DESIGN MODIFICATION OF BEAD EXTRUDER HEAD ASSEMBLY

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ABSTRACT

At the manufacturing facility of APOLLO TYRES Ltd. Kalamassery they have installed a single screw rubber extruder for the bead winding operation. In the trail runoff this extruder created certain problems which were detected. On further examination it was found that defects were caused due to certain imperfections in extruder head assembly. As the result of the defects, the quality of the beads obtained was found to be poor. This in turn would affect the overall quality and the durability of tyre manufactured. The machine also suffered from frequent breakdowns thereby reducing the productivity and causing bottlenecks in the flow of operation. So we decided to replace the existing door type head assembly with flange coupling. The primary objective of our project is to rectify these defects of the existing design and reduce the material loss as well as the heat loss. We designed the flanged coupling and did comparative thermal analysis using three materials and the best one was proposed to the company. New design can be accommodated in existing frame work of the machine without any major alternation. The proposed work is supposed to keep the quality standard of the products within the specified tolerances, so that the company can maintain an edge over other products.

Keywords: rubber extruder, tyre, head assembly

1. INTRODUCTION

Extrusion is a process used to create objects of a fixed cross profile. A material is pushed or drawn through a die of desired cross-section and or to work materials that are brittle, because the material only encounters compressive and shear stress. Extrusion process may utilize a single material, or may utilize two or more different materials extruded simultaneously to create single or multi layered objects. The extrusion head is the process tool that shapes the extradite that is the tool that determines shape, properties, structure and dimension of the extradate as well as mutual position of the elements in the extrusion process. The extrusion head is the tool an open forming cavity i.e. the extrusion die. The extrusion head to ensure the occurrence of proper physical and chemical process in the
polymer flow channels. The extrusion head is fixed to the end part of the plasticizing system of the extruder. Small extrusion heads are fixed mainly by means of bolt connection or bolt pin connection (usually hinge-type connection) or by means of screwed shape ring. Larger extrusion head are fixed by means of bolt connections that are very often provided with a vertical support on the extruder foundation. The extrusion head, usually provided with a vertical support, is connected to the last preparatory supplementary device.

Our project deals with the design modification of the extruder of the single screw extruder installed at the tyre manufacturing facility of APOLLO TYRES Pvt. Ltd. Kalamassery. The extruder employed for the function of bead winding application was found causing certain problems that are affecting the normal functioning. In this project we have proposed a newly improved extruder head that is expected to rectify the problems.

### Nomenclature

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>mean diameter of the extruding line or inner diameter of the hub in mm</td>
</tr>
<tr>
<td>D</td>
<td>outside diameter of hub in mm</td>
</tr>
<tr>
<td>L</td>
<td>length of the hub in mm</td>
</tr>
<tr>
<td>$D_1$</td>
<td>pitch circle diameter of bolts in mm</td>
</tr>
<tr>
<td>$D_2$</td>
<td>outside diameter of flange</td>
</tr>
</tbody>
</table>

According to Sharma Anil R in tire industries the formation of rubber is an important aspect for the manufacturing of tire. This formation is done in the Banbury mixer by adding various different compounds in the rubber. The rubber initially cut in the required proportion by Bale cutter and processed in the mixer. After process Rubber forwarded to the hot extruder and cold extruder for the formation of tread, bead, sidewall, ply etc. In this paper i have completely reviewed the formation of master and final rubber also discussed about the importance of compound added in the mixing of rubber.

According to R I Janesthis study is concerned with the effects of varying...
individual key process parameters on the performance of a single-screw extruder, by comparing process distributions namely the residence-time distribution and shear-rate distribution. The parameters considered are channel geometry, rotational screw speed, and back pressure due to the die. The material theology is based on high-moisture mashed potato, with Herschel-Bulkley rheology. This paper highlights two main complications in simulating an extruder: the complex geometry and the rheological description.

According to M.H.N. Famili and S. Moradi after the extrusion process the remaining of polymers in the extruders cause some problems like degradation and impurity in process, therefore after each batch the extruder should be cleaned. Using self-wipe twin-screw extruder is a method, to solve this problem. Production of self-wipe screw modules is very difficult, time consuming and is not economical. In this research, we have presented a novel, quick and economical method for producing self-wipe modules with desirable profiles. Keywords: Twin-screw extruder, self-wipe, intermeshing co-rotating screws.

