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Numerical Analysis of Screw Pump for Maximum Helical Angle and Pitch

T.Jagannadha Rao
Department of Mechanical Engineering,
Vaishnavi College of Engineering,
JNTUK, India.

K.Srinivasa Rao
Department of Mechanical Engineering,
Vaishnavi College of Engineering,
JNTUK, India.

J.Bala Bhaskara Rao
Department of Mechanical Engineering,
SISTAM College,
JNTUK, India.

ABSTRACT:

The screw pumps having wide range of applications in the field of ships, medical and space applications. The first applications, dating back to the third century B.C., included irrigation and land drainage. The screw pump is thought to have been first used in Egypt in 1972. After several other types of pumps were invented, the screw pump was not used as much because these other pumps could handle higher head capacities. The discharge obtained from a screw pump basically depending on pressure difference developed from inlet to outlet and that pressure difference depends on many parameters like helix angle, pitch of the screw, type of thread, fluid properties and speed of rotation. For a given screw pump the material properties and based on the application of fluid properties are considered to be constant. The helix angle and the pitch of screw are two parameters which influences the flow.

In this project pitch was optimized based on computer based fluid flow analysis and the induced stresses also calculated for the safe operation. In the conventional design the visualization of flow and variation of pressure gradient at different points requires imagination but in the case of computer based simulation the visualization is better and also we can see the flow of fluid. In this project for the fluid flow analysis FLUENT software and for the stress analysis ANSYS are adopted as tools. For the better modelling PRO-E software is utilized and discretization and boundaries are specified by using HYPER MESH as tool.

The basic advantages of Hyper Mesh is the coordinate address data (CAS) at each grid point separately stored, so that while transferring the model from one package to other package continuity will not be missed. To design a Screw Pump for Maximum Pressure Difference and Maximum Suction Pressure for Required Discharge two factors are considered one is helical angle of the screw and another one is Pitch of screw**.** After analysis in the screw pump at constant helix angle and different pitch values at 45^0 helix angle and 314 mm pitch we got maximum pressure difference up to 2 bar and maximum velocity 14.235 m/s.

1. INTRODUCTION:

Screw pumps are used to transfer high viscous fluids like granular materials grease oils etc. These pumps are positive displacement and self-priming pumps. The basic advantages of screw pumps are, these pumps occupies less space and light in weight so that these pumps are mainly used in ships and space applications. Micro screw pumps are used to create artificial blood pressure to force the blood particles inside the human body, by this way these pumps have significant application in the field of medical and biological. The screw pump consists of shaft with helical screw and ends of the shaft is supported in the casing with bearings. The casing having one inlet pipe and one outlet pipe, when the screw rotates due to the helical blade the material moves in forward direction so that the pressure difference is exists between inlet and outlet and the pressure difference caused for further sucking of the material from inlet and also caused for delivery.

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The rotation of screw will cause for the application of two forces on the fluid

1. Tangential force
2. Normal force

The Tangential force is parallel to the axis of screw and it caused for forcing the substance in forward direction and Normal force is caused for moving up the material from shaft to annular portion of the blades. The Tangential force which is responsible for material moment and directly depends on the Helix angle and pitch of the screw. Haifa EI-Sadi, Nabil Email [1] the transient performance of micro screw pump was investigated numerically .The micro screw pump operation depends on the surface sweep forces. This numerical investigation is a comparative study of transient flow behaviour in a micro channel with rotating screw with different cross sectional geometries. The effect of screw thread, pitch, Reynolds number and pump load were studied. When the screw pitch is increased, the pump requires less time to reach steady state flow rate.

