Aerodynamic and Topology Optimization of Micro Scale Radial Turbine

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1. Introduction

The structural analysis has been carried out by some researchers. For example: a coupled CFD-FEM analysis for a relatively high pressure ratio radial turbine was presented by Shanechi et al [1]. In their study the authors, starting from the meanline, designed a three dimensional radial inflow turbine with some emphasis on blades geometry in order to enhance both; the turbine's output power and efficiency. Also, the structural analysis was included in their studies through the enhancement that they did in terms of the blades' stresses and deformation. However, the fatigue analysis, which is considered one of the main problems for rotating parts, was not included in their analysis. Furthermore, the ranges of boundary conditions as well as the output power were different from the range which this study aims to analyse.
The effect of sudden shut down on the transient thermal fatigue life for an edge hole crack in the case structure of a gas turbine was a study established experimentally and analytically recently in [2]. The results showed that in spite of the similarity in the stress distribution in the two difference material behaviour, elastic perfectly plastic and linear elastic, the propagation of crack was different. Moreover, their analysis showed that cooling rate of the turbine case is the most influential parameter in the thermal fatigue crack growth.

2. Body of abstract

Developing small scale turbines pauses challenges in terms of increased stresses due to high rotational speed leading to increase in component thicknesses and turbine overall weight. The failure which might happen in these components is not only lead to economic losses but it can cause losing in human live. Therefore this study assesses both; the structural and aerodynamic performance of a Small Scale Radial Turbine SSRT by integrating finite-element methods FEM and Computational Fluid Dynamic CFD.

3. 3D Numerical Analysis:

The aerodynamic simulation of 3D turbulent viscous flow in the SSRT geometry was achieved using ANSYSCFX solver. Single phase, steady-state 3D viscous, compressible flow was chosen. A first order upwind advection scheme with topology, as suggested by [3], was selected because the high stability when it is numerically dealt. In order to do the analysis for the complete stage, stator and rotor, in the stator and rotor stage interface was applied. The steady state flow accompanied with generalized grid interface feature of CFX was selected for stage analysis. In the blade passages, for both the rotor and the stator, the periodic boundary conditions were applied. The load distribution, which is the results of the aerodynamic load, at three different values (2, 3 and 4) of pressure ratio is presented in Figure 1. It shows the pressure profiles (which will be the reason for the stresses on each; the bladed and hub) on both; the suction side and pressure side along the non-dimensional meridional coordinate.
The transport equations of k-ω are as below:

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_j}\left(\Gamma_k\frac{\partial k}{\partial x_j}\right)+G_k-Y_k+S_K \qquad 1$$

$$\frac{\partial}{\partial t}(\rho\omega)+\frac{\partial}{\partial x_i}(\rho\omega u_i)=\frac{\partial}{\partial x_j}\left(\Gamma_k\frac{\partial\omega}{\partial x_j}\right)+G_\omega-Y_\omega+S_\omega \qquad 2$$

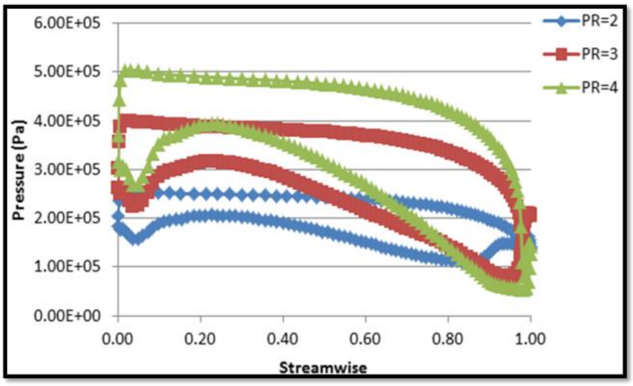

Fig. 1 Load distribution of the SSRT[4]

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