Design and Analysis of Plastic Moulding Die and Runner Shape Optimization by Using Analytical Hierarchy Process

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Abstract:
The designing of mold is a complicated process. In mold designing various parameters are to be adjusted for successful mold design. Here I use the CAD software to design the mold and to analysis of various parameters for design of mold. The CAD software’s use are CREO 2.0 and ANSYS. Here I design the molds by using both analytical and software methods for different parameters. The main failure modes of the plastic mold surface wear, deformation and fracture. The crash reasons depend on working conditions, mold materials and thermal properties, stresses due to ingates etc. Material selection of plastic mold is resolute by their using performances and life of material. By analytic calculations of gate types, gate size, sprue, runners, margin of clamping holes and all other parameters and locations in mold plate. The analysis of mold we can suggest a proper material selection, size, and optimizing the shape of the ingate or runner and the position of the runner. The runner provides the liquid material to the mold but the runner is cut over the die so it produces the stresses in the die if the stress produce is more than the material properties of the die then the failure of the die is occurs. To avoid the collapse of shape of the runner and the position of the runner is to be selected properly so the stress is minimizes and the crash of the die is avoided and the stress can be minimized. Here we use the analytical hierarchy process of the optimization of the runner cross section. We take the ANSYS results and apply this technique on it so that i get the optimum cross section for the runner and we take that runner cross section and design the moulding die, past deceitful the moulding, create the die on CNC machine.

Keywords: Plastic Moulding Die, Analytical Hierchey Process, Optimum Runner Cross Section.

I. INTRODUCTION
Plastic is base to determine the plastic process flow. It is a material that can produce many shapes that can be second-hand by human life and all of plastic products are produce from various type of operation or process. All of product with different type of plastic material depend to wanted. Plastics are divided into two groups’ thermoplastics and thermo sets. Therefore moulded into various forms and hardened for commercial use. It is perfect for this modern age. It is glow, burly, simply moulded and durable. Although plastics are thought of as a modern invention, These materials behaved very much like today’s affected plastics and were often used like to the way manufactured plastics are currently applied. Injection moulding is very generally used for manufacturing a variety of parts, from the least component to entire body panel.

Various type of runner cross sectional shapes often adopted include full round, half round, square, rectangle, trapezoidal and adapted trapezoidal. Runner shape selection depends on desired moulding size, the type of plastic and the moulding situation as runners are preferred to be on one half of the mould only, the best compromise is a trapezoidal shape, with base fillet. [1]

Design and manufacture of dies for plastic injection moulding is one of the most challenging tasks. As a consequence extreme expertise is vital to accomplish perfection. Plastic injection moulding technology demands highest value addition within shortest time period, cold runner system could be the reply for it; because cold runner system would be simplest. [2]

II. PROBLEM STATEMENT
A parameter setting system such as gate, runner and sprue inside the plastic injection mould are located by mould makers using check and fault method. This situation, people that have a lot of experience in injection moulding process who capable to decide the size and place of feeding system especially in two plate mould are needed. The problems create when this person cannot perform the job with fine process and needed to take much time to think and make an experiment. Misuse time and higher price maybe happened during this period. This situation happened at past time before process analysis can perform with software. [5]

III. OBJECTIVES
The main objectives are:
i. The design plastic part and design feeding system like sprue, runner and gate in two plate injection mould.
ii. To set optimum process parameter like injection pressure, speed, temperature and other and Analysis plastic flow in two plate injection Mould.
iii. To prepare a product design for “a joint credit card & USB holder” by using design analysis software.
iv. To design and test the plastic injection mold for the exact product. [8]

IV. DESIGN METHODOLOGY

The paper highlights a practical design procedure or methodology of an injection molding die, adopted by analyzing the various parameters to create a precious industrial part namely RAM component for an electrical transformer has been choked out in detail aspect which is as follows.

A. Design Methodology

To start a new mold design, the designer should know some important points to shun some mistakes ahead of going further. Product position design, material usage, correction shrinkage of the material and number of cavities and selection of mold base. It should large enough for suitable fill rate and small adequate close off and prevent back flow or over packing. The mould which contains one or two basic parts

B. Cad/Cam for Mould Design

The designer of injection mould design system is proposed based on practical design parameters and conceptual design stage mostly consists of concept generation and concept evaluation. CAD/ CAM can help designers to speedup plan for the plastic division and mould plan process and decrease the long lead time.

C. Mould Flow Analysis

The moulding flow analysis was performed using Autodesk Mold Flow analysis software. The sequence of work involved in mold flow analysis is given under.

I. Converting the 3D model in STEP format and Meshing the model by using dual domain type of mesh.

II. The meshed file to the solver package specifying the boundary condition, loads such as injection pressure, injection time, die temperature, thaw temperature, textile properties etc.

III. Building the feed system such as sprue, runner and gate, cooling lines and mesh the feed system and cooling lines.

V. THEORETICAL AND ANSYS WORK

Calculation for die

We know that

- Locking pressure = 110kN/cm²
- Injection pressure = 40kN/cm²
- Area of cross section of cavity = 80³46mm²
- Tensile strength of material of die = 450N/mm²

Thickness of die = \( \frac{F \times L}{B \times f} \)

Where

- \( F \) = maximum force applied on die (N),
- \( L \) = length of cavity (mm),
- \( B \) = width of cavity (mm),
- \( f \) = tensile stress of material of die (N/mm²).

Maximum force \( F \) = (pressure * area)

\( \frac{110000}{100} \times (80 \times 46) \) N

Now, thickness of die = \( \frac{\sqrt{1((110000 \times 80 \times 46))}}{450 \times (1 - (1 - 1/100)^2)} \)

= 140 mm

Calculation of runner

A. Runner with Circular Cross-Section

For calculating the area of cross-section of circular runner we need the diameter of the runner.

\( D = \frac{w \times L}{\pi} \)

Where,

- \( D \) = diameter of runner (mm)
- \( w \) = weight of material to be injected (gm)
- \( L \) = length of runner (mm)

Now weight of material to be injected= volume × density of material to be injected

Volume of material to be injected = \( 2 \times \pi \times (R^2 - r^2) \times h \)

= \( 2 \times \pi \times (17.8^2 - 8^2) \times 46 \) mm³

= 23411.148 mm³

Since, the material will also be in the runner so the volume will be taken approximately = 24000mm³.

And the volume of runner is taken as 6000mm³

We are assuming that Nylon-6 is the material of the product.

Density of Nylon-6 = 1.12gm/mm³

Now, weight of material = \( \frac{24000 \times 1.12}{1000} \) gm

= 33.6 gm

Diameter of runner = \( \frac{1}{2} \times \pi \times (80^2) \)

= 13.5 mm

FIGURE 1

CIRCULAR CROSS-SECTION RUNNER

B. Runner with Square Cross-Section

Since the area of cross-section will remain same in both the runners. So for calculation of side of square cross-section area are to be equated.

Equating the area for the circular cross-section runner with the area of square cross-section runner, we get the side of square cross section runner equal to 8mm

Side of square cross-section runner = 8mm.
FIGURE 2
SQUARE CROSS-SECTION RUNNER

C. Circular Cross-Section
1. Centre Position of Runner

2. Upper Position of Runner

FIGURE 3
CENTRE POSITION OF RUNNER (A) TOTAL DEFORMATION IN CENTRE IN LOWER DIE (B) EQUIVALENT ELASTIC STRAIN IN CENTRE IN LOWER DIE (C) EQUIVALENT STRESS IN CENTRE IN LOWER DIE (D) MAXIMUM PRINCIPAL STRESS IN CENTRE IN LOWER DIE (CIRCULAR CROSS-SECTION)

FIGURE 4
UPPER POSITION OF RUNNER (A) TOTAL DEFORMATION IN UPPER IN LOWER DIE (B) EQUIVALENT ELASTIC STRAIN IN UPPER IN LOWER DIE (C) EQUIVALENT STRESS IN UPPER IN LOWER DIE (D) MAXIMUM PRINCIPAL STRESS IN UPPER IN LOWER DIE (CIRCULAR CROSS-SECTION)
3. Lower Position of Runner

![Figure 5](a)

**FIGURE 5**
LOWER POSITION OF RUNNER (A) TOTAL DEFORMATION IN LOWER IN LOWER DIE (B) EQUIVALENT ELASTIC STRAIN IN LOWER IN LOWER DIE (C) EQUIVALENT STRESS IN LOWER IN LOWER DIE (D) MAXIMUM PRINCIPAL STRESS IN LOWER IN LOWER DIE (CIRCULAR CROSS-SECTION)

![Figure 5](b)

![Figure 5](c)

![Figure 5](d)

D. Square Cross-Section

1. Centre position of runner

![Figure 6](a)

**FIGURE 6**
CENTRE POSITION OF RUNNER (A) TOTAL DEFORMATION IN CENTRE IN LOWER DIE (B) EQUIVALENT ELASTIC STRAIN IN CENTRE IN LOWER DIE (C) EQUIVALENT STRESS IN CENTRE IN LOWER DIE (D) MAXIMUM PRINCIPAL STRESS IN CENTRE IN LOWER DIE (SQUARE CROSS-SECTION)

![Figure 6](b)

![Figure 6](c)

![Figure 6](d)
2. Upper position of runner

![Image](a)

![Image](b)

![Image](c)

![Image](d)

**FIGURE 7**
UPPER POSITION OF RUNNER (A) TOTAL DEFORMATION IN UPPER IN LOWER DIE (B) EQUIVALENT ELASTIC STRAIN IN UPPER IN LOWER DIE (C) EQUIVALENT STRESS IN UPPER IN LOWER DIE (D) MAXIMUM PRINCIPAL STRESS IN UPPER IN LOWER DIE (SQUARE CROSS-SECTION)

3. Lower position of runner

![Image](a)

![Image](b)

![Image](c)

![Image](d)

**FIGURE 8**
LOWER POSITION OF RUNNER (A) TOTAL DEFORMATION IN LOWER IN LOWER DIE (B) EQUIVALENT ELASTIC STRAIN IN LOWER IN LOWER DIE (C) EQUIVALENT STRESS IN LOWER IN LOWER DIE (D) MAXIMUM PRINCIPAL STRESS IN LOWER IN LOWER DIE (SQUARE CROSS-SECTION)
VI. RESULT

TABLE I
RESULTS OF CIRCULAR AND SQUARE CROSS-SECTION

<table>
<thead>
<tr>
<th>Position of runner</th>
<th>Cross-section of runner</th>
<th>Total deformation (m)</th>
<th>Equivalent elastic strain</th>
<th>Equivalent stress (Pa)</th>
<th>Max principal stress (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>Circular</td>
<td>1.43e-14</td>
<td>2.76e-12</td>
<td>0.52</td>
<td>0.52</td>
</tr>
<tr>
<td>Lower</td>
<td>Circular</td>
<td>1.46e-14</td>
<td>1.73e-12</td>
<td>0.34</td>
<td>0.27</td>
</tr>
<tr>
<td>Upper</td>
<td>Square</td>
<td>1.9e-14</td>
<td>2.59e-13</td>
<td>0.41</td>
<td>0.31</td>
</tr>
<tr>
<td>Lower</td>
<td>Square</td>
<td>1.43e-14</td>
<td>1.45e-12</td>
<td>0.25</td>
<td>0.24</td>
</tr>
</tbody>
</table>

VII. CONCLUSION
In this paper the concept of AHP use for the selection of multiple criteria selection process. For selection of mould design parameter, i choose the AHP method for selection process. We use new approach for the selection design parameter. This method gives extremely correct and value based product.

Here we use SOLIDWORKS 2014 for the designing of dies and runners of different cross sections (like circular, square). The analysis work of dies and runners is done by using ANSYS 14.5 simulator. I work with integrating theoretical aspect with practical study and get the desired output.

From Stress analysis result, i conclude that MOULD DESIGN with CIRCULAR cross section has given optimum result of all stress analysis parameters like cooling time, strength, mouldability, etc.

VIII. REFERENCES


[6] Hong-Seok Park And Xuan-Phuong Dang,” Design And Simulation-Based Optimization Of Cooling Channels For Plastic Injection Mold”.