The range of the efficiency of the micro-screw pump was between 3 and 75% depends on the dimensions of screw pump and the properties of fluid. Hakim Bensaidane [2], he explained a finite element modelling of permanent magnet micro actuator. The permanent magnet micro actuator is coupled with a micro screw pump, which can be used in biomedical applications for the pumping of biological fluids such as blood. The characteristics evaluations concern the flow rate pressure head of the micro screw pump for various rotational speeds also investigated. The finite element modelling of magnetic micro actuator of blood screw micro pump is prepared. Marcus Vinicius C. Alves,jader R. Barbosa jr.,Alvaro T.Prata [3] explained an alternative analytical solution of the pure drag flow in single screw extruders which is also applicable to intermediate values of the screw channel cross sections aspect ratio. He studied the isothermal flow of a Newtonian fluid in a small curvature screw channel where the motion of screw flights are taken into account in the boundary conditions.

The complete analytical solution of a simplified model of a single screw extruder was solved using the GIIT.K.Rabiger, T.M.A.Maksoud, j.Ward, G.Hausmann [4] In the investigation of the pumping behaviour of multiphase screw pumps, handling gas-liquids mixtures with very high gas volume fractions, theoretical and experimental analyses were performed. A new theoretical screw pump model was developed, which calculate the time-dependent conditions inside the several chamber of a screw pump as well as the exchange of mass and energy between these chambers .A new theoretical screw pump model was developed to calculate the volumetric and thermodynamic pump characteristics. The parabolic pressure profile is turning back into linear profile. Johannes Wartburg[5]The grooved feed extruders (GFE) for quality production at lowest costs require screw and barrel designs capable of achieving gradual increase in pressure along the extruder and low friction in the feed section. Barrier melting and mixing zones are compared with smooth bore extruder (SBE) Li Xiao-hai, ZhuLi,Zhao Ji-min,Jiang Shu-zhong [6]

This paper investigates a special low speed high torque permanent magnet synchronous motor(PMSM) to directly drive the screw pump without gear box because the requirement of energy conversion and environmental protection, current induction motor(IM) with gear box for screw pump is unqualified. Design constraints are surveyed for the special PMSM both form the motor structure and performance. To reduce cogging torque, analytical analysis is carried first. Computed aided design (CAD) is adopted for PMSM designing. The magnetic field and load performance are analysed with the finite element method (FEM).Jing-wen tian,Mei-juan gao,Hao zhou,Kai li [7] Considering the issues that the relationship between the fault of screw oil pump existent and fault information is a complicated and nonlinear system, and the wavelet neural network is presented in this paper. Moreover, we adopt a method of reduce the number of the wavelet basic function by analysis the sparse property of sample data, and the learning algorithm based on a gradient descent was used to train network. The fault diagnosis system based on wavelet neural network can correctly diagnose the work state of screw pump. The self-repair function was designed with the fault diagnosis system, it can effectively avoid the case of screw pump rod lock or twist off, which is very important to the oil safety in production. T. Ohbayashi, T. Sawada, M.hamaguchi, H. Miyamura [8] Pumping characteristics of the screw vacuum pump ware investigated. The aim of this study was to establish a method of the performance prediction and a way to design the pump that satisfies specific requirements. The performance was analysed by the balance among geometrical pumping speed, net throughput and leaks. The leaks flow through clearances between a screw rotor and a stator, and clearances between to meshing rotors. was proposed and the analytical model was verified through the experiments.

Gao Meijuan Tian Jingwen [9] Considering the issues that the relationship between the fault of screw oil pump existent and fault information is a complicated and nonlinear system, and the radial basic function network (RBFNN) has the advantages of learning speed rapidly and find ability of function approaching and model classify, a fault diagnosis system with natural repair function for screw oil pump based on RBFNN is presented in this paper. We construct the structure of radial basic function network that used for the fault diagnosis of screw oil pump, and adopt the K-Nearest Neighbour algorithm to train the network. With the ability of strong self-learning and function approach and fast convergence rate of radial basic function network, the diagnosis system can truly diagnostic ate the fault of screw oil pump by learning the fault information. Chiu-Fan Hsieh, Yii-Wen Hwang, Zhang-Hua Fong [10] In this paper, a profile of claw-type rotor is designed by means of the theory of gearing and the equation of under cutting. The designed profiles are suitable for straight rotor lobes if using in a machine with radial suction and discharge ports.

Besides, for the twin-screw rotors with claw-shape, we develop a methodology to verify the drawbacks of gas sealing in the design of US patent 6,129,535, US patent 6,139,297 and UK patent 2,292,589..A brief description about the fluid properties was given by Bansal [12] and A.K.Jain. Bansal described about the fluid properties, fluid parameters, and their significance. A.K.Jain[13] described about the type of fluid and laws of viscosity. A.K.Jain described about the various types of flows and he described the full concept about the dynamics of fluid flow and fluid governing equations such as Bernoulli’s equation, N-S equation, which are very important in comparing the fluid flow. He also described about varies types of flow properties and conducted many experiments on varies types of flows. The two important authors called H.K.Versteeg and W.Malalasekera [14] briefly described about CFD analysis and given complete description about the CFD advantages, disadvantages, applications and complete analysis of CFD packages. They also explained the complete theory about the CFD governing equations and given information about the CFD discretization methods. Another important concept related to this field is Finite-Volume Method that was adopted by Patankar [15] who studied and explained about this method. He also described about various derivative methods regarding this FVM solution methods and numerical techniques.

2 STEPS INVOLVED TO SOLVE THE PROBLEM

- Preparation of model (Representation of physical model as mathematical)
- Grid Generation (Discretization)
- Defining of physical properties of fluid and boundary conditions
- Solving & post processing
  a) Sol-1.Fluid flow analysis
  b) Sol-2.Stress based analysis

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Preparation of model (Representation of physical model as mathematical)

The model was prepared by using pro-E.Pro engineering is powerful solid modelling software. It develops models as solids, allowing us to work in a 3dimensional environment. These models have volume and surface area, so we can calculate mass properties directly from the geometry that we create. Although we manipulate their display on the screen the models remain as solids. The screw pump consists of Shaft with screw blade, Casing, Inlet and outlet.

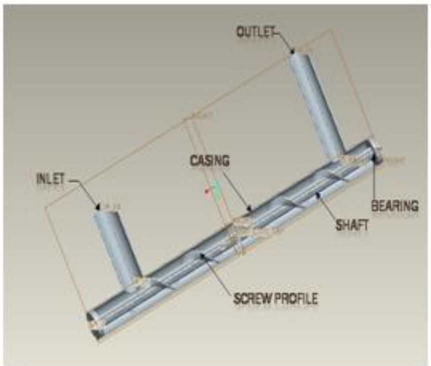

Fig1.Main parts of screw pump

Grid Generation (Discretization):

The total screw pump model from Pro-E is imported into Hyper mesh for grid generation.The main advantage of using Hyper mesh is it can generate surface meshes and inside volume meshes. Inside volume meshes are used for fluid flow analysis for finding fluid properties.Volume mesh or "solid meshing" uses 3-dimensional elements to represent fully 3-D objects, such as solid parts or sheets of material that have enough thickness and surface variety that solid meshing makes more sense than 2-D shell meshing. A surface mesh or "shell mesh" represents model parts that are relatively two-dimensional, such as sheet metal or a hollow plastic cowl or case. In addition, surface meshes placed on the outer faces of solid objects are used as a baseline mapping point when creating more complex 3-D meshes (the quality of a 3-D mesh largely depends on the quality of the 2-D mesh from which it.

