ANALYSIS OF FLEXIBLE HOSE USED TO DRIVE A FIRE FIGHTING WATER MONITOR TRAILER

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Abstract— **When a place catches fire it is well observed fact that a most of the time is wasted by the fireman while extinguishing fire due to larger distance present between the place of the fire and the hose or water monitor. Because of which huge amount of water is wasted because of evaporation during jet impact. It is impossible to take water monitor close to fire because of high temperature. Hence, an effective fire fighting cannot be done. As it requires delivery of water at right time, right place and in adequate quantity. To reduce the distance present in between water and place of the fire an innovative method of fire fighting using hydraulically driven vehicle is developed by Prof. Prashant S. Kadu. The vehicle uses the pressurized water from the pump to move forward taking into account the property of straitening, elongation and buckling of special purpose hose used for fire fighting. When the water is pumped, then pushing force developed due to straightening property of the fire hose is used to move the vehicle [1]. As flexible hose is used as medium to drive the trailer there is intense need to analyse the behaviour of hose and stress induced in it. The increasing trend of stress is observed with reduction in diameter of hose and increase in pressure of water. In this paper, efforts were taken to analysis the behaviour of hose at different pressure, when hose is straight and bends. This research will help to determine stress induced inside hose when it is straight or bend and the response of hose when hose is use as drive.**

Keywords— **water monitoring trailer, tractive effort, and flexible hose.**

I. INTRODUCTION

For efficient and economical fire fighting of large and intense fire water is required to be sprayed from closer distance of the fire point. This can be achieved by taking the water monitor closer to the fire point. Thereby proper targeting, less evaporation and reduction in the distance from the fire point is possible.

For this propose Drive is needed to develop which will run on power other than conventional power.

The water hose when subjected to high pressure have a tendency of straightening. It can be used for pushing a remotely controlled vehicle closer to the fire and distance can be reduced extensively. The water hose can sustain much higher temperature for longer duration and extreme conditions as compared with other devices. Water and water pump are easily available along with the fire tender. A hydraulically driven trailer is developed, which is driven by the flexible hose. In the present research, behaviour of hose at different water pressures is studied and stress analysis is carried out.

II. CURRENT SCENARIO OF FIRE FIGHTING EQUIPMENTS

Conventionally water monitor trailer is taken closer to fire either manually or by towing it by first response vehicle (i.e. fire brigade van). It can also be driven by using internal combustion engine or remote controlled electrical AC/DC motor drives. Recently fire fighting robots driven by DC motors are developed. The internal combustion engines use either petrol or diesel as a fuel, which are highly inflammable. So it cannot be used as a drive for water monitor trailer because of very high temperature of fire. Similarly, the remote controlled electrical drives use battery as a power source. The batteries are also inflammable and there can be possibility of explosion while using this drive for firefighting even if it is water shielded. Hence there is need to develop alternative drive.

Straightening of a hose is proposed to be used to push the vehicle. The pulling is done by the same hose as it is flexible and works as a rope. However, in fire fighting, pushing of fire tender is a problem. At the time of pulling it does not require any remote control as by that time the fire is extinguished. [1]

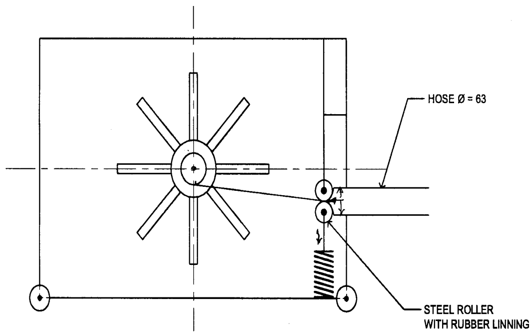

Fig 1. .Flexible hose arrangement on an innovative trailer

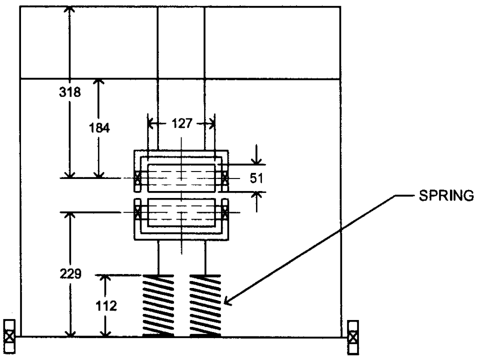

Fig 2. Adjustable roller arrangement

III .PROBLEM IDENTIFICATION

1. Behaviour of hose at different pressure

2. Stress induced in the hose with respect to various pressure ranges.

IV.MODEL DEVELOPMENT

The trailer is designed and fabricated by considering the following specifications.

TABLE I. SPCIFICATION OF TRAILER

Sr.No	Component	Specification In (mm)
1	Trailer frame	1200 ×600×600
2	Hose reel diameter	560
3	Hose reel axel Diameter	25
4	Trailer wheel	140
5	Roller Diameter	100
6	Spring mean Diameter	51

Fig 3.Actual Innovating monitoring trailer

V. PROCEDURE TO CALCULATE DIFFERENT STRESS

When pressurised water is supplied inside the hose hoop stresses are induced on inside section of hose .The stress intensity inside hose changes with the change in length of hose. Analysis of these stress induced inside hose is very essential in case of flexible hose. Maximum hoop stress acts on outer diameter [2]. If the section area of hose is initially deformed then there is need to find out the stress induced by some other equation.

Assumption-

i. Strain, displacement and isotropic behaviour of material is assumed
ii. Non linearity's are neglected.
ii. The hose is considered as a hollow cylinder

So, circumferential stress in flexible hose.

$$\sigma_c = \frac{PD}{2A} \qquad \text{Eqn-I} \qquad \text{-[2]}$$

Stress in flexible pipe with effect of bending in hose.

$$\sigma_b = \frac{PD}{2A} + E \times C \times d\theta \qquad \text{Eqn-II} \qquad \text{-[2]}$$

Where,
P-Pressure inside Pipe, D- Diameter of Hose, A-Cross section of hose, t- Thickness of hose ,C-Distance from neutral surface of the wall to most remote Surface, E-Young's Modulus of Elasticity, I- Moment of Inertia of Cross Section

$$\frac{M}{EI} = d\theta - \text{Change in Curvature} = \frac{1}{Ro} + \frac{1}{R1}$$

R_1-Deformed Radius

R_o-Original Radius

$$\frac{1}{Ro} = \frac{M}{EI}$$

$$M = \frac{Pr^2}{4}$$

$$\sigma_b = \frac{PD}{2A} + C \times \frac{M}{I} \qquad \text{Eqn-III} \qquad \text{-[2]}$$

Calculations of critical pressure due to water hammer

$$P = V \times \sqrt{\frac{\rho}{\frac{1}{k} + \frac{D}{E \times t}}} \qquad \text{Eqn-IV} \quad - \quad [3]$$

Where,
P-Pressure at Inlet of Hose V – Velocity of flow
K- Bulk Modulus of water P – Density of Water

VI. CALCULATIONS

The pressure range is selected on basis of pressure range available at water pumps used for fire fighting. The maximum hose length considered for experimentation available was 18 meter. By considering pressure value of 0.2941Bar, 0.5883Bar, 0.88253Bar, 1.176Bar, 1.47Bar, 1.765Bar, 2.059Bar, 2.3535Bar in equation I, II, III the stress values were obtained for different hose length of 1M,1.5M,2M,3M,4M,6M,10M. The calculation of critical stress is done by using Eqn-IV.
Trend of stress value is obtained after calculations. The static analysis of the roller and hose assembly model is done by using ANSYS software.

TABLE II. PROPERTIES HOSE MATERIAL [4]

Sr. No.	Property	Value	Unit
1	Material	Nylon filament	-
2	Modulus of Elasticity (E)	2×10^{8}	N/m^2
3	Bulk Modulus of Hose	2×10^{10}	N/m^2
4	Positions Ratio	0.4988	-

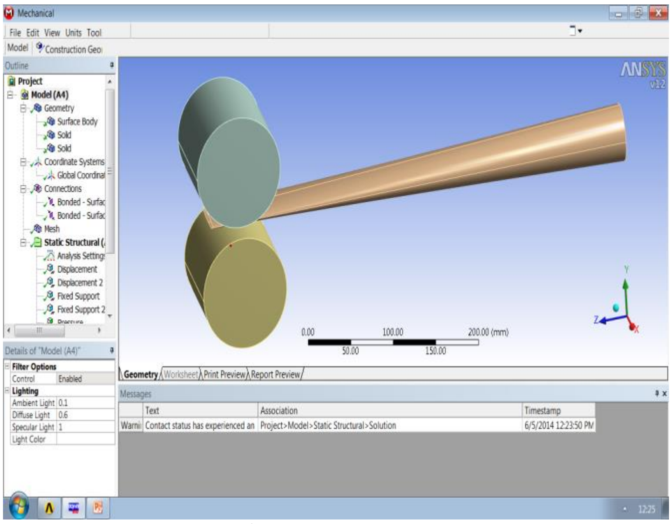
Fig 4.CAD model of hose roller assembly developed in creo

In mesh generation, finite elements were generated with average element size of 7mm which auto was generated by software, with fixed type boundary condition.

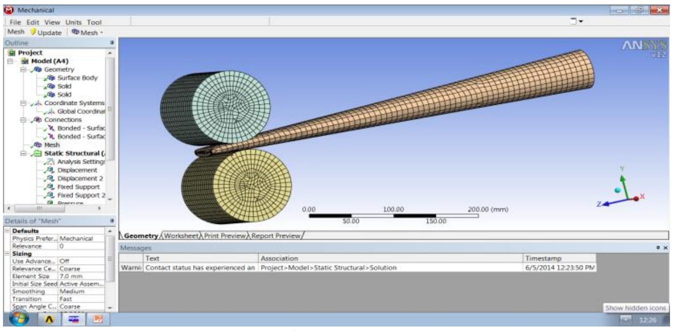
Fig 5. Meshing of Roller and hose Assembly

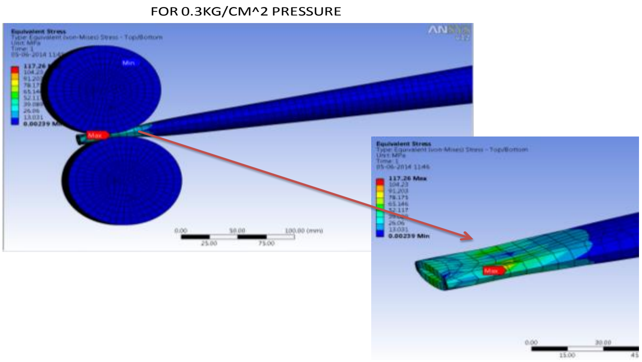

Fig.6 Stress intensity on hose material at pressure $0.3kg/cm^2$
In the similar way the analysis of hose is done for given pressure range.

VII. RESULT AND DISCUSSION

Case-I: Hoop stress inside the bend hose:

In present research work the hoop stress calculations for different water pressure viz. 0.2941Bar, 0.5883Bar, 0.88253Bar,1.176Bar,1.47Bar,1.765Bar,2.059Bar,2.3535Bar, were done for hose lengths 1, 1.5,2,3,4,6,10M. At corresponding lengths and the pressures, the hoop stresses induced inside the hose are calculated. At different diameter of hose viz 50mm, 48mm, 38mm, 28mm, 18mm, 8 mm using equation I, II, III. It is observed that there is increase in intensity of stress induced with reduction in diameter. The trend of results obtained by analytical calculations match with trend obtained using ANSYS software. The maximum stress intensity in hose is observed at the contact point of roller.

Case-II: Stress induced due to critical pressure:

Roller closes the hose opening, which create water hammer effect on the roller resulting in creation of critical pressure inside hose, which then cause increase in back pressure inside hose. Because of the backpressure higher stress are induced inside the hose. Which are calculated by using equation IV. In the present research the back pressure is calculated for discharge of $0.0033m^3/sec$,$0.0023m^3/sec$,$0.0013m^3/sec$. It has been observed that intensity of stress induced due to water hammer increases with reduction in diameter of hose at conical section, It vary in linear patter i.e. increase in stress is observed with reduction in diameter.

VIII.CONCLUSION

The main emphasis of project was to study behaviour of hose under pressurised fluid flow and movable closure of one of the end with a specially designed mechanism. The stress analysis under two different condition of hose position is done. It has been observed that the values of stress calculated analytically are very high as compared to maximum stress values obtained from software analysis but trend of stress induced is similar in both cases.

- It is observed that, the hose straightens under pressurized fluid flow.
- The stress analysis pattern shows that, the maximum stress intensity is observed at the contact point of rollers.

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