Twin-screw extrusion is extensively used for mixing, compounding, or reacting polymeric materials. Recently many researchers are trying to do some modification in polymers for specific purpose. Reactive extrusion, reactive blending and polymer reinforcement are some of the new topics in research that are more dependent on twin-screw extruder type and configuration. The flexibility of twin-screw extrusion equipment allows this operation to be designed specifically for the formulation being processed. For a specific reaction, the residence time distribution in twin-screw extruder is less than the batch systems. Therefore, this accounts for a decrease of polymer degradation, giving better product than the batch systems. Good residence time distribution, good mixing and high capability of heat and mass transfer in twin-screw extruders led us to use this apparatus. In twin-screw extruder, the screws may be co-rotating or counter-rotating, intermeshing or non-intermeshing, conjugated or non-conjugated. In addition, the configurations of the screws themselves may be varied by using forward conveying elements, reverse conveying elements, kneading blocks or other designs in order to achieve particular mixing characteristics.

3. EXISTING MODEL

RUBER BEAD EXTRUBER WITH DOOR TYPE HEAD

The extruder we are using is 90 mm cold feed rubber extruder. This machine is mainly used for extrusion process. This machine is used in beading section for addition of bead at end of tyre. The screw used is about 90mm in diameter hence it is known in this name. This screw rotates with help of external motor. Raw rubber is supplied in to the machine from the top, the rate of extrusion is done according to the screwing action and the rate of rotation of screw. When the rubber comes in contact with the screw, along with the rotation of the screw the rubber also starts rotate and move forward with high force. The size of the bead increases and decreases in proportional to the number of the string used.
By using normal method there is a chance of leakage through the gaps and causes time waste because the door has to be opened every time the die is in put in. It requires more maintenance so it cause more maintenance cost. Since the door is opened and closed it can cause the door to lose its rigidity and making it more prone to burst open. If the door is not properly locked it could be danger to the workers. The rate of production is decreases and fatigue of the workers increases .Efficiency of the machine decreases which leads to material wastage. It is not economically feasible.

4. CFD MODELLING

4.1 DESIGN MODIFICATION

All the datas are from PSG design data book

- The inner diameter of the hub of flange is taken as $d=85 \text{ mm}$. It is taken as the diameter of existing system.
- Outside diameter of the hub of flange is taken as $D = 2d = 170 \text{mm}$. Here $d$ is the inner diameter of hub
- Length of the hub $L=1.5d=127.5 \text{mm}$. It is the combined length of both flange used in coupling. Here $d$ is the inner diameter of coupling.

4.2 THERMAL STRESS

- It is assumed that the material on either sides of flange coupling is considered as constrained.
- Thermal stress acts only on the inner cross section of flange coupling.
- The material selected to study must have high melting point and low thermal expansion coefficient.

- Pitch circle diameter of the bolt is given by the equation $D_1 = 3d =225 \text{mm}$. This equation is taken as per the design of flange coupling.
- Outside diameter of the flange is taken as $D_2 = D_1 + (D_2 - D) =340 \text{mm}$. Here $D_1$ is the pitch circle diameter of bolt and $D$ is the outside diameter of hub.
- Thickness of flange $t_f =0.5d=42.5$
- The material selected for study are:-
  1. Titanium
  2. Cast iron
  3. Steel
  4. Brass
  5. Copper
Table 1. Shows Thermal stress of different materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Melting point (°C)</th>
<th>Coefficient of thermal expansion (µm/m0°C)</th>
<th>Modulus of elasticity (N/mm²)</th>
<th>Thermal stress (N/mm²)</th>
<th>Yield stress (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>1083</td>
<td>16.2</td>
<td>1.23</td>
<td>245.08</td>
<td>130</td>
</tr>
<tr>
<td>Titanium</td>
<td>1800</td>
<td>11.8</td>
<td>1.05</td>
<td>152.39</td>
<td>225</td>
</tr>
<tr>
<td>Steel</td>
<td>1510</td>
<td>11.1</td>
<td>2.08</td>
<td>283.98</td>
<td>370</td>
</tr>
<tr>
<td>Cast iron</td>
<td>1300</td>
<td>9</td>
<td>1.00</td>
<td>110.7</td>
<td>98-276</td>
</tr>
<tr>
<td>Brass</td>
<td>927</td>
<td>16.7</td>
<td>.97</td>
<td>199.24</td>
<td>124-310</td>
</tr>
</tbody>
</table>

4.3 ANALYSIS

4.3.1 3D MODELING

We have created a 3D model of the flange coupling in solid works 2011 according to the new design modification to gives the full view of the model. We have created air domain, flange coupling and rubber in solid works. We select air domain space to over convenience and flange coupling according to the following specifications

![Figure:1 3D model of flange coupling.](image-url)
4.4 THERMAL ANALYSIS
We use Ansys 14.6 to conduct the thermal analysis of the flange coupling. Copper, steel, and titanium were chosen to conduct thermal analysis. We imported the solid works file to the ansys geometry and created mesh. There were 453764 elements and 142653 nodes. The mesh was fine at the interface of molten rubber-flange and flange-air. The following figure shows the mesh.

![Mesh Model](image)

Figure 2: Mesh Model

4.6 MATHEMATICAL MODELING
The equations that govern the fluid flow and heat transfer process are as follows [3].

- **Continuity**
  \[
  \frac{\partial}{\partial x_j}(\rho u_j) = 0
  \]
  \(1\)

- **Momentum**
  \[
  \frac{\partial}{\partial x_j}(\rho u_j u_i - \tau_{ij}) = -\frac{\partial p}{\partial x_i}
  \]
  \(2\)
  Where \(\tau_{ij} = 2\mu s_{ij} - \frac{2}{3}\mu \frac{\partial u_i}{\partial x_j} \delta_{ij} - \rho u'_i u'_j\)
  \(s_{ij} = \frac{1}{2} \left( \frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right)\)

- **Energy**
  \[
  \frac{\partial}{\partial x_j}(\rho u_j c_p T - F_{h,j}) = 0
  \]
  \(3\)
  Where
  \[f_{h,j} = k \frac{\partial T}{\partial x_j} - \rho C_p \overline{u'_j T'}\]

5. BOUNDARY CONDITIONS
We choose air domain the surface of the flange. The air is considered to be as steady flow and the ambient...
temperature as 27 °C. The molten rubber is flowing through inlet of the flange with .1 m/s velocity and 150 °C temperatures. The molten rubber have 1.15 kg/m³ density, 2200 J/kgk specific heat, 0.5 w/mk thermal conductivity, 64.3 kg/ms viscosity.

6. RESULTS AND DISCUSSION

- Copper flange

![Temperature Contour of copper](image)

Figure 3. Temperature Contour of copper

- Steel flange

The following figure shows the temperature contour of flange made of Steel. The left side is the inlet and the right side is the outlet. The temperature at the outlet is 396.75711 K. the temperature convection to the air domain is 305.6221 K and the net temperature is found to be 305.95007 K.
The following figure shows the temperature contour of flange made of Titanium. The left side is the inlet and the right side is the outlet. The temperature at the outlet is 396.23999 K. the temperature convection to the air domain is 305.69122 K and the net temperature is found to be 306.03217 K.

6.1. TEMPERATURE RESULTS

- **COPPER**
  - To Air : 305.6221 K
  - Net : 305.95007 K
  - Outlet : 392.728 K
TITANIUM
Outlet : 396.75711 K
To Air : 305.53372 K
Net : 305.8772 K

STEEL
Outlet : 396.23999 K
To Air : 305.69122 K
Net : 306.03217 K

7. CONCLUSION
The project was carried to rectify the defects of the existing design of single screw rubber extruder for the bead, considering cost factor and ease of operation. The new design can be accommodated in existing frame work of the machine without any major alternation. The proposed is supposed to keep the quality standards of the products within the specified tolerances, so that the company can maintain an edge over other products. We selected Titanium, Cast Iron, Steel, Brass and copper as flange materials. The thermal analysis was conducted on copper, steel and titanium. It is found that copper conduct more heat to surrounding and the titanium have the least value, so we recommend titanium as the flange material.

8. ACKNOWLEDGEMENT
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9. REFERENCES
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