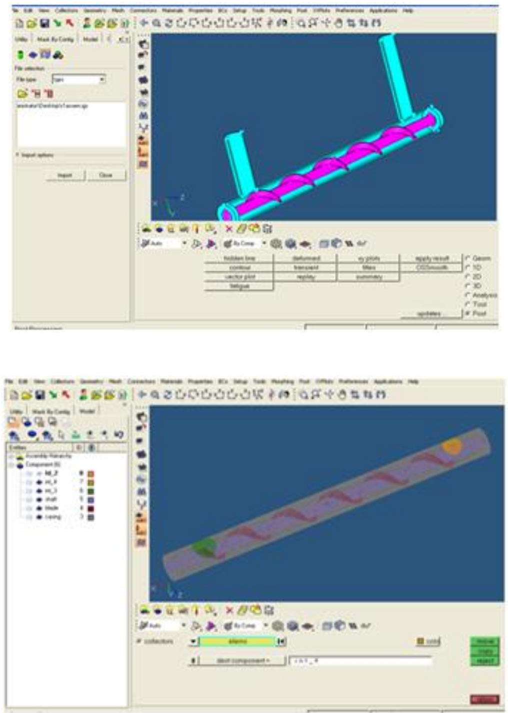

Fig 2.Main parts of screw pump with grid generation

Defining of physical properties of fluid and boundary conditions

1. Fluid Details

Fluid = Sludge
Density = 1500 kg/m^3
Temperature = 35^{0}C
Kinematic Viscosity = 10 Cst

2. Geometric Parameters

Capacity = 10 m^3/hr
Speed = 1600 rpm
Different pitch values= 188,219,251,282,314(mm)
Different Helix angles = 41^0, 43^0, 45^0, 47^0, 49^0

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3. Boundary conditions

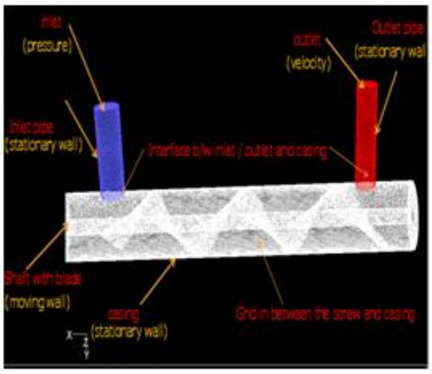

Fig 3 Boundary conditions

Fluid Flow Analysis:

The fluid properties like pressure, velocity, are calculated by using fluent. By keeping helical angle as constant at different pitch values fluid flow analysis is carried out for finding maximum pressure difference and maximum velocity.

Stress Based Analysis:

It is mandatory to conduct the stress based analysis for finding bending stresses. After completion of fluid flow analysis .the pressure vanes over the helix blade are transferred for stress based analysis in Ansys. The induced stress limits are calculates and compared with allowable limits for the safe operation.

3 INTRODUCTION OF COMPUTATIONAL FLUID DYNAMICS

Computational Fluid Dynamics (CFD) is a science, which deals with the motion of the fluids, forces caused for the fluid motion and dynamics behaviour of the fluid under these forces. There are two approaches in the fluid dynamics; experimental fluid dynamics and theoretical fluid dynamics. Computational fluid dynamics constitutes new "third approach" In the philosophical study and development of the whole discipline of fluid dynamics. In a screw pump, when the screw rotates fluid will move in forward direction and the suction pressure created from inlet to outlet. Due to the mass and inertial force of material stresses will induce in the screw pump.

Basically in this project fluid flow analysis is carried to maximize the pressure difference from inlet to outlet which leads to increase the discharge. The maximum pressure values are calculated by using fluid flow analysis in FLUENT. All the CFD codes contain three main elements. They are: Pre-processor, Solver and Post processor.

4 RESULTS & DISCUSSSION:

Different geometric parameters i.e. pitch, blade diameter, shaft diameter, helix angle, capacity of pump and speed of screw and constant fluid properties are taken to calculate fluid properties like pressure and velocity are calculated and also velocity contours, vector contours and pressure contours are prepared. Keeping helix angle as constant i.e. $\alpha = 45^0$ and different pitch values, fluid properties are calculated

