Composite Rubber Sleeve Analysis of Pinch Valve Using Radioss FE Package

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Abbreviations:  
EPDM - Ethylene Propylene Diene Monomer.  
API - American Petroleum Institute.  
BS - British standards.

Abstract

Pinch valve is a control and shut-off valve, used for slurry application where abrasive or corrosive, powders, or granular substances are present. Sleeve is the critical and replaceable part in the pinch valve.

Design and optimization of sleeve is difficult for the mining applications. Pinching force is needed to design manual, pneumatic and hydraulic actuators. The pinching resultant forces which is coming from the composite sleeve, while pinching is calculated by simulations.

The operating conditions are internal pressure and pinching movements. Composite sleeve is the composition of rubber and nylon fabric, we optimized the composite sleeve thickness and number of fabric layers required to withstand the operating pressure and pinching movements.

Our focus is to calculate reaction forces for the design of manual and pneumatic actuators, optimization of composite sleeve thickness, placement of nylon fabric and its thickness.

And also we optimized the shape of the valve body according to the shape of the sleeve under pressure and pinching condition.

Introduction

The demand of pinch valves in Pulp and paper, mining and power sector is ever increasing in growing economies like India. A pinch valve may be the best type of valve for flow control application if the operation temperature is with in the limit of the polymer. A pinch valve is a full bore or fully ported type of control valve which uses a pinching effect to obstruct fluid flow. Pinch valves used for fluids employ a device that direct contacts process tubing. Forcing the tubing together will create a seal that is equivalent to the tubing’s permeability.

Major components of a pinch valve consist of body and a sleeve. The sleeve will contain the flow media and isolate it from the environment, generally used for slurries or processes with entrained solids, because the flexible rubber sleeve allows the valve to close drop tight around solids. The sleeve material can be selected upon the corrosiveness and abrasiveness of the flow media, a suitable synthetic polymer can be chosen.

In literature certain empirical formulae have been established to calculate the Reaction forces. In course of time finite element analysis method is used extensively for the simulation of the composite rubber sleeve analysis of a pinch valve.
MATERIAL MODELING:

Major components of a pinch valve are body, sleeve and pinching mechanism.

*Sleeve:* Sleeve is a composite of rubber and nylon fabric. Several rubber qualities are available for pinch valve sleeves such as Natural rubber, EPDM, Nitrile, Viton, Neoprene and Butyl. Pinch valves work without almost any wear of the elastic rubber sleeve, because the kinetic energy of the solids is absorbed through the extremely high elasticity of the rubber. The rubber sleeve acts as an anti-abrasive, for the closing of the rubber sleeve or flow force is required. Due to its great impact resilience, rubber sleeve starts opening as the force is removed.

*Nylon fabric:* Sleeves in a pinch valves are made very similar to an automobile tire. The rubber sleeve is reinforced with Nylon, Rayon or other belted-ply fibers. Nylons cords are the optimum reinforcing material, due to the nyons high tenacity toughness, the superior fatigue resistance and good adhesion to rubber.

Process Methodology

FINITE ELEMENT IDEALIZATION
The pinch sleeve is idealized with 8 nodded brick elements of size 10 mm thickness of rubber is 9 mm reinforced with nylon fabric layers (as shown in figure 3) of shell elements of size 10 mm. Upper and lower pinches are shell elements of size 10mm sleeve flanges are constrained and pressure applied on the sleeve bore. The linear transatory motion given in opposite direction to both the pinches.
**Material models and Properties:**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Components</th>
<th>Mat. Model</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Natural rubber</td>
<td>Law 42</td>
<td>Solid- P14</td>
</tr>
<tr>
<td>2</td>
<td>Nylon fabric</td>
<td>Law 19</td>
<td>Shell-P9</td>
</tr>
<tr>
<td>3</td>
<td>Steel (Upper,lower pinch)</td>
<td>Law 1</td>
<td>Shell-P1</td>
</tr>
</tbody>
</table>

*Table 1: Material laws and property*

**Results & Discussions**

Here below are the simulation results

*Figure 5: Von mises stresses on rubber.*

*Figure 6: Von mises stresses on nylon*
Figure 7: Von mises stresses on rubber and nylon

Figure 8: Resultant forces in Z direction due to pinching.

Figure 9: Before simulation

Figure 10: Modified and optimized shape
Body shape optimized to increase the life of sleeve, reduce weight, cost as shown in the above figure 9 and 10.

**TESTING**

The testing was carried out at WEIR MINERALS INDIA test centre to meet the design requirements. The test was performed as per the testing standards API – 897/ BS: 5146. For the manual valves the closing force calculated using torque wrench is compared with simulated results are as follows

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Valve size (Inches)</th>
<th>Hand wheel size (mm)</th>
<th>Experimental force (N)</th>
<th>Resultant force (N) by simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 Inch</td>
<td>150</td>
<td>173</td>
<td>165</td>
</tr>
<tr>
<td>2</td>
<td>3 Inch</td>
<td>250</td>
<td>280</td>
<td>266</td>
</tr>
</tbody>
</table>

For the Pneumatic valves the actuator is selected according to the resultant force obtained from the simulation results and tested according to standards.

**Discussion**

The resultant force obtained from the simulations is taken for the design of manual and pneumatic pinch valves. It is found that test results are comparable with 5% of error with simulation results. There are various reasons for the difference in the results, the most dominating reason is accurate measurement of torque required to close the pinch valve.

**Benefits Summary**

In speed to market, prototype cost has been reduced significantly, we can easily choose or design actuators. Product design process has been improved we have reduced number of prototype testing from three to one, so product design cycle time minimized, we are horizontally deploying this method to all other types of valves.

**Challenges**

Optimising rubber and nylon fabric thickness is difficult without the Radioss FE analysis, because we don’t have mathematical model and history of this composite sleeve material for the validation. We tested the composite material, nylon fabric and rubber and validated through the Radioss.

**Future Plans**

For the validation of results without the prototype we need to find out the mathematical models for nylon fabric and rubber, and mathematical model for the hardness coefficient of rubber we need to find out because practically we are measuring the rubber hardness by shore hardness, and the values feeding in the Radioss is in terms of hardness coefficient.
Conclusions

The composite rubber sleeve analysis of the pinch valve is being simulated using RADIOSS simulation package and the result is quite satisfactory. It has provided a basic method for the simulation of the pinching of Rubber sleeve Models having very large no of DOF can be easily modeled and solved using RADIOSS. HYPERVIEW is a very good tool for the post processing of the analysis results.

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REFERENCES

1. API – 897/ BS: 5146, ANSI/ISA 75.08-1999, BSR/ISA 75.10.01 – 200x
2. Users Reference Manual Altair Corporation