ANALYSIS OF FLOW THROUGH PUMP IMPELLERS BY FINITE ELEMENT METHOD

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CERTIFICATE

This is to certify that the thesis entitled 'ANALYSIS OF FLOW THROUGH PUMP IMPELLERS BY FINITE ELEMENT METHOD' being submitted by Biswajit Maiti to the Indian Institute of Technology, Delhi (India) for the award of the degree of Doctor of Philosophy in Applied Mechanics Department is a record of bonafide research work carried out by him under our supervision and guidance. The thesis work, in our opinion, has reached the standard fulfilling the requirements for the Doctor of Philosophy Degree. The research report and the results presented in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

The existing literature indicates the growing need for developing a fully three-dimensional analysis technique to visualize the flow field in the bladed passages of a pump impeller. The flow through the blades of a pump impeller is highly complex, unsteady, turbulent and three dimensional in nature. So, most of the numerical solutions, presently known invariably idealize the flow as steady, inviscid flow. The usual numerical procedure consists of computations on two families of stream surfaces. The first, known as hub-to-shroud (H-S) surface, has extensions ahead and beyond the passage. The second type of surface, called blade-to-blade (B-B) surface, are surfaces of revolution at the passage entry and are generally presumed to remain so throughout the passage. However, a quasi three-dimensional calculation is often performed through proper combination of B-B and H-S surface solutions to obtain a three-dimensional flow pattern. Numerical techniques, such as Streamline curvature method, Finite difference method and Finite element method have been used to investigate H-S and B-B flow fields and to obtain quasi three-dimensional solutions. Finite element method, comparatively a modern technique, has achieved considerable appreciation for accomodating complex geometries of impellers with relative ease.

In the present work, finite element method has been used to analyse the fully three dimensional flow through the impellers of centrifugal and axial flow pumps. The fluid flowing through the impeller is idealised as inviscid and incompressible and the flow is assumed to be steady and irrotational. The governing equation is the Laplace equation, subject to the proper boundary conditions which are of Dirichlet and Neumann type. Variational principle has been adopted to solve the governing equation. The flow domain consists of flow passage between two consecutive blades of an impeller with suitable extensions at the entry and exit surfaces. The extensions at the blade inlet and outlet are considered to be periodic boundaries where flow properties repeat. A 'superposition' technique to satisfy the Kutta-Joukowsky condition at the blade trailing edge has been adopted. Different criteria for the actual implementation of this boundary condition have also been tested.

Flow through an axial flow and a centrifugal pump impeller has been analysed. Effect of various geometrical parameters and inlet flow conditions (for axial flow pump) on the pump performance has been also studied. The study has shown that the programme developed fulfils the preliminary requirements for being a useful tool for the performance prediction of a pump.

To estimate the effect of various idealisations made in the analysis, an experimental set up has been fabricated to measure the pressure distribution over the blades of a centrifugal pump impeller and also other flow parameters. To compare the experimental results with theoretical analysis, flow through the same experimental impeller has been analysed by finite element method. A graphical comparison of the variation of co-efficient of pressure along the impeller blades between the experimentally measured and theoretically computed values has shown a reasonable agreement at various flow rates and pump speeds. It has been concluded that within the framework of idealisations, it is possible to use the present methodology based on finite element method to design the flow passages in the pump impellers without resorting to expensive model tests. The analysis can be further refined by taking into account various real fluid effects, such as, viscosity and compressibility effects.

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