Structural stability Investigation on Nickel Alloy-901 and Rane-77 made Gas Turbine Guide Vanes with Impingement Cooling

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***Abstract* —** *Gas turbine efficiency is directly proportional to inlet temperature. Increase of temperature increases the thermal efficiency and power output. Structural stability of the material depends on the shape, material and load. It is required to analyze the structural stability of such gas turbine components at elevated temperature. The cooling design is hollow portion and greatly influence on the structural stability of gas turbine components. This research focuses on the material influence on guide vane with impingement cooling design. The high temperature super alloys like Nimonic 901 and Rane 77 were considered for the analysis. The Pro –E and ANSYS R14 were used for design and FEM analysis respectively.*

Keywords — *Guide Vane, Gas Turbine, Impingement cooling, ANSYS, PRO-E. Structural Stability NIMONIC 901, RENE 77.*

I. INTRODUCTION (SIZE 10 & BOLD)

Gas turbines have extensive applications like locomotive, power generation, marine propulsion, aircraft and other industrial prime movers. The overall temperature difference is reason for thermal efficiency and work output of a thermal device. Hence the gas turbine operates as much as high temperature about 1000 to 1500°C [1-3]. In particularly aerospace applications operates gas turbines higher inlet temperature like 1,727°C [4-6], and with a high pressure ratio about 50 at compressor [6]. Such high temperatures causes thermal damages (melting, corrosion, oxidation and erosion) [7and degradation of local or global structural strengths of blades, vanes and other components and it was estimated that half of the lifespan of the blades gets reduced due to small temperature difference by improper cooling [3,6,9]. The damages include blade trailing-edge cracks [8], buckling and risk of blade failure [11], thermal-fatigue [8,10,11], Many studies were conducted on optimization of lip thickness to slot height ratio (***t/H***) in trailing edge cooling of blades and vanes [12 -17] in which Kacker *et al*. [12,13] considered lip thickness constant to estimate film cooling effectiveness, Taslim *et al* [14,15] varies slot geometries and blowing ratios. The ***t/H*** ratio from 0.5 to 1, decrease the overall film-cooling effectiveness by about 10% [14-16]. The decreases of ***t/H*** ratio, increases the film-cooling effectiveness [17-19]. [20] considered a a rectangular divergent channel which consists of serpentine shape with ribs, dimples/protrusions, guide vanes, and pin fins at the tip turning the region for his heat transfer studies. [21] studied the cooling performance at tip surfaces of guide vanes and blades at turning regions and insisted the importance of proper design to obtaining desired effects. [22] recommended installing guide vanes in the tip turning regions most suitable way to improve cooling of tip surfaces. [23] insisted that selection appropriate cooling technique with respect to configuration is must. The authors suggested two pass channels cooling at moving blades. This research work investigates with materials behaviors at elevated temperature for impingement cooling design on gas turbine fixed blade (guide vane). The Pro-E and ANSYS are employed to design and analysis. ANSYS is generally the preferred tool for analyzing structural stability. [24] used CATIA and ANSYS to design and investigate the structural stability of various components of Two-Wheeled Inverted Pendulum. In later [25] investigated the suitability of Kevlar29/epoxy composite for drive shaft. The influence of cooling design such as impingement and shower head type on gas turbine guide vanes which are made up of Nimonic 901[26], RENE 77 [27], CMSX 4 [28] were reported. The sample guide vane of gas turbine is shown in Figure.1. This research work includes the software tools like PRO/E and ANSYS 14.5 for pursuing the investigation of material stability under high temperature for the desired design of cooling on the guide vanes (fixed blades) of gas turbines.

II. Materials and Methods

The Nickel Alloy 901 and RENE 77 were considered as materials for guide vanes of the gas turbines. The modelling and Structural Stability investigations like displacement analysis, Stress Analysis and strain analysis were carried out.

A. NICKEL ALLOY 901/ NIMONIC 901

It is also nickel based super alloy widely applicable at high temperature environments. Superior creep resistance, high yield strength, good forging characters, etc. at elevated temperature are the merits of this material. Its significant properties were included in the structural stability analysis..