1. The Effect of Pitch over Pressure Head in the Screw Pump

The pitch can be defined as longitudinal distance between two consecutive threads. Pitch and helix angle are independent parameters, so that to find the best pitch value for maximum pressure head, one of the parameter should be kept as constant. Initially 45^0 helix angle is considered for the analysis and that value we kept as constant for the initial analysis different pitch values are considered at that helix angle. At 45^0 helix angle the normal and tangential components are equal. For this analysis pitch and helix angles are considered in the parametric form in terms of shaft diameter. Here the shaft diameter (d) is 40 mm and blade diameter is considered at 2d,2.5d,3d,3.5d and 4d, corresponding pitch values are in between 188 mm to 314 mm.Whe screw pitch is increased, the pressure difference increase from inlet to outlet, this is due to increase of thrust force over the material.At constant helix angle and different pitch values the pressure, velocities are calculated and velocity contours, vector contours, pressure contours are shown in Appendix A. At 45^0 helix angle and 314 mm pitch value we got maximum pressure difference up to 2 bar and maximum velocity of 14.235 m/sec and at 314 mm

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pitch value the velocity contours, vector contours and pressure contours are as shown below.

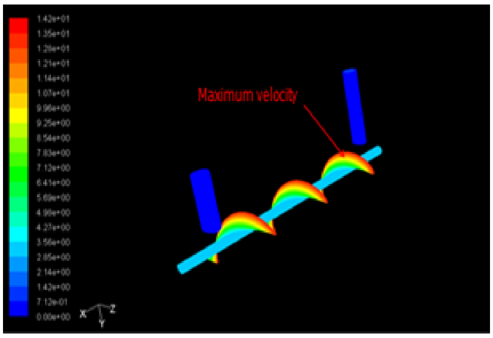


Fig. 4 Contours of velocity diagram

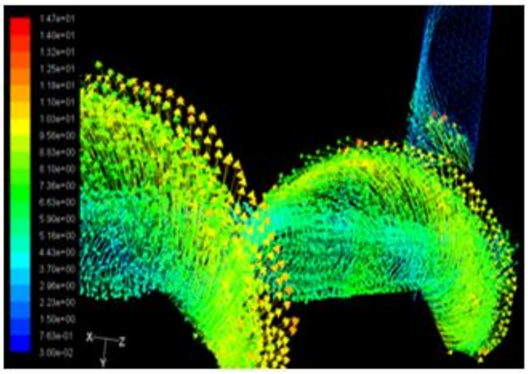


Fig.5 Contours of vector diagram

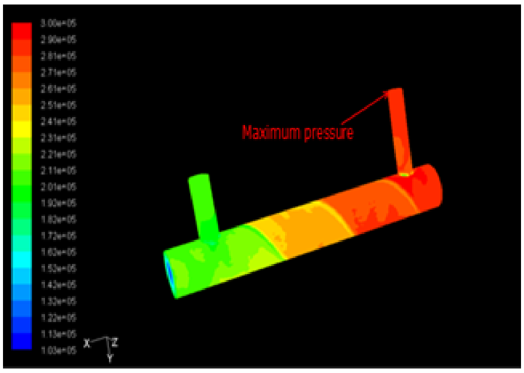
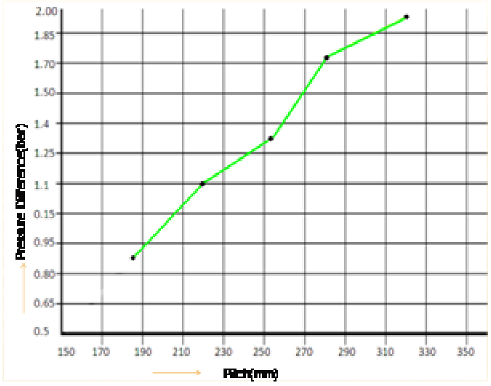


Fig. 6 Contours of pressure diagram

If the pitch is continuously increased that will caused for reduction in number of helical on a given length of screw pump. If the number of helical is less again it caused for reduction in the pressure difference and rate of increment of pressure will decrease when the pitch changes from 282 mm to 314 mm from graph.

GRAPHICAL REPRESENTATION OF PITCH AND PRESSURE DIFFERENCE



2. Stresses based analysis

It is mandatory to conduct the stress based analysis for finding bending stresses. After completion of fluid flow analysis, the pressure values over the helix blade are transferred for stress based analysis. The material was taken as stainless steel. The material properties are young's modules (E) = 203GN/m^2, Density (ρ) = 7910 kg/m^3, Poissions ratio (1/m) = 0.3. The max induced normal stress in x, y, z directions and shear stress in xy, yz and zx are calculated from which we got max bending stress 12 MN/m^2 in Y-direction and this is within allowable limit and the design is safe.The pressure obtained in FLUENT is exactly applied on the blade.

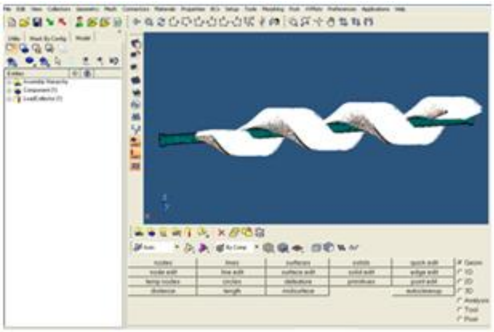


Fig. 7 Import pressure from FLUENT analysis

Export pressures from Hyper Mesh to Ansys

Export pressures from Hyper Mesh to Ansys for stress based analysis .The user profile in Hyper Mesh is Ansys.

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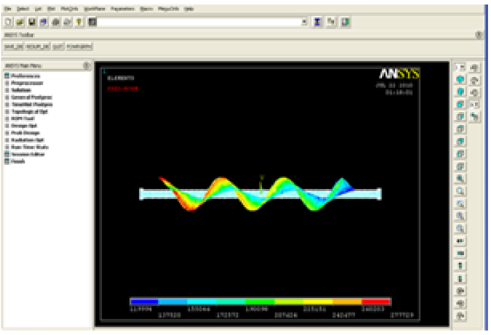

Fig. 8 Pressure on Screw

After Exporting pressures from Hyper Mesh to Ansys for stress based analysis, apply boundry conditions in Ansys . The ends of the shaft are fixed ie. Close the all degrees of freedom at ends.In Hyper Mesh we allready define material properties, element type, grid generation etc.

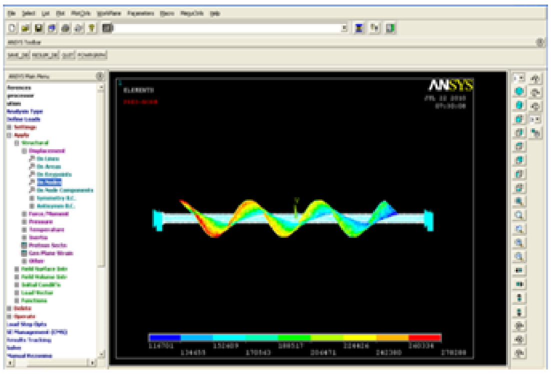

Fig. 9 Induced Boundary conditions

The max induced normal stress in x, y, z directions and shear stress in xy, yz and zx are calculated from which we got max bending stress 12 MN/m^2 in Y-direction and this is within allowable limit and the design is safe.

CONCLUSION:

The objective of this project is to study the effect of geometric parameters such as screw pitch and helix angle as well as flow parameters such as pressure difference and velocities. All the values are calculated in parametric form so that this analysis can be applied for screw pumps with different geometric parameters. Numerically the resulting conclusions are summarized here:

At 45^0 helix angle and 314 mm pitch value the pressure difference in between inlet to outlet is maximum and its value is 2 bar and maximum velocity obtained at this condition is 14.235 m/s. The max pressure values obtained in fluid flow analysis are transferred for stress based analysis. The max induced normal stress in x, y, z directions and shear stress in xy, yz and zx are calculated from which we got max bending stress 12 MN/m^2 in Y-direction and this is within allowable limit and the design is safe.Based on the results of this investigation, at 45°helix angle and 314mm pitch we got max pressure difference up to 2 bar and max velocity is 14.235 m/s for required discharge.

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