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SPORK PRODUCT DESIGN, ANALYSIS & IT'S MOULD DESIGN USING CAD/CAE TECHNOLOGY

Nilesh B. Patil[1], Prof Amit J. Somwanshi[2]

[1] *B.E Mechanical Engineering, Matoshri College of Engineering and Research Centre, Nashik*
[2]*Assistant Professor, Mechanical Engineering Department, Matoshri College of Engineering and Research Centre, Nashik*

Abstract —*The part design process involves a series of considerations or compromises so that each of these important demands can be met. Therefore, die and mold makers are forced to develop and adapt the newest technology in part and process design including process modelling, rapid prototyping, optimized tool path generation for high speed cutting, machinery and cutting tools, surface coating. Injection molding is most popular method that is used to make plastic product due to high productivity, efficiency and manufacturability. This report presents the development of a plastic product "Spork" (i.e. Combination of Spoon and Fork) with different materials analysis and its injection mold design. Fabrication is carried out starting from the process planning and assembly procedures.*

Keywords- *Spork; Unigraphix NX; 3D model; Mold.*

I. INTRODUCTION

Injection molding is an advance manufacturing technique for creating parts from both thermoplastic and thermosetting plastic materials. Molten plastic is injected at high pressure into a mold section, which is the inverse of the product's shape. The mold is made by a mold maker from metal, usually either steel or aluminum, and processed by using precision machines to form the required shape features of the desired part. Injection molding is most widely used for manufacturing a variety of parts, from the smallest part to entire body panels of vehicles. The most commonly used thermoplastic materials are polypropylene (low cost, lacking the strength and longevity of other materials), ABS, polyamide etc. The ultimate aim of a machine is to produce no scrap material and increased product quality with reduced labour skill requirements low energy consumption, and minimal maintenance. Nowadays plastic product used is more than metallic products due to its ease of production and high performance. Worldwide plastic consumption is at least 125,000 million pounds (by weight). About 30% of all the plastic parts are manufactured by the injection molding process. This is one of the process that are greatly preferred in manufacturing industry because it can produce complex-shape plastic products and having good dimensional accuracy with short cycle times typical examples are automobile industry, aerospace, casings.

II. PROBLEM STATEMENT

On the basis of reference Preliminary product and mold design parameters we are going to design and analysis of Spork product and also design its mold cavity by doing modifications in that previous mold design arrangement.

- We are going to design non existing new product having features of both Spoon and fork named as "spork"
- Design mold cavity for this new Spork with modification in previous reference spoon mold arrangement.

III. OBJECTIVES

The main objective is to develop a component which fulfils given quality and strength requirements according to safety point of view. Developing a design protocol for the tool to manufacture the mold component "Spork", with the following design objectives

- To develop eating utensil with multiple features.
- To reduce plastic waste.
- To improve the Production rate.
- To reduce operation Cycle time.
- To reduce the Scrap materials.

To reduce Production Cost.

Fig 1 Spork Concept

IV. SCOPE OF THE WORK

The problem identified was approached scientifically by the following means:
The scope of the study for this project consists:

- Study of component.
- Conceptual design and drafting.
- Analysis for the component.
- Preparation of assembly and mould base drawings.
- Preparation of detailed drawing of core and cavity with all other mould elements.

V. METHODOLOGY

Methodology is a systematic approach for the realization of total task. It consists of the following details:

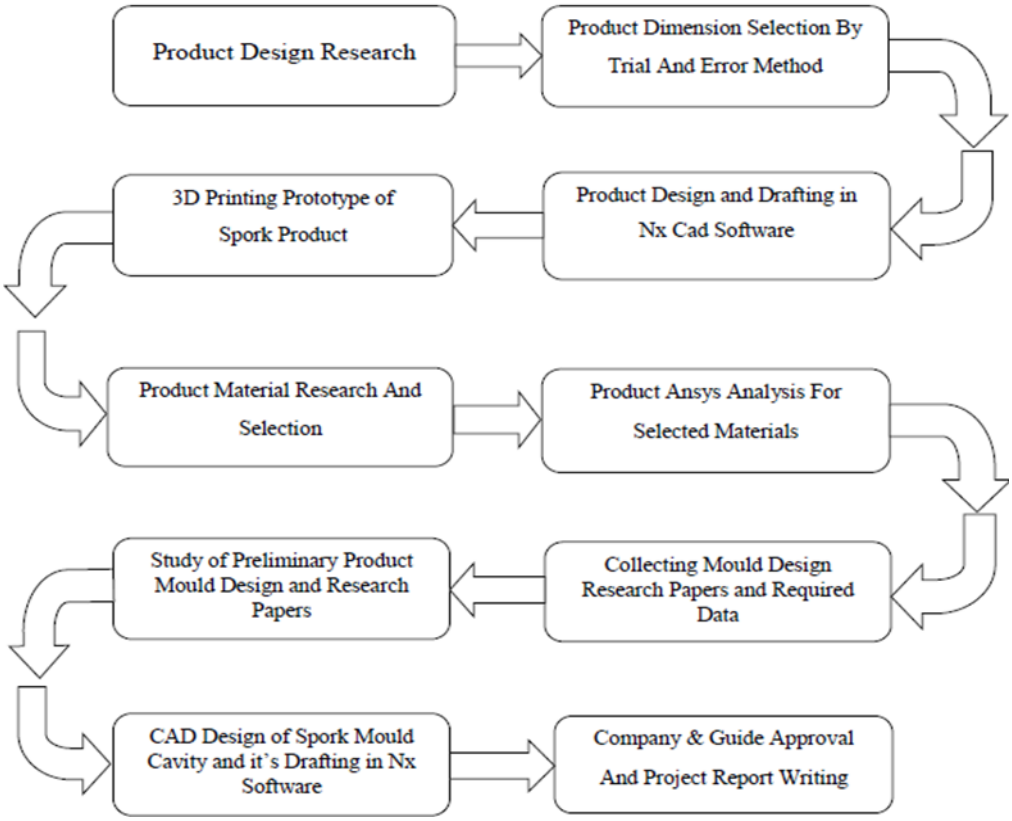

Fig 2 Plan of work Flowchart

This project is divided into following Main parts:

1) 3D Modelling & Drafting of the Plastic Product (CAD)

As it is totally new Product, so we will study the Different Design concept and its history. We don't have any standard data available so the dimensions will be selected on the basis of trial and Error method. The 3D model of Spork (i.e. Spoon+Fork) Product is Design and Drafting is done on Nx CAD Software.

2) Analysis of the Plastic Product in Ansys Software (CAE)

As Design of Spork is completed, we will study about the different Food Grade Polymer materials available and do the Ansys analysis of product for each material. During Ansys analysis we will study the difference in Behaviour of different materials and parameters like stresses generated, Weaker Section in bending, Deflection of product under loading condition and Finally generate report and select the Best Suitable Material for Spork Product. When Product successfully pass in ansys analysis test i.e. the design is safe then we will 3D print the Prototype of Spork Product.

3) Mould Design & Drafting in UG NX Software (CAD)

It is the Last and important stage of our project is to design Mould Cavity for the Spork Product but before the Start of Designing We Will Study the Preliminary Design of spoon mold provided by Sunaxis for Reference, Will Find The flaws of their mold Arrangement and modify it to improve the production capacity, reduce cycle time and the Scrap Generated for this we will study the mold design parameters from reference books and research paper. The 3D design and Drafting work of Mould will be done in Unigraphix Nx10 CAD Software.

VI. SPORK PRODUCT DESIGN

CONCEPT: A Spork is an eating utensil designed with features of both a spoon and a fork. The overall shape is similar to a regular spoon complete with a handle and a small bowl-like structure at the end. At the very end of the Spork are short tines that are used for consuming solid food. Also known as runcible spoon, sporks are often provided by take-out restaurants as disposable utensils. They are generally composed of plastic material and made through a thermoforming process. The concept of combining spoons with forks is not new. One of the first patents were issued in the United States for such a product was done in 1874. In this patent, design is described that has a handle, spoon bowl, knife-edge, and fork tines. This is said to be the basic design concept for all future combination eating utensils. Through the next decades, improved products and materials were patented. One of the patented design had a deeper bowl and shorter tines that made it useful for eating liquids. Plastics are adopted as the construction material of choice during the 1940s and 1950s. The term Spork was introduced during a patent issued in 1970 to the Van Brode Milling Company.

