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An Overview of Design,Optimization and Vibration Analysis of Peristaltic Pump Using Finite Element Analysis

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ABSTRACT

A peristaltic pump is a type of positive displacement pump that moves fluid by squeezing a tube or hose causing the fluid inside to follow the motion of the roller. Peristaltic pumps are valuable for pumping abrasive or corrosive fluids that could damage or contaminate rotors or gears and for pumping delicate fluids such as blood. The objective of the paper is to identify the various methods of design and optimization of peristaltic pump. Effect of vibration on performance of peristaltic pump will be studied to find out the natural frequency and mode shapes of peristaltic pump by numerical and experimental methods and also to study method of experimentation.

Keywords— Abrasive, Blood, Optimization, Peristaltic Pump, Roller.

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I. INTRODUCTION

Peristaltic pumps are widely used in medical and pharmaceutical industries .It is also useful for applications requiring rugged pumps with minimal maintenance.

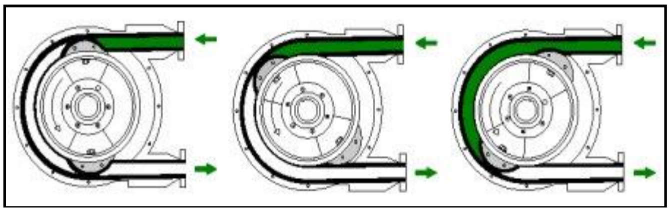

Fig.1.1 Schematic representation of a peristaltic pump

Peristaltic pump works on the principle of peristalsis process carried out in human body. The human intestine is in fact a peristaltic pump as muscle contractions push the food forward through the bowels. The fluid is contained within a flexible tube fitted inside a circular pump casing. A rotor with a number of 'rollers', 'shoes' or 'wipers' attached to the external circumference compresses the flexible tube. As the rotor turns, the part of tube under compression closes thus forcing the fluid to be pumped to move through the tube. Fig. 1.1 shows the schematic representation of a peristaltic pump. The modern peristaltic pump is moreover designed with the built-in possibility of using different sizes of tubes.Peristaltic pump are positive displacement pump which generally rotate at a slow speed. Rotating bodies with mass, generally induce vibrations in the system. Vibrations cause noise in the system and finally noise causes disturbance in the efficiency of the system. It is observed in existing design of the peristaltic pump that they induce a vibration in system. To damp the vibration the common remedy used is to make the body highly rigid. Hence

designers increase the thickness of the body and roller. Addition of material increases the weight of the system.
In recent decades with development in mathematics and computers very efficient FEM software's were developed (E.g. – ANSYS, Abaqus etc). These software's in combination with high computational powered work stations (computers) are working very efficiently. But for using FEA software, highly experienced people are required because a small mistake in assumption or applying boundary condition may be cause of larger error in results. Most important thing about FEA is that results which are inaccurate as well as correct, may be displayed in colored image. In this dissertation FEM approach is used to check the existing design and it is verified by experiments and optimization is carried out to get better performance of the pump. By considering all above facts, this paper tries to cover literature which deals with Design, Optimization and Vibration Analysis of Peristaltic Pump using Finite Element Analysis.

II. Literature Review

Many of researchers have contributed in development of Peristaltic Pump.

I A MECHANISM FOR THE PERISTALTIC PUMP FOR INCREASING THE LIFE OF THE TUBE.

King. O (1985) invented a mechanism for the peristaltic pump for increasing the life of the tube. The tubes are fixed at ends of tubing and said relative angular displacement about the center line of the tubing in between 1/10th and 1/12th of a turn about the central axis of the tubing. The curved tube has an inner radius which is little less than its outer radius this results in smaller deviation from relaxed or zero stress. The invention is particularly applicable to pumps which incorporate an encompassing wall against which the tube is squeezed. Passage of the cam roller over the inner surface of the tube will result in twisting of the tube in direction to diminish the degree of pre-twist. The result is less movement out of the curved plane that would occur in the absence of pre-twist. King. O (1985) invented a mechanism for the peristaltic pump for increasing the life of the tube. The tubes are fixed at ends of tubing and said relative angular displacement about the center line of the tubing in between 1/10th and 1/12th of a turn about the central axis of the tubing. The curved tube has an inner radius which is little less than its outer radius this results in smaller deviation from relaxed or zero stress.

II DYNAMIC BEHAVIOUR OF THE BEARING HOUSING

Giacomo Marenco et al. (2009) presented a paper on describing the dynamic behaviour of the bearing housing. Bearing housing design having good dynamic behaviour can reduce vibration level and dramatically improve both the reliability and the life of the whole pump assembly. The authors discussed about the approach for analysis of the pump. The modal analysis of the pump was done to find the natural frequencies using the finite element analysis. Harmonic analysis of the end section of the pump was done. The harmonic response was used find the behaviour of the pump under different speeds. The results were validated with experimental results. The design was modified and analysis was done again. Giacomo Marenco et al. (2009) presented a paper on describing the dynamic behaviour of the bearing housing. Bearing housing design having good dynamic behaviour can reduce vibration level and dramatically improve both the reliability and the life of the whole pump assembly.