B. RENE 77

It is preferred for high temperature applications about 1000oC like aviation, petroleum, gas turbine, space flight, ship, etc. because of its significant properties at elevated temperatures like excellent oxidation resistance, with stand at long term stress, creep properties, reliable in physical and chemical properties, good impact and toughness strengths etc. values of such unique properties were included in the analysis.

C. STRUCTURAL ANALYSIS

The modelling works were carried out Pro/E and analysis works were done at ANSYS 14.5 work bench. The dimensional particulars of the guide vane with impingement cooling design is shown in Figure 2. The 3D meshed model is presented in Figure 3. The structural analysis like stress analysis, strain analysis and displacement analysis were considered. The comparative study of materials involved in manufacture them is focused on this research. The young's modulus 201000 Mpa, the

Fig. 1 Fixed blade (Guide vane)

Material density 0.00000814 kg/mm^3, Poisson Ratio 0.24 were considered for NIMONIC 901 made blades. In case of RENE 77 made blades, the young's modulus 200000 MPa, Poisson Ratio 0.30, material density 0.000077 kg/mm^3. In the meshed model made with 186 nodes, and pressure 0.188 N.mm^2. The displacement analysis carried at ANSYS 14.5 work bench. The displacement with respect to turbine load was observed and shown them for NIMONIC 901 made blades in Figure 4 and for RENE 77 made blades in Figure 5. The maximum displacements were observed on the concave side of cooling passage near by its sharp turning. The stress analysis for the above said blades. The Figure 6 for NIMONIC 901 made blades and the Figure 7 for RENE 77 made blades. Similarly for strain analysis were depicted in Figure 8 and figure 9 forv the NIMONIC 901 made blades and RENE 77 made bladesrespectively.