Sporks can be made from all types of materials like steel, wood, glass, and plastic. By far the most oftenly used material is plastic, specifically polypropylene and polystyrene. These materials are combined with other additives to create the well finished utensil. It is important to note that all the materials used to manufacture Spork are regulated by the United States Food and Drug Administration (FDA) to ensure that they are safe for contact with food.

VII. SOFTWARE DESIGN OF SPORK

The 3D modelling and Designing of Spork product is done in Siemens Unigraphix Nx10 Software and different views of Spork Product is as follows:

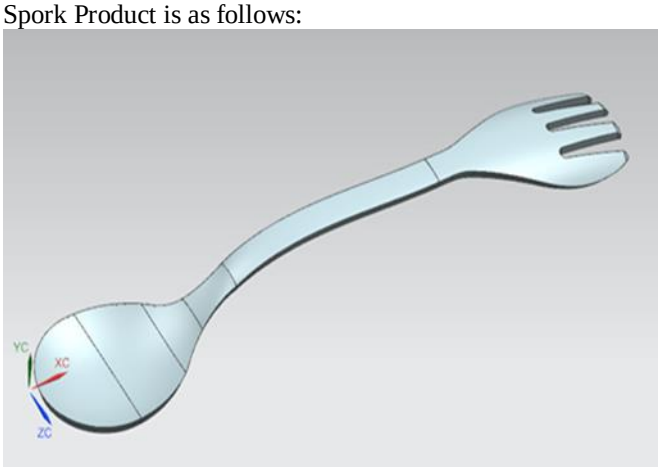

Fig 3 Spork spoon side inclined view

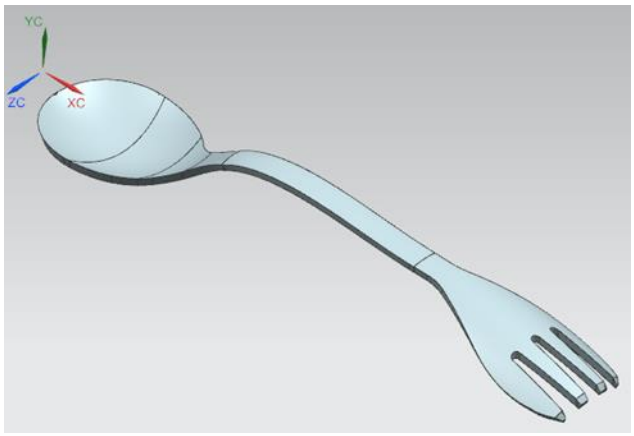

Fig 4 Spork Fork side inclined view

VIII. SPORK PRODUCT DRAFTING

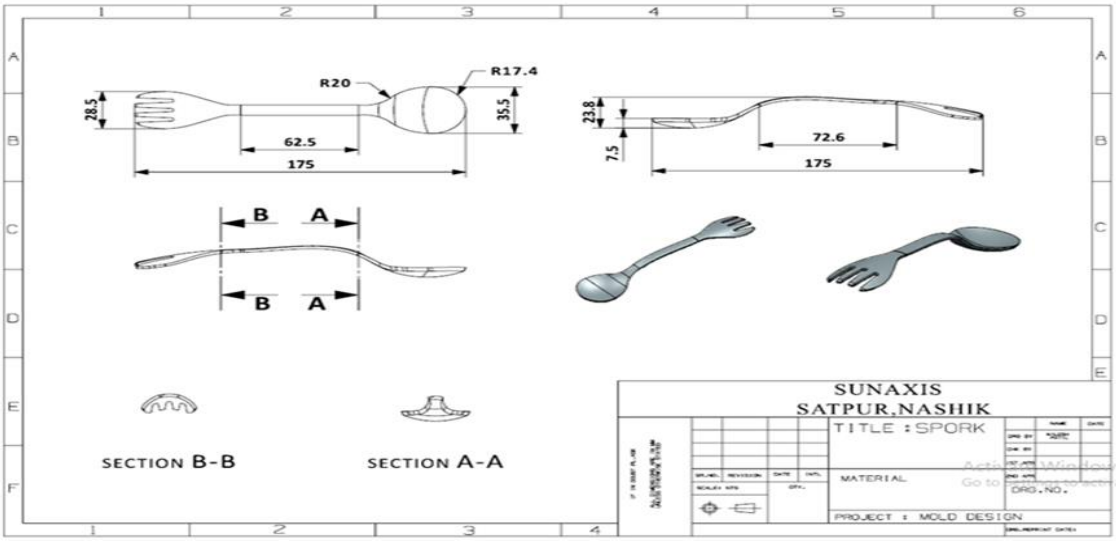

Fig 5 Spork Drafting

IX. 3D PRINTING PROTOTYPE OF SPORK PRODUCT

The Prototype of Product is a necessary thing while developing new product to check its Aesthetic appealing, in hand comfort feel and to check its working ability. For making prototype 3d printing Technique is used. So the “prt” file of Nx

