.8.8: Filling Pressure analysis

NX EasyFill Analysis simulates the drop in pressure at the flow front of the molten metal due to drag and frictional effects in the mold. The pressure drop simulation displays the pressure distribution of the part cavity at the end of filling (EOF) stage. From the pressure distribution, you can check the pressure transmission and evaluate the flow balance of the design.

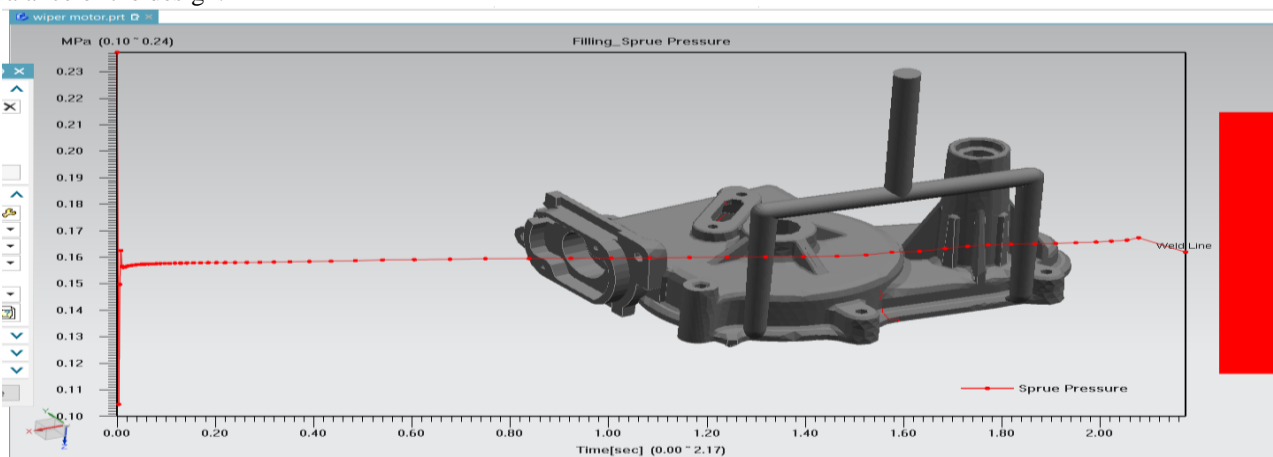


Fig.8.9: Weld Line Analysis

Different flow patterns also lead to a wide variety of weld line results, which can cause cosmetic blemishes or structural issues in parts. With NX EasyFill Analysis, you can observe the results and optimize gate locations.

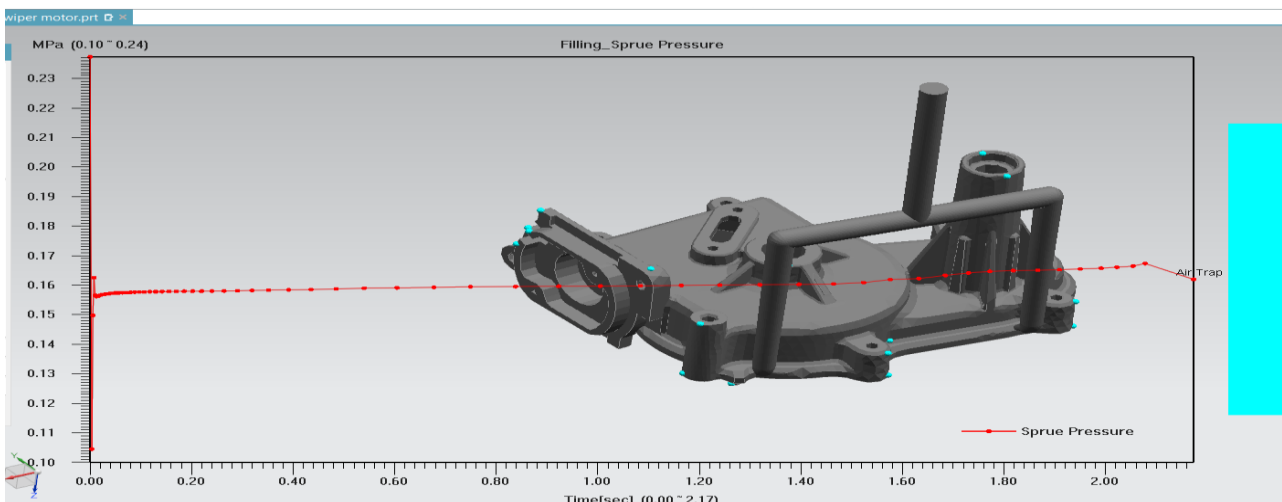


Fig.8.10: Air Trap Analysis



Designers can use NX EasyFill Analysis to visualize the position of air traps in the molding process. Different flow patterns cause a wide variety of air trap results, and EasyFill Analysis enables you to adjust venting designs to avoid such problems.

Table No.8.1: Result Comparison

As per above graphs we find following results:

Sr.No.	Gate Locations	Filling Time (Sec.)	Pressure (MPa)	Temp. (°C)	Air Traps	Weld Lines
1	Pervious Gate Location	0.869	0.062	Approx 645.0	More	More
2	Current Gate Location	0.644	0.046	Approx 525.0	Less	Less

Above table show are current gate position and previous gate position result at different parameters that shows current gate position required less pressure, time and temperature to fill cavity as well as less weld lines & Air traps with respect to previous gate position.

- In the previous gate location the air trap creating more due to improper gate location. The air trap distribution is showing by rolling point in this figure. The graph is showing how to increase the air trap with respect to increase time and sprue pressure.
- In current gate location customer getting better result compare to the previous gate location. Now based on proposal and as per guide line of Siemens software change the gate location which is showing in the above figure. As per analysis based on current gate location filling pressure is less and the value of pressure is 0.046mpa.
- In previous gate location weld line create more due to improper location of gate. Other reason behind this issue is more ribs and less radius fillets near gate location.
- In the previous gate location the filling temperature is more and it is near about 645 degree centigrade. In current gate location the filling temperature is less compare to the previous gate location with respect to time and sprue pressure.

IX. CONCLUSION

The project gives a brief introduction about the work accomplished in design including the explored applications in Unigraphics& with design related information. This project is basically dependent upon pressure die casting. It also gives a view of design consideration involved in Mould & Die-casting-Dies. It gives the idea of the flow of project from the stage of design to till manufacturing of components.

In Results It has been clear that in current gate system required less pressure, filling time and temperature compare to pervious gating system other which shows that solidification are uniform and also the casting simulation technology has become an essential tool for casting defect troubleshooting and optimization method. It improves quality product without shop-floor trials. With the use of optimization techniques gating system of the casting are improve and increase the yield percentage of the casting. This would result reduction in cost and material saving. Many design rules, are developed over the years through experience and study. But For wide spread application, simulation programs must be easy to use, fast, and reliable. This can be achieved by integrating method design, solid modelling, and simulation techniques. The Simulation software has proven its reliability and accuracy in predicting internal defects which help to reduced shop floor trials, and optimization using a single software program. Some other conclusions are:

- The work accomplished in design including the explored applications in Unigraphics& with design related information.
- This work gives the idea of the flow of project from the stage of design to till manufacturing of components.
- Approx 20 kg Die weight reduced by using wage plate in die components.
- With help of draft analysis we provide draft angle to Ribs and provide radius at sharp corners for eliminate catching issue in Core insert.
- By changing gate position we reduce filling time, filling pressure and filling temperature which helps to reduce various casting defects like as shrinkage, weld line, flash, short-sort etc.

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