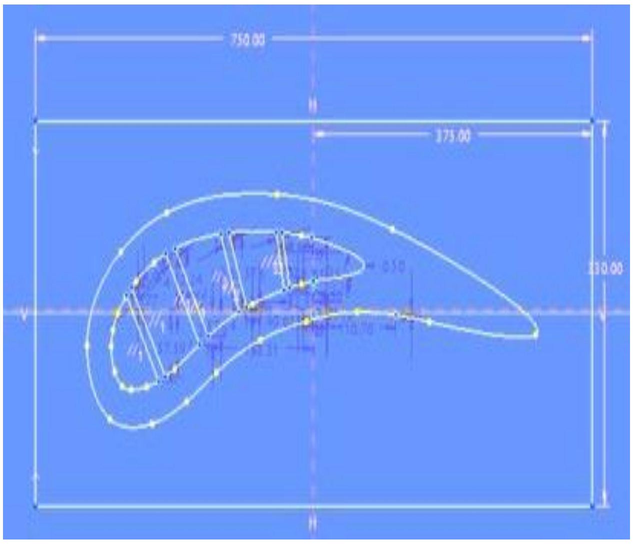

Fig. 2 2D-model of Guide vane with impingement cooling design

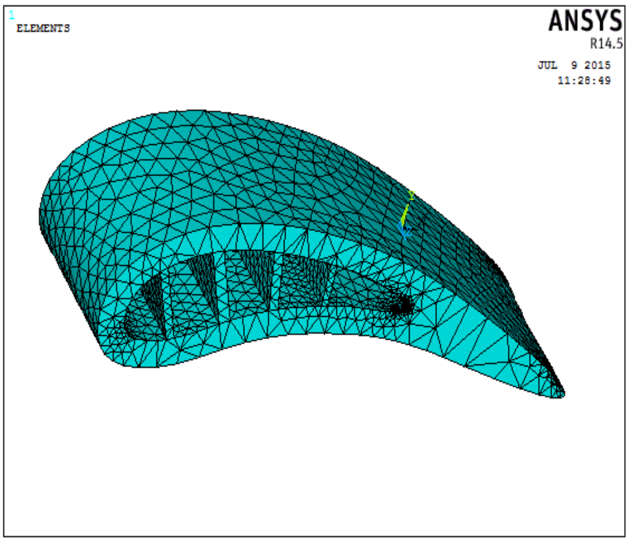

Fig. 3 Meshed model of Guide vane with impingement cooling design

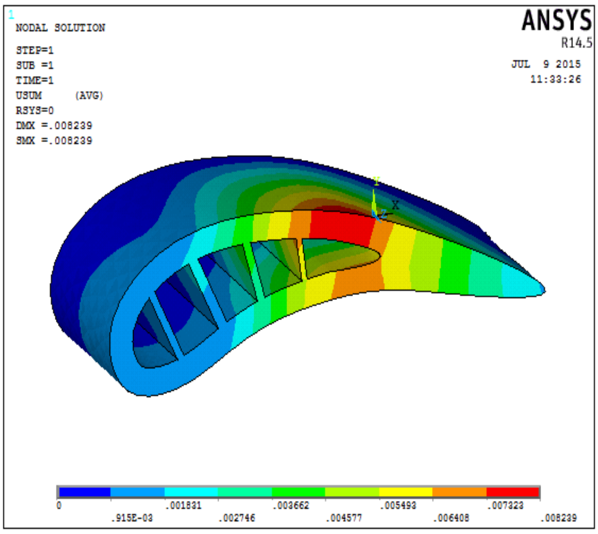

Fig. 4 Displacement analysis for Nimonic 901 blades

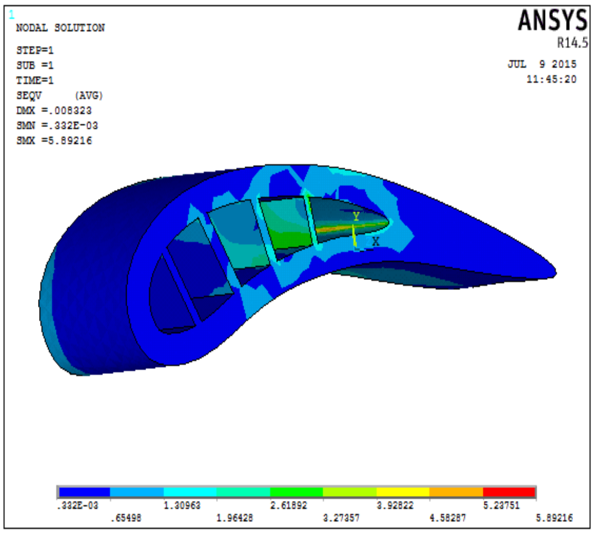

Fig. 7 The stress analysis for RENE 77 made blades

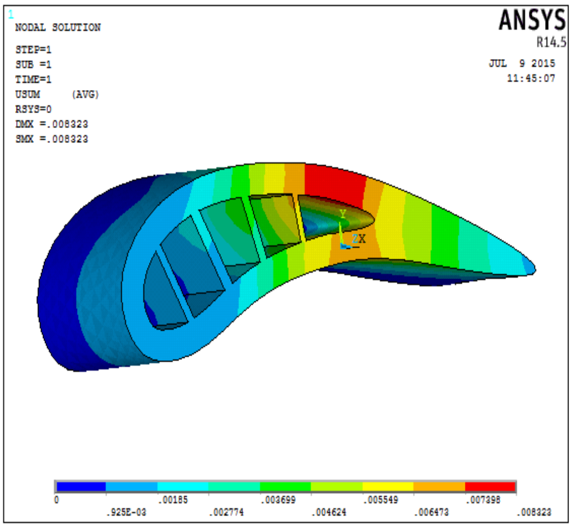

Fig 5 The displacement analysis for RENE 77 blades

