Original Article

Development of a Hose Reel (Swivel Joint) Suitable for High Suction Pressures

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Abstract

As the importance of hose reels is known in applications such as fire and safety systems, agricultural equipment, underwater diving equipment and oil industries, it is also worth observing the need of hose reels for applications involving the suction (negative) pressures. Some of the applications of negative pressures or vacuum include sewage and drainage cleaning systems, coal industries, cement industries and many more. So, it becomes of utmost importance to develop equipment that increase the convenience using vacuum for various applications. One such equipment for increasing the convenience for applications involving vacuum would be a hose reel. It is proposed to develop a hose reel that is acclimated to high vacuum pressures. The effect of different parameters associated with the seal materials and their effect on sealing performance using FEA tool will also be studied.

Keywords: Suction, Reel.

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INTRODUCTION

Hose reels are used to wind, unwind, and store spools of hose that are designed to transport gases and liquids for industrial applications. Hose reels are made of steel, stainless steel, plastic, or wood. Most products have ports for maintaining fluid flow during rewinding. There are several basic types of hose reels. Collapsible devices can be assembled and disassembled for compact storage or shipment. Portable hose reels are designed to be moved by hand, typically with a handle. Live connection reels are installed with special hardware that enables the media to continue to flow while the hose is still on the reel. Storage reels are designed to hold continuous items such as cable, hose, paper, or rope for relatively long periods of time. Complete hose and reel assemblies consist of a reel, hose, and integral hardware such as a nozzle.

A) Hydraulic swivel joint

A swivel joint is nothing but a joint that allows connection between the rotary side and stationary side of the pipe or hose which might have relative motion among them. Swivel joints allow complete 360-degree rotation in both clockwise and as well as anticlockwise direction in light and heavy-duty applications while protecting the hoses from getting tangled with other machine components. This also prevents mechanical stresses from developing, which would have resulted from hose twisting, bending and stretching. Therefore, this helps in increasing the hose life and ultimately machine downtime can be avoided. Swivel joints can be designed in such a way such that they can operate in different ranges of temperatures and pressures, and also in different kinds of outside conditions and atmospheres.

Swivel joints use ball bearings and seals to form a joint that is flexible and leak proof at the same time to serve the purpose of transporting fluids without any leakage.

B) KAMVAC

"KAMVAC" is a truck chassis mounted industrial vacuum loader and emptier uses vacuum for collecting of sludge, sewage and other materials. it can be fabricated for different volumetric capacities of sludge collection tanks and various FAD ratings of pumps. The main function of KAMVAC vehicle which is a product of M/s Kam – Avida Enviro Engineers Pvt Limited, is collecting the solid and liquid effluents in the sludge collection tanks under high vacuum, from water drains or manhole chambers.

C) Desired characteristics for vacuum seals

1. Low vapour pressure at service temperature
2. Compression of seal – 15 % to 30 %
3. Clamping pressure
4. Seal must be seated against the low-pressure side
5. Surface finish (16 micro inch to 32 micro inch)
6. Permeability of seal material
7. Low Vacuum weight loss

D) NBR Material

Nitrile Butadiene Rubber (NBR) is one of the most popular type of rubber in the automobile and industrial product line-up. The properties of NBR rubber depends on percentage of element named acrylonitrile (ACN) in the base polymer. The main upside of NBR rubber is that it is resistant to water, grease, fuel etc. These mentioned properties make NBR one of the most popular elements used for sealing purposes. The seals made from NBR rubber could be used for sealing various substances like hydraulic oils, hot and cold water, organic substances etc. [1]

Some of the important beneficial aspects of nitrile rubber seals which favour our application of suction hose reel in the KAMVAC vehicle include:

1. Operating temperature range firing from -35 ° Celsius to +135 ° Celsius
2. Good abrasion resistance
3. Low vacuum weight loss
4. Better resistance to ageing, organic substances and water.

As O- ring seals are generally used in various kinds of hose reels, the handbook of Parker Seals (Parker Hannifin India Pvt Ltd.) [5] was refereed.

RESEARCH GAPS IDENTIFIED

- The absence of hose reels that can handle high suction pressures (-ve pressure).
- It was found that industrial grade manual hose reels are difficult to handle in the winding and un-winding operations.
- Checking suitability of NBR seal material for high suction application.

3D – MODELLING

The process of creating a 3D model of a suction hose reel from scratch involves the following steps:

1) Creating a new CAD model of the outer reel in 3D Modelling software.

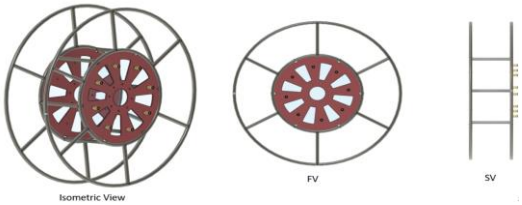

Fig.1: Outer Reel

2) 3D modelling of the outlet flange assembly.

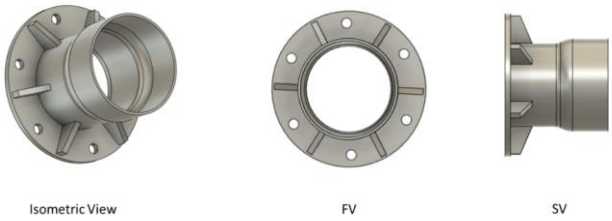

Fig.2: Outlet Flange Assembly

3) Creating a 3D model for inlet cum support flange assembly.