software is converted into "stl" format and slicing process is done in "Ultimaker Cura 4.4" software. Then the Spork Prototype was printed on "Anet A8" printing Machine and the material used is PLA. The time required for printing is 2hr 30min and the Scale is 1:1. The pictures of 3d printed prototype is as follows:

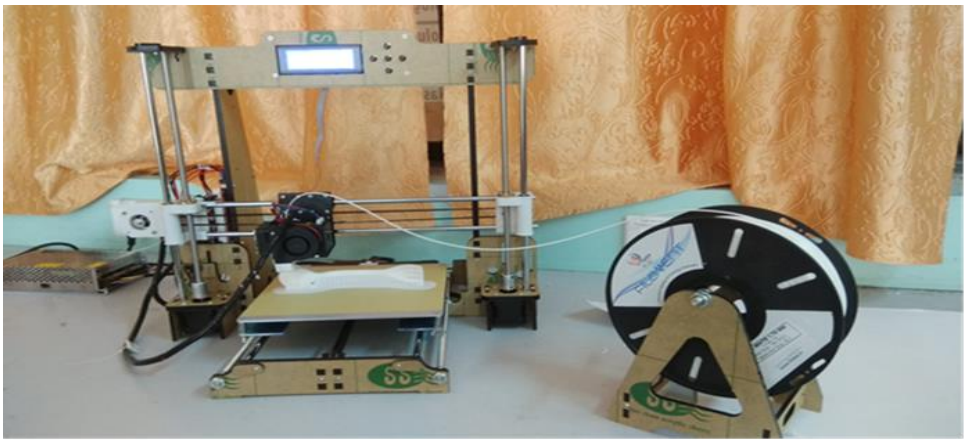

Fig 6 Anet A8 Machine Setup

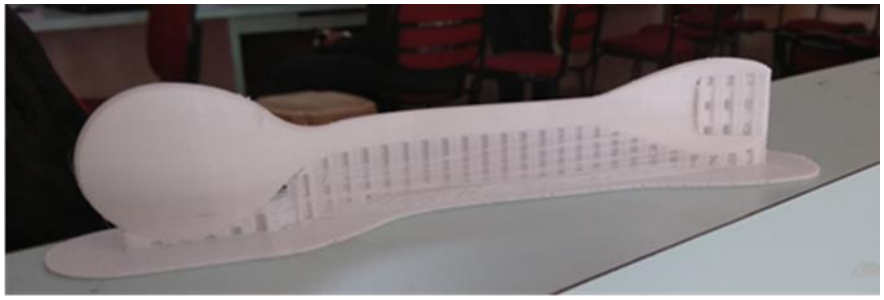

Fig 7 Spork Prototype

X. MATERIAL SELECTION

Product designers have the option to choose from a variety of different materials when selecting the material of construction for a particular product. Depending on the appliance, plastics compete with materials like woods, sheet metals, cast or forged metals, ceramics, or glass. In many cases, plastics offer distinct advantages over the other materials in terms of performance, cost, or performance/cost ratio. However, in most cases, each of the competing materials offers inherent benefits, and of course some limitations. The designer must attempt to correlate with end-use performance requirements of the product with the property profiles of the individual materials in an attempt to obtain the best material for the application.

As our Project is concern with Kitchen eating utensil so it is necessary to use food friendly materials to avoid harm to human health while using Spork product. So we found out following three polymer materials which are food friendly and can be usable in our Spork product:

1. Polycarbonate (PC)
2. Polypropylene (PP)
3. High-Density Polyethylene (HDPE)

1. Polycarbonate (PC)

This material is more hydrolytically stable than polyesters, with superior clear visibility and impact strength. Typical characteristics of polycarbonates are transparency, toughness, strength, rigidity, and fairly high heat resistance. These properties make polycarbonates the resins of choice for many industrial and household applications.

Material Properties:

Property	Unit	Polycarbonate
Density	g/cm3	1.2
Young's Modulus	Mpa	2380
Poisson's Ratio	-	0.399
Bulk Modulus	Mpa	3927.4
Shear Modulus	Mpa	850.61
Thermal Conductivity	W mm^-1 C^-1	2.05e-004
Tensile Yield Strength	Mpa	62.1
Tensile Ultimate Strength	Mpa	67.4
Melt Temperature	(°C)	288
Mold Temperature	(°C)	104

Table No 1 Polycarbonate Properties

2. Polypropylene (PP)

Polypropylene has a crystalline structure with a high level of stiffness and a high melting point compared to other commercial thermoplastics. The Hardness is obtained from the methyl groups in its molecular chain structure. Polypropylene is a lightweight polymer with a density of 0.90 g/cm3 that makes it suitable in many industrial and household applications.

Property	Unit	Polypropylene
Density	g/cm3	0.90
Young's Modulus	Mpa	915
Poisson's Ratio	-	0.443
Bulk Modulus	Mpa	2675.4
Shear Modulus	Mpa	317.05
Thermal Conductivity	W mm^-1 C^-1	1.95e-004
Tensile Yield Strength	Mpa	26.2
Tensile Ultimate Strength	Mpa	29.9
Melt Temperature	(°C)	177
Mold Temperature	(°C)	49

Table No 2 Polypropylene Properties

3. High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) is a commodity thermoplastic polymer that has been widely used in different packaging applications. Its outstanding features such as regular chain structure, combination of low cost and low energy demand for processing, excellent biocompatibility and good mechanical properties to make HDPE expand its application continuously. Even in heat transfer application, where the materials should have superior thermal conductivity like steel and many other metals, the demand for HDPE in this field is also growing. HDPE is widely used because their lighter weight, high corrosion resistance and low costs.

Material Properties:

Property	Unit	HDPE
Density	g/cm3	0.97
Young's Modulus	Mpa	1080
Poisson's Ratio	-	0.418
Bulk Modulus	Mpa	2195.1
Shear Modulus	Mpa	380.82
Thermal Conductivity	W mm^-1 C^-1	4.81e-004
Tensile Yield Strength	Mpa	25.7
Tensile Ultimate Strength	Mpa	29.6
Melt Temperature	(°C)	204
Mold Temperature	(°C)	43

Table No 3 HDPE properties

XI. PRODUCT ANALYSIS FOR DIFFERENT MATERIALS

- Load Applied = 102gms or 1N
- Fixed Support = Fork Side
- Load Point = Spoon

1. Polycarbonate (PC)

	Total Deformation	Equivalent Stress
Minimum	0mm	1.961e-015Mpa
Maximum	24.535mm	17.803Mpa
Average	7.8522mm	1.3225Mpa

Table No 4 Polycarbonate Analysis Result

- Allowable Yield Strength =62.1 Mpa
- Allowable Ultimate Strength =67.4 Mpa

2. Polypropylene (PP)

	Total Deformation	Equivalent Stress
Minimum	0mm	4.3477e-014Mpa
Maximum	50.728mm	14.922Mpa
Average	16.262mm	1.0615Mpa