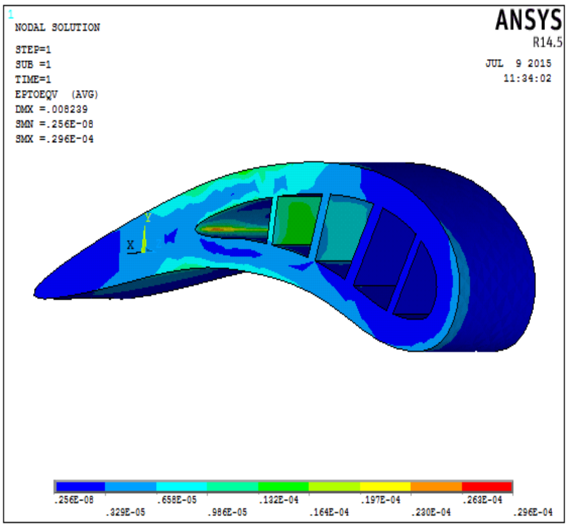

Fig. 8 The strain analysis for Nimonic 901 blades

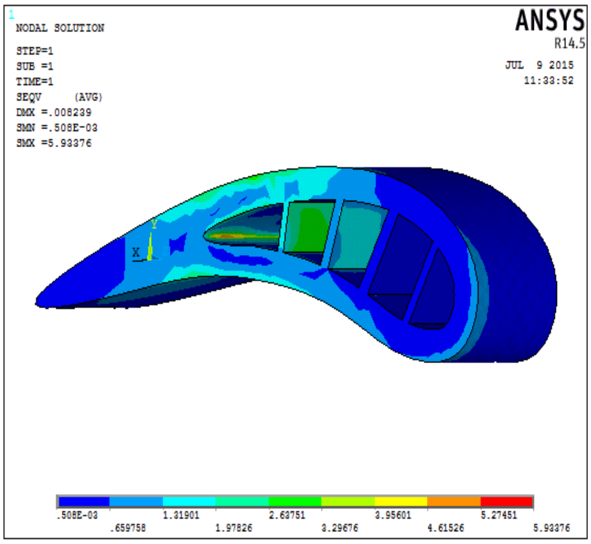

Fig. 6 The stress analysis for Nimonic 901 made blades

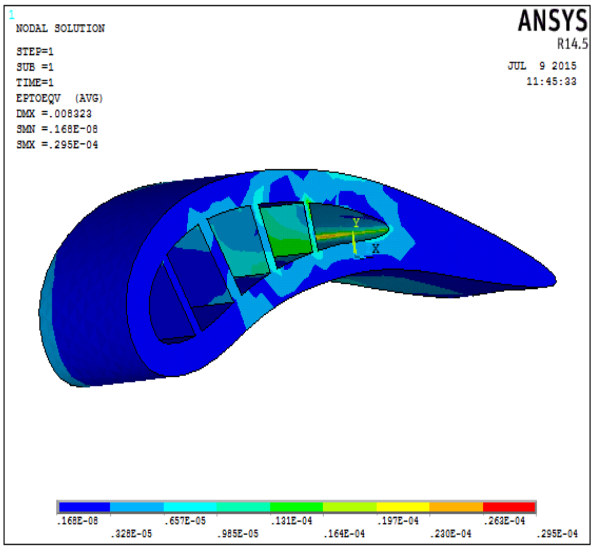

Fig. 9 The strain analysis for RENE 77 made blades

TABLE I
RESULTS OF STRUCTURAL ANALYSIS

Guide Vane made up of	Displacement (mm)	Stress (N/mm2)	Strain
NIMONIC-901	0.008239	5.93376	0.296e-4
RENE-77	0.008323	5.89216	0.295e-4

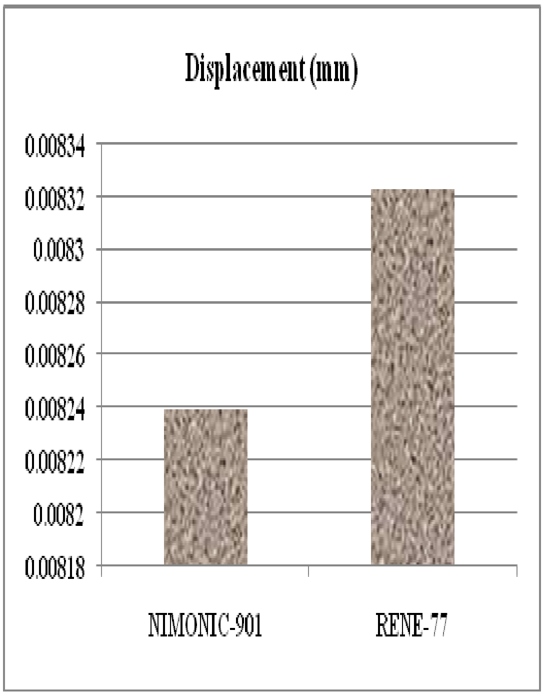

Fig. 10 The results of Displacement Analysis

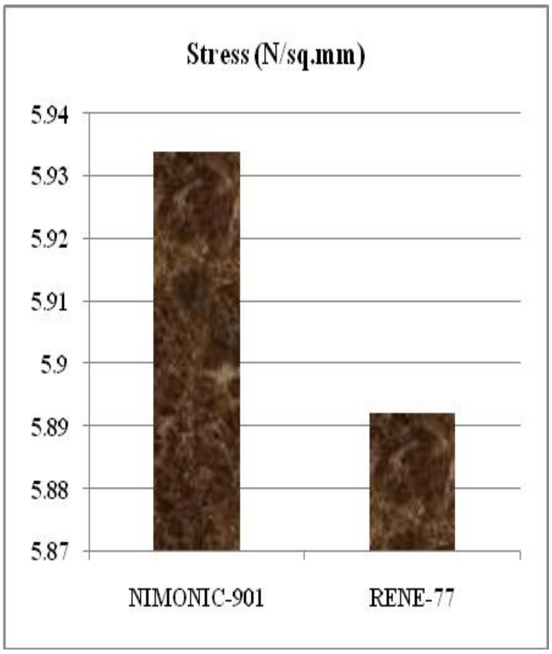

Fig. 11 The results of Stress Analysis

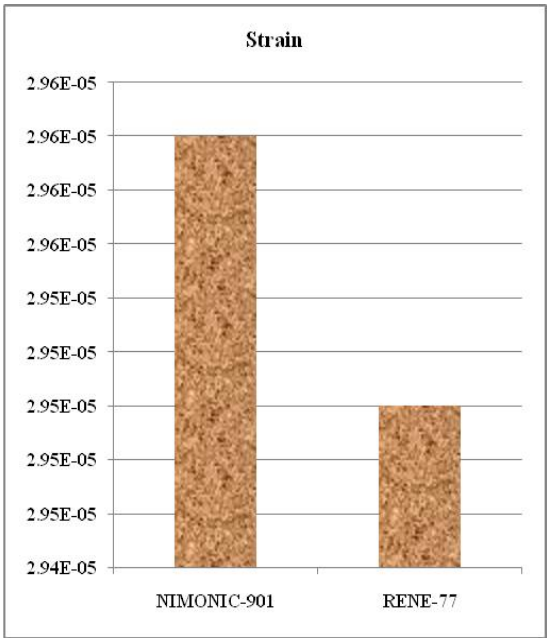

Fig. 12 The results of Strain Analysis

III. RESULTS AND DISCUSSIONS

The structural analysis on NIMONIC-901 and RENE 77 made guide vanes with impingement type cooling design were carried out and reported results in the Table1. The results of Structural Analysis were compared in Figure10 for displacement analysis, Figure 11 for the Stress analysis and the Figure 12 for the Strain Analysis. The result reveals that both the materials are performing well under in the tested condition for displacement as well as strain. The stress bearing capacity per square millimeter little higher for NIMONIC-901 (Refer Figure 10). The higher values of stress, strain and displacements were noticed at a sharp turning of cooling design and its nearby. Hence the sharp turning may be avoided.

IV. CONCLUSIONS

Cooling is indispensable for guide vanes of gas turbines. The cooling design and material which it is made up of are responsible for structural stability of them at elevated temperature. The NIMONIC-901 and RENE 77 materials were considered for investigation with impingement type cooling design on guide vanes. The NIMONIC-901 exhibits little more stress bearing capacity and equivalent displacement and strain with RENE 77. The influence of design was noticed that regardless of materials the more Displacement, stress and strain were encountered at the sharp turning of cooling design. The sharp turning may be avoided in the design.

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