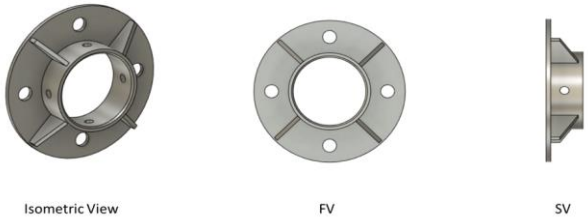

Fig.3 Inlet Cum Support Flange Assembly

4) Generating a model of non – drive axle assembly.

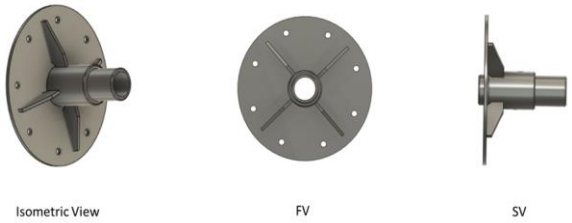

Fig.4: Non-Drive Axle Assembly

MANUFACTURING AND ASSEMBLY

5) Manufacturing of the outer hose reel structure. The hose would be wounded and un-wounded over this outer structure of the reel.

Fig.5: Manufactured outer reel

6) Making of support for mounting of the hose reel over the vehicle chassis.

Fig.6: Support for mounting hose reel

7) Assembly of the inlet and outlet flange assemblies with the outer reel.

Fig. 7: Flange Assemblies installed on reel

8) Fitting of the hub assembly with the hose reel.

Fig.8: Hub Assembly with reel

9) Connection of swivel joint with the storage tank.

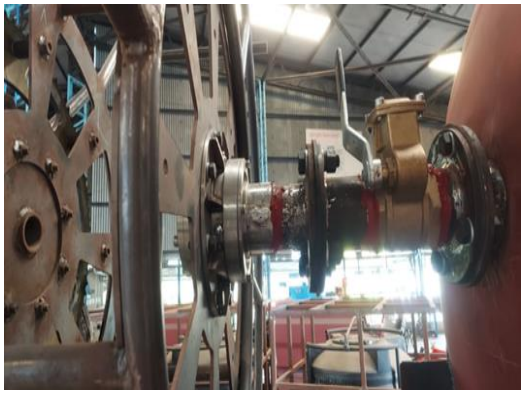

Fig.9 Connection between hose reel and storage tank

Finite Element Analysis

The finite element analysis was performed on the swivel joint consisting of NBR O-ring seal with the applied vacuum load of 4000mm of water column on to the swivel joint. The condition which proves that the swivel joint is leak proof is that the maximum contact pressure obtained in analysis should be at least equal or more than the applied vacuum load of 4000 mm of water column (0.3922 bar). For analysis which includes materials like rubber, in our case NBR rubber, which are type of non – linear materials, for these kinds of analysis it is required to use Non – linear Hyper elastic material models provided in the analysis softwares. The various kinds of hyper elastic material models include Mooney-Rivlin, Neo Hookean, Arudda-Boyce, Ogden model etc.

Table 1: Ogden constants for FEA

Property	Value	Unit
Ogden 1st Order		
Material constant (μ1)	2.15	MPa
Material constant A1	1.56	
Incompressibility Parameter(D1)	0	Pa^-1

Results And Discussion

The finite element analysis of the swivel utilizing NBR O – ring seal was conducted using Ogden Non – Linear Hyper elastic material model. Three different constants mentioned above including material constant μ1, material constant A1 and incompressibility parameter D1 were given as inputs so that the material would behave in a similar way as that of NBR rubber.

The condition for leak proof joint is that the contact pressure must be equal or greater than the applied vacuum. The applied vacuum was about 4000 mm of water column (0.3922 bar), and as seen in the above figure the maximum contact pressure obtained in the simulation is 0.04275 MPa (0.4275 bar), which is greater than the applied vacuum pressure. Hence, it can be said that the O – ring seal is safe for the application and can be utilized in the application of KAMVAC vehicle, which is a kind of industrial vacuum cleaner.

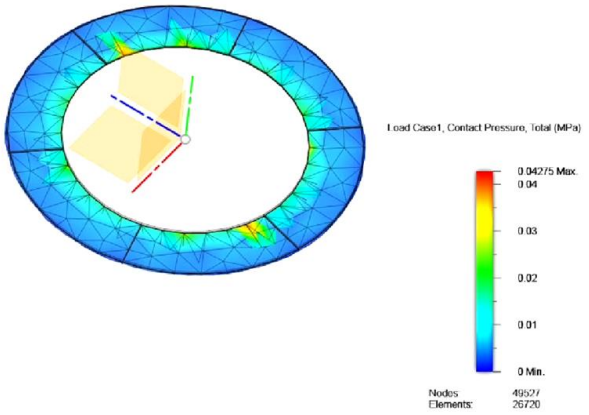

Fig. 10: FEA of O- ring seal

Also, in the experimental inspection of the KAMVAC vehicle the following results were obtained in the test report.

Table 2: Specifications of suction hose reel

Purpose	Suction
Operating Pressure	0.5 bar(vacuum)
Hose length	30 meters
Hose diameter	3 inches
Hose material	J26 PVC
Seal Type	O – ring
Seal material	NBR (Nitrile Butadiene Rubber)

As the obtained results seemed to be satisfactory, the suction hose reel was given a green flag and would be used in the upcoming KAMVAC vehicles.

Conclusion

It can be concluded that the NBR O – ring seal can withstand the applied vacuum and is suitable for use in the application of KAMVAC vehicle which uses suction hose reel, which is the most important part of the KAMVAC vehicle to carryout the suction operation for cleaning purposes using vacuum. Also, the suction hose reel (48HRSU0010) developed is suitable for use in the upcoming KAMVAC vehicles as the swivel joint in the suction hose reel is able to generate a maximum contact pressure of 0.4275 bar which is greater than the applied vacuum of 4000 mm of water column (0.3922 bar).

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