Table No 5 Polypropylene Analysis Result

- Allowable Yield Strength =26.2 Mpa
- Allowable Ultimate Strength =29.9 Mpa

3 HDPE (High Density Polyethylene)

	Total Deformation	Equivalent Stress
Minimum	0mm	6.8023e-015Mpa
Maximum	46.578mm	15.835Mpa
Average	14.904mm	1.1537Mpa

Table No 6 HDPE Analysis Report

- Allowable Yield Strength =25.7 Mpa
- Allowable Ultimate Strength =29.6 Mpa

Best Suitable Material: From all above analysis following Conclusion and important Factors are obtained for all three materials and the selection will be done by considering all factors from material properties, its behaviour under loading, stresses generated in Spork product, total deflection occur and its Market Cost.

Material	Result Obtained	Market Rate (/kg)
Polycarbonate (PC)	Average Deflection=7.8522mm Average Stress Obtained=1.3225Mpa	120 Rs
Polypropylene (PP)	Average Deflection=16.262mm Average Stress Obtained=1.0615Mpa	98 Rs
HDPE	Average Deflection=14.904mm Average Stress Obtained=1.1537Mpa	110 Rs

Table No 7 Analysis Report

From all above results the Polypropylene (PP) material is selected for manufacturing the Spork due to following reasons:

- Minimum Stress is produced.
- Flexible Material.
- Lower in Cost.

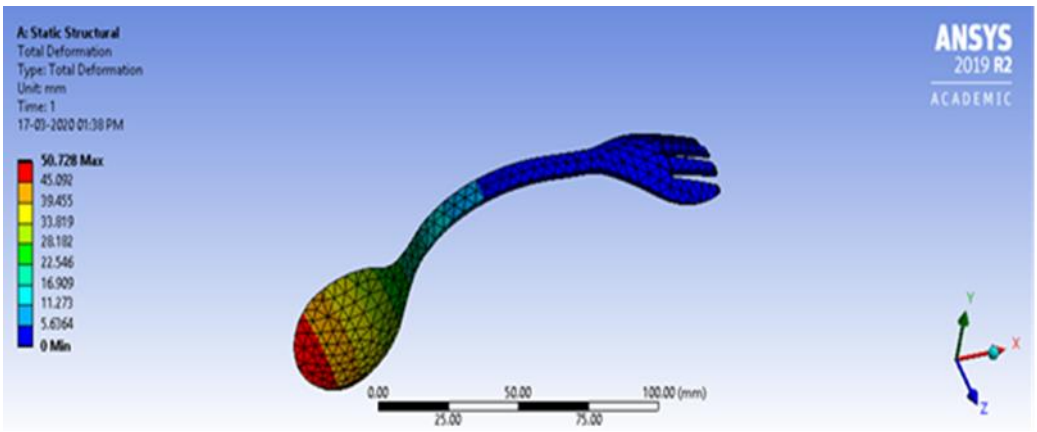

Fig No 9 Polypropylene Total Deformation

XII. PRELIMINARY MOLD DESIGN

The Preliminary Mold design was made for ice-cream Spoon and we take reference of this for our new mold design project. So the Actual mold design arrangement of previous product is as shown in following image.

Fig No 10 Preliminary Mold

After studying previous Mould design and its design factor we found out some design improvement were required. The problem with previous mold is that the linear arrangement required more space. So due to size limitation it can produce only 4 spoon injected part in one cycle, which is very less so the production cycle time required was more. Also the

second problem with linear arrangement was the distance for material travel from sprue, runner upto gating point is so large due to this the mold fill up time required more and also the major problem was due to the long runner passage the Scrap generation also more so we are going to avoid this problems with new mold design by changing its arrangement and doing some modifications.

XIII. PROPOSED DESIGN OF SPORK MOLD

The New mold design having Circular cavity arrangement. The benefit of this arrangement we obtained is the product cavities are doubled as compared to linear arrangement, because in linear arrangement mold, in single cycle only 4 Spork product can be produced but in new circular arrangement in single cycle 8 Spork product can be produced.

