Design and Modeling of Cooling Circuit of Injection Moulding

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ABSTRACT

Injection moulding is the most popular manufacturing process for producing parts of simple as well as intricate shapes by the injection of molten material into the mould. Basically, this project is based on the complete design of plastic injection mould with the help of cad software. In this project various cooling circuit has been designed and performed plastic injection flow analysis in Autodesk Mould Flow Advisor to select appropriate cooling circuit for better quality product. Different mould components has been designed to create a complete mould assembly and performed kinematic and dynamic analysis of the mould assembly and global interference check on Creo Parametric. In this way this project is an approach to obtain the better mould design so that to avoid trial and error method.

Keywords– *Injection Moulding, Autodesk Mould Flow Advisor, Creo Paramet*

I. INTRODUCTION

Mould is a container used to shape molten material into specified products. In this project we are discussing about plastic moulds. Plastic moulds are basically created of aluminum or steel material. Mould consists of core and cavity, core gives internal shape and the cavity gives external shape to the product. Moulds can be single impression or multi impressions. Moulds can be classified in to different types.

Classification of moulds according to the method of molding process

1. Injection molding
2. Blow molding
3. Compression molding
4. Rotational molding

1. **Injection molding** In this process the molten plastic material is injected into the closed mould and then it is allowed to cool down and solidify to acquire the shape of the mould. After solidification the product is ejected out from the mould by ejection system.

Example dashboards and bumpers, interior parts, all types of Lids like bottle caps, cups, Medical devices like plastic syringes, containers and medical tools, Electrical switches and Electrical equipments, CDs and DVDs.

2. **Blow molding** In this process a semi-molten material known as parison or preform is suspended inside the mould which consists of two cavity halves. After that the air gun is inserted from the mouth of the mould so that the air is blown inside the parison to expand it up to the inner wall of the cavity. Then coolant is circulated inside the mold to solidify the product and then the product is ejected out.

Example Mineral water bottles, oil bottles, oil canes, kids' toys, cosmetic products bottle.

3. **Compression molding** In this process the plastic material in granular or palletized form is kept in the open mold and then the mold is closed down. The overall molding process is carried on by applying heat and compression to the mold. Due to the compression the material acquired the shape of the core and cavity. This process is usually used for thermosetting material.

Example Electrical Switches, Dinner sets, heavy electrical components.

4. **Rotational molding** In this process the plastic material is charged in heated hollow mold and then the

mold is rotated (usually in two axes) so that the soften material spread uniformly throughout the volume of the mold and adhere to the wall of the mold to acquire its shape.

Example Water tanks, dust bins, big toys.

1.1 Injection Moulding and Its Components

Injection moulding is the most popular manufacturing process for producing parts of simple as well as intricate shape by the injection of molten material into a mould. In this process the molten plastic material is injected into the closed mould and then it is allowed to cool down and solidify to acquire the shape of the mould. After solidification the product is ejected out from the mould by ejection system. Components of injection moulding are - mould base, core and cavity, feed system, cooling system and ejection system. (Fig 1)

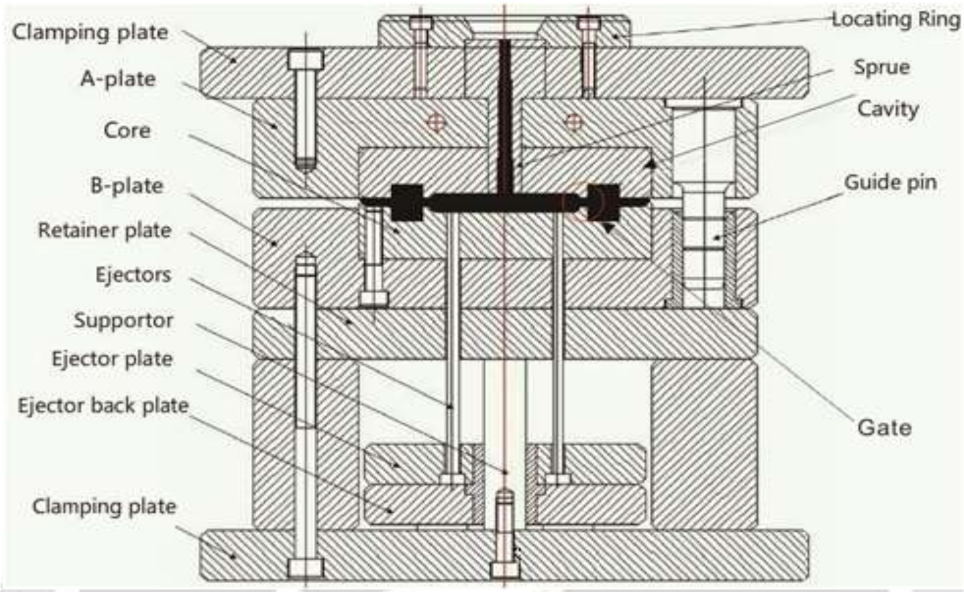

Fig. 1 Component of Injection Moulding

1.2 Split Injection Moulding

Split injection moulding is a process that is used where there is an amount of undercut. The undercut may be external & internal. A moulding which has a recess or projection is termed as undercut moulding. In split injection moulding, the mould is divided into two halves. For required movement of split cavity there is a need of actuation method which can actuates the split into two parts. These methods are of different types, which are:

1. Finger cam actuation method
2. Dog-leg cam actuation method
3. Cam track actuation method
4. Hydraulic actuation method
5. Angled lift actuation method
6. Spring actuation method.

1 Finger cam actuation method In this system, hardened, circular steel pins, termed as finger cams, are mounted at an angle in the fixed mould plate. The splits, mounted in guides on the moving mould plate, have corresponding angled circular holes to accommodate these finger cams. As the mould opens, the finger cam forces the split to move outwards, sliding on the mould plate. The movement can be computed by the formula

$M = (L \sin\theta) - (c / \cos\theta)$

Where M = splits movement,

θ = angle of finger cam,

L = working length of finger cam,

c = clearance.

2 Dog leg cam actuation method This method of actuation is used where a greater splits delay is required than can be achieved by the finger cam method. The dog leg cam which is of a general rectangular section is mounted in the fixed mould plate. Each split incorporates a rectangular hole, the operating face of which has a corresponding angle to that of the cam. The relevant formula for calculating the opening movement, the length of cam, and the delay period are given by

$M = L_a \tan\theta - c$

$L_a = (M + c) / \tan\theta$

$D = (L_s - e) + (c / \tan\theta)$

Where M = movement of each split,

L_a = angled length of cam,

L_s = straight length of cam,

θ = cam angle,

c = clearance,

D = delay,

e = length of straight portion of the hole.

3 Cam track actuation method This method of actuation utilises a cam track machined into a steel plate attached to the fixed mould half. A boss fitted to both sides of the split, runs in this track. The movement of the splits can thus be accurately controlled by specific cam track design. The relevant formulae for calculating the distance traversed by each split, the length of cam track, and the delay period are as follows

$M = L_a \tan\theta - c$

$L_a = (M + c) / \tan\theta$

$D = L_s + c / \tan\theta + r\,(1/\tan\theta - 1/\sin\theta)$

Where M = movement of each split,

L_a = angled length of cam track,

L_s = straight length of cam track,

θ = cam track angle,

c = clearance,

D = delay,

r = radius of boss.

4 Hydraulic actuation method In this method the splits are actuated hydraulically, it is not dependent on the opening movement of the mould. The splits can be operated automatically at any specific time by including this function in the operating programme of the machine. On machines which do not programme for auxiliary cylinder control it is necessary to add a separate hydraulic operating circuit to the existing system. However, to reduce the cycle time to a minimum it is desirable to operate the splits while the mould is opening.

5 Angled lift actuation method In this method the splits are mounted in a chase bolster which forms part of the moving half of the mould. The splits are caused to move out with an angular motion, the outward component of which relieves the undercut portion of the moulding. The splits are normally actuated by the ejector system. The alignment of the splits, when closed, is accomplished by their being seated in the chase bolster. The main requirement of the guiding system is that the split must be restrained to move smoothly in the required plane.

6 Spring actuation method This method obviates the use of cams altogether, incorporates compression springs to force the splits apart and utilises the angled faces of the chase bolster to close them. The outward splits movement must therefore be limited so that they will re – enter the chase bolster as the mould is closed. This design is limited to mouldings which incorporate relatively shallow undercuts. Calculations for the arrangement are limited to those for the splits opening movement

$M = ½ H \tan\theta$

Where M = movement of each split,

H = height of locking heel,

θ = angle of locking heel.

A suitable angle for the locking heel is between 20^0 and 25^0, and therefore approximately

$M = 0.2 H$

II. PROPOSED ALGORITHM

In this project we have done analytical calculation to evaluate various dimensions of mold components. In our case we have chosen split cavity injection mold in which compressed spring method is used to actuate split cavity, so for that first of all we have done calculation to find appropriate value of spring diameter, spring length, stiffness co-efficient etc.

Selection of spring is very important for this type of actuation as it depends on following features: -

1. Length of travel of the split movement.
2. Spring must be able to deliver the load required to actuate the split.
3. Stiffness co-efficient of spring must be optimum to avoid too much stress which could result in lower fatigue life.

2.1 Analytical work

1. **The formula used for calculating the splits opening movement**

$M = 1/2 \times H \times \tan\theta$

Where, **M =** movement of each split

H = height of locking heel

θ = angle of locking heel

Suitable angle of locking heel is 20^o to 25^o.

2. **Calculation of Spring Stiffness Coefficient**

$F = k*X$

Or, **$k = F/X$**

Where, **F** is the restoring force of the spring directed towards equilibrium

K is the spring constant in $N.m^{-1}$

X is the displacement of the spring from its equilibrium position

In the above formula first of all we have to calculate **(F) Force** required to actuate the split cavity with particular acceleration.

$F = m \times a$

Where, **m** is the mass of the object (kg)

a is the acceleration required (m/s^2)

First of all a plastic component which is having a shallow undercut is selected & for that component spring actuation method has been selected which is one of the types of split injection moulding. Then analytical calculation performed to evaluate various dimensions of mould component & value of spring dia., length, stiffness coefficient etc to avoid too much stress which can result in lower fatigue life. After that created 3D models of different parts of mould on **CREO PARAMETRIC** & assemble these parts to create a complete mould & then performed dynamic & kinematic analysis. Efficient cooling circuit designed in **AUTODESK MOULD FLOW ADVISOR** & performed analysis to obtain quality prediction, time to reach ejection temperature, volumetric shrinkage at ejection, sink mark estimate & cooling time variance. Among these analyses results most efficient cooling circuit design chooses & created that in **CREO PARAMETRIC**. (Fig.2)

III. EXPERIMENT AND RESULT

The experiment evaluates the result that cooling system in any injection moulding processes plays a vital role so five different types of cooling circuits have been designed in **AUTODESK MOULD FLOW ADVISOR** software & select the best cooling circuit design among them on the basis of different aspects then performed analysis to examine quality prediction, time to reach ejection temperature, volumetric shrinkage at ejection, sink mark estimate & cooling time variance. After checking this all result the best cooling circuit has selected to obtain better quality product & created that in **CREO PARAMETRIC.** (Fig.3.1, Fig 3.1 (a) to Fig 3.1 (e)) 3D models of different parts of mould on **CREO PARAMETRIC** & assembles these parts to create a complete mould & then performed dynamic & kinematic analysis.

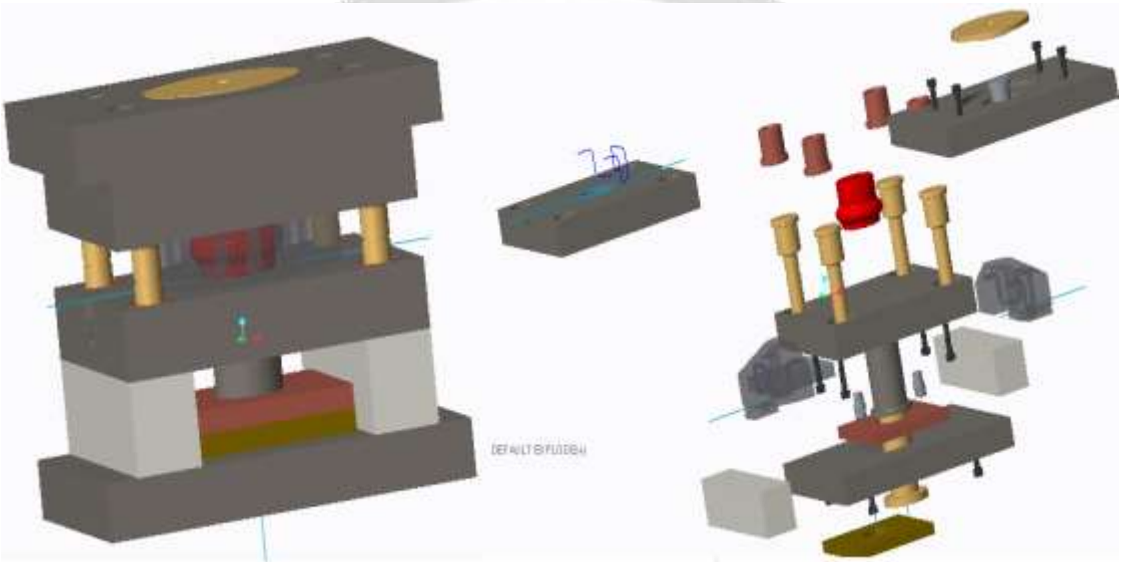

Fig. 2 Mould & its exploded view

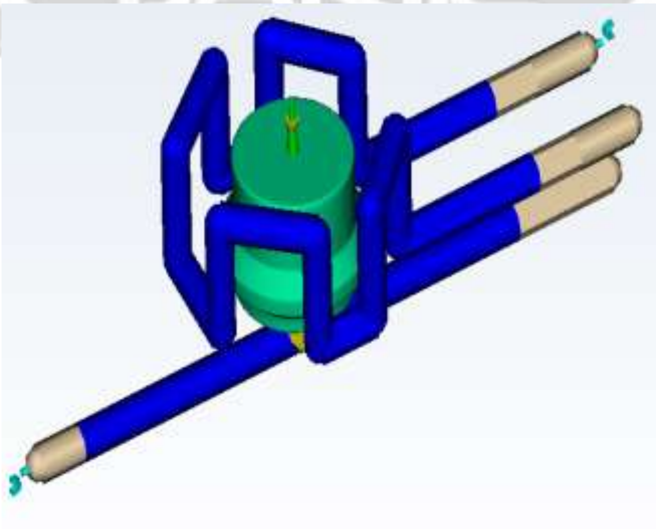

Fig.3 Cooling circuit design

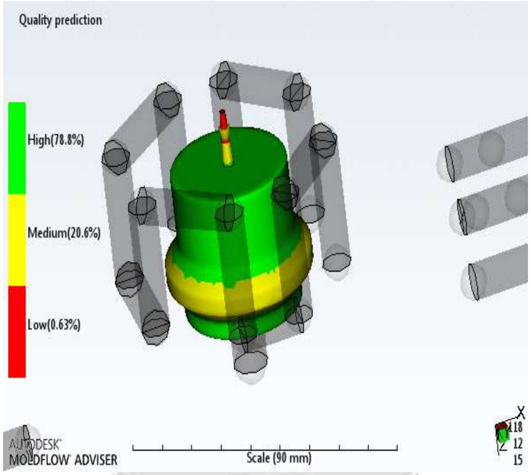

Fig 3.1(a) Quality prediction

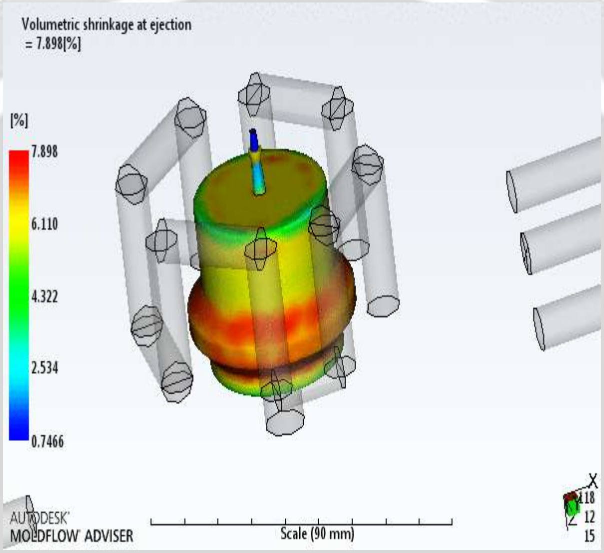

Fig 3.1 (c) Volumetric shrinkage at ejection

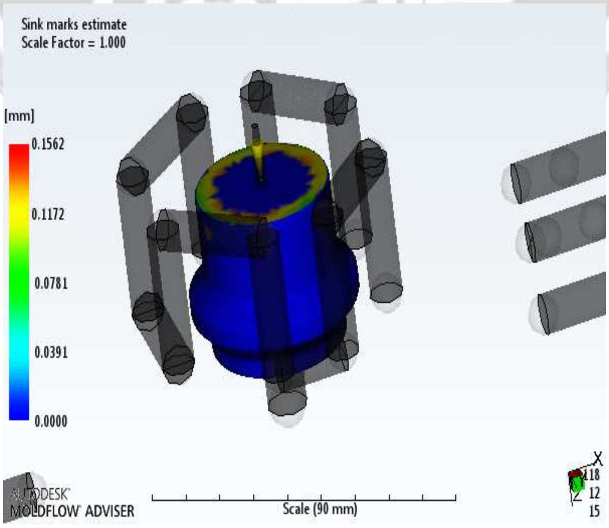

Fig. 3.1 (d) Sink mark estimate

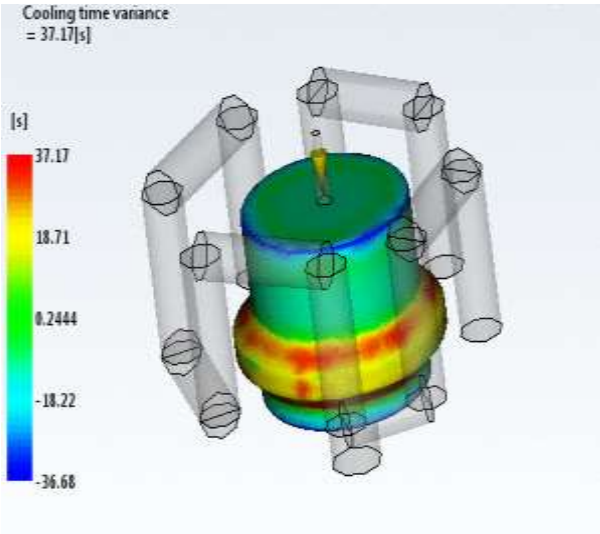

Fig 3.1(e) Cooling time Variance

IV.CONCLUSION

After all this analyses results at the end we find that cad assisted mould design helps us in different aspect like to save money, time & material. Cad assisted mould design helps us in identifying global interference between different mould components which cannot be otherwise find without creating actual mould, basically it obviates trial and error method. By doing such analysis and simulation actual time frame required to travel given distance in respect to other moving parts can also be find. Efficient cooling circuit can also be selected for better heat dissipation from the mould assembly which gives 78.8% quality product.

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