III PRESSURE PULSATION PERISTALTIC PUMP

Francesco Moscato, et al. (2008) studied pressure pulsation in peristaltic pump. Inlet and outlet pressures obtained by the mathematical model have been compared with those measured in various operating conditions: different rollers' rotating speed and different tube occlusion rates. The complete electric analogue model was built for the pump. The researchers' found that the flow pulsation is caused during the roller engaging with the tube and disengaging with the tube. The angle that the roller covers to fully engage (disengage) with tube was imposed by the geometry of the pump and was set equal to 32°. Using the lumped model the researchers showed that the tube's inner walls do not adhere perfectly and hence a regurgitate flow occurs through the meatus. Direction and magnitude of this flow depend on both the pressure gradient across the squeezing roller and the fluid resistance through the meatus. At this position roller-I had fully engaged and roller-II was at the beginning of its disengaging phase. The inlet pressure decreased for the peristaltic effect due to the engaged roller, while outlet pressure decreased for the suction effect due to the tube shape recovery mechanism at the disengagement of the other roller. The researchers suggested through this paper that changes in the roller can help to reduce the pressure pulsations. Francesco Moscato, et al. (2008) studied pressure pulsation in peristaltic pump. Inlet and outlet pressures obtained by the mathematical model have been compared with those measured in various operating conditions: different rollers' rotating speed and different tube occlusion rates. The complete electric analogue model was built for the pump. The researchers' found that the flow pulsation is caused during the roller engaging with the tube and disengaging with the tube. The angle that the roller covers to fully engage (disengage) with tube was imposed by the geometry of the pump and was set equal to 32°.

IV FINITE ELEMENT ANALYSIS TO STUDY THE BEHAVIOUR VERTICAL PUMP UNDER VIBRATION.

Massimo Scali (1992) used finite element analysis to study the behaviour vertical pump under vibration. A finite element model was created to represent the actual vertical pump. The pump was assumed to be running at critical speed. The modal analysis was initially done to find the natural frequency of the pump and mode shapes of the pump. The design was then modified to shift the natural frequency away from the operating g frequency. The analysis of the modified design was done using finite element analysis. The pump was assumed to be running at critical speed. The modal analysis was initially done to find the natural frequency of the pump and mode shapes of the pump. The design was then modified to shift the natural frequency away from the operating g frequency.
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V DESIGN AND DEVELOPMENT OF ROTARY PERISTALTIC PUMP

S.R Dhumal, et al. (2012) discussed about the different design and development for the rotating peristaltic pump. In all four concepts were discussed in the paper. The theoretical calculations were performed to for flow rate. The flow rates of four design concepts were compared. Different parameters were also compared like friction, ease of replacement, axial thrust, floor space and pulsating flow. After comparison, author concluded on the one of the concept. The author mentioned in the paper about pulsation in fluid flow is due to different reasons like viscosity of the fluids, mechanism of the pump and even the rotor speed.

VI FLUID-STRUCTURE INTERACTION ANALYSIS OF A PERISTALTIC PUMP

Nagi Elabbasi, et al. (2011) studied fluid-structure interaction analysis of a peristaltic pump. The model captures the peristaltic pumping action, and the interaction between the rollers, tube and fluid. It was used to predict the stresses and strains in the tube, as well as the flow and flow fluctuations. The author has considered the 2 roller peristaltic pump interacting with the Newtonian fluid. He has considered the standard elastomeric material and used a standard Mooney- Rivlin hyperelastic material model. The analysis is carried out with frictionless condition. The results were found only for 50 % of occlusion. Also no experimental analysis was carried out..

VII VIBRATION OF PUMP

S. M. Abdel-Rabman et. al (2003) published a paper on case study of vibrations in the pump. In case studies the pumps like centrifugal pump and axial rotation pump. Case study consists of the different failure of the pump shafts, failures in bearing, vibrations and noise. The vibrations in pump were calculated by analytical approach. The fatigue failure was observed in the vertically mounted pumps. The failure was basically caused because of the vibrations. Authors also studied about behavior of the pump under variable speed of the motor and vibrations. Frequency analyses were done on the six machines at no load and full load conditions to define the causes of high level of vibration. Dynamic unbalancing of the rotors, alignment of the shafts, and replacement of the faulted items were done according to the scheduled maintenance program which could bring back the pumps to a good condition capable of performing their duty in safe operation and minimum maintenance costs.

VIII FINITE ANALYSIS OF THE CENTRIFUGAL PUMP FOR FATIGUE LOADING AND MODAL ANALYSIS.

Manish Dadhich et al. (2015) published a paper describing the finite analysis of the centrifugal pump for fatigue loading and modal analysis. The fan assembly of the centrifugal pump was imported to in commercial FEA software package. The rotation and the temperature were applied as boundary conditions. The life of the centrifugal pump was found using finite element approach. The modal analysis was also done using the finite element approach. Modal analysis computes the natural frequencies of the centrifugal pump fan. It was observed that natural frequency of the fan was far away from the operating frequency.

III. CONCLUSION

From the literature review it can be seen that researchers and inventors have worked on developing various methodologies for improving the efficiency of the pump as well as to minimize the wear of the tube. Many researchers have mentioned about use of major cause of failures in pumps is vibrations. It was also mentioned that use of finite element analysis helps in find the solution on damping the vibrations in pump.

The main research issues are:

1. The design of pumps is generally based on empirical relations. For peristaltic pump, which is positive displacement pump has no such design procedure.
2. Vibrations in pumps cause noise in the system.
3. There are different reasons for vibrations and it is necessary to find the root cause of the vibration to damp it.
4. Many a time’s vibration contributes to fatigue failure of the system. Hence it is necessary to find the natural frequency of the pump to avoid the resonance.

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