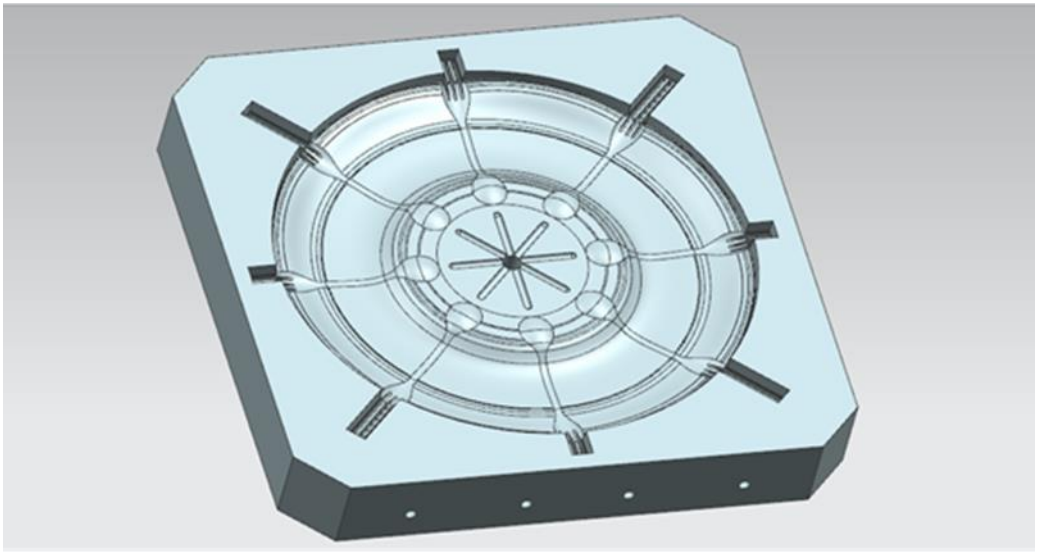

Fig No 11 Spork Core

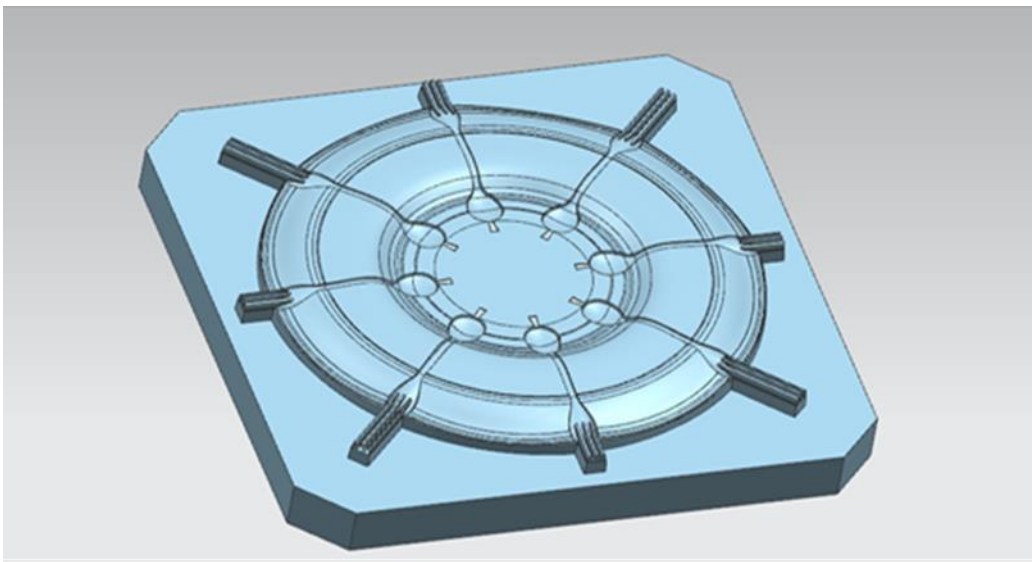

Fig No 12 Spork Cavity

So the Production Cycle time required for new mold arrangement is less as compared to previous arrangement. The molten material travel in previous mold design was large through runner and gating point due to this the scrap generation was more, but in new mold design this problem is avoided as the material enters at centre point of cavity. Also the runner passage from sprue to gating inlet is short so material waste is also reduced. As the production capacity of new mold is doubled in single operating cycle therefore the electricity required for production is also reduced.

XIV. SPORK MOLD DRAFTING

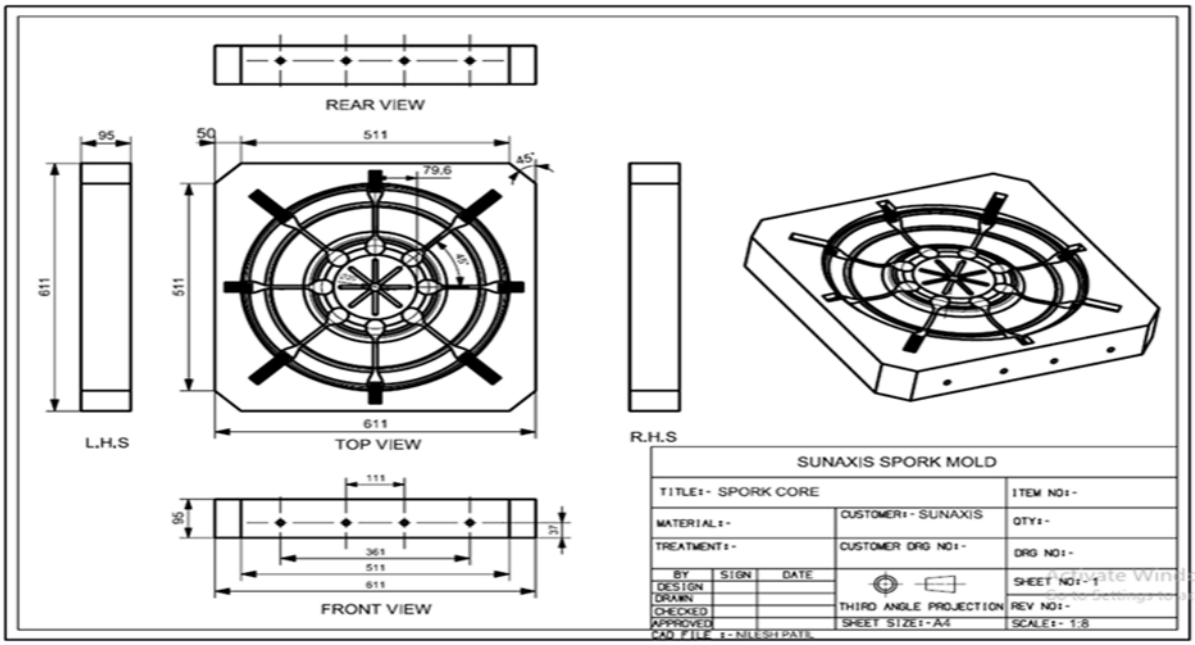

Fig No 13 Mold Drafting

XV. ADVANTAGES

1) Twice products are able to manufacture as compare to previous arrangement.
2) Production time is reduced as the mold filling, holding, cooling time is reduced.
3) The material wastage is reduced i.e. less scrap is generated.
4) Electricity required for production cycle is reduced is as compared to previous arrangement.
5) As the overall production cost is reduced the seller can sell its product in less price to become strong competitor in market.

XVI. CONCLUSION

- Injection molding is one of the most widely used manufacturing processes in the plastic industry due to its quick cycle of production, material and colour flexibility, low labour costs, design flexibility and low waste. Injection molding is the preferred process for manufacturing thermoplastic and thermosetting plastics parts of diverse industrial sectors.
- By doing certain modification the production capacity of the new mold setup is increased also the production time and electricity required is less and scrap generation is reduced in new circular mold arrangement design.
- Spork Product is designed in such a way that it have multiple features of spoon and fork so there is no more need to use two individual utensil for consuming solid as well as liquid food. Due to this the plastic use is reduced and Spork product is portable and easy to carry.

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