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STRUCTURAL INVESTIGATION ON NEMONIC-901 MADE GAS TURBINE GUIDE VANES

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KEYWORDS: Nimonic 901, turbine vanes, showerhead cooling, impingement cooling, stress analysis, strain analysis, displacement analysis.

ABSTRACT
Nowadays Gas turbine inlet temperature is raised to improve overall thermal efficiency and net power output. The cooling of guide vanes is imperative to avoid their thermal damages and forced deterioration of their life span. The cooling designs influence the structural stability of such guide vanes. This research paper considered two kinds of cooling design, namely impingement cooling and showerhead cooling. The vanes are made up of Nimonic 901. The structural analyses were carried out for both cooling design blades individually. The Pro-E employed for both modeling and ANSYS R14 Finite Element Analysis. The result shows that the improved design of cooling is structurally safe and stable. The structural stability with respect to cooling design ensured for improved cooling design.

INTRODUCTION
Gas turbines play a vital role in the power sectors like thermal power plants, gas power plants, atomic power plants, etc. The design of such industrial gas turbines must ensure the safety, reliability, efficiency and cost (Amos et al 2004). The increase of temperature of inlet gas is to increase the power output as well as thermal efficiency in gas turbines (Han 2004), Han and Huh (2010). But, nowadays gas turbines operate at very high temperature (about 1500°C). Apart from mechanical load, physical forces, theses high temperature operating conditions cause the thermal damages on vanes and blades even though high temperature alloy materials used for fabricating them. A strong diminution in blade's lifespan may due to the small variation of temperature (Luca et al 2014), For ensuring reliable operation, usually such cooling is done by compressed air (about 650°C) passes through the airfoils to maintain their temperature approximately 1000°C. The Even small difference can reduce the life of the blade by half. Though various cooling techniques exist, the selection of appropriate cooling techniques and its design is a complicated task, because of the involvement of a wide variety of geometrical and flow parameters. Sufficient care must be taken to accurately design of such cooling facility to avoid premature failures. The design of such cooling system is a complicated and challenging task which involves numerical modelling, complex interaction, forming strong streamline, developing turbulent layer, etc., On curved surfaces (Elnajjar et al., 2013). Öztekin et al. (2012) investigated in turbulent slot jet cooling of concave plate. The authors varying surface curvature and achieved most excellent cooling performance for the dimensionless value of the curvature of impinging surfaces R/L = 1.3. Further (Öztekin et al. (2013) numerically as well as experimentally investigated the flow on concave surfaces which subject to a slot jet flow and developed the k-ε turbulence model, in which the increase of dimensionless nozzle-to surface distance reduces the pressure coefficient (Cp) at the stagnation point. Hamdan et al. (2011) and Yang et al (2011) investigated on the semi-circular heated surface with confined slot jet impingement. Isman et al. (2008) concluded after experimenting with various turbulence models that the k-Ɛ models produce perfect results over the impingement surface. ANSYS is generally used for design Mechanical Machines, investigates alternate materials and their compatibility for the applications. For example Saravanan et al (2016a) designed Two-Wheeled Inverted Pendulum for the Material Handling. The authors used CATIA for 3D modelling of structural components like the handle, motor bracket,wheel Boss, support stem of handlebar, loading platform, base plate, Flange, support bracket, etc., and assembled them and analyzed by means of Finite Element Analysis in ANSYS work bench. Saravanan et al (2016b) investigated alternate material for the drive

shaft. The authors considered composite materials like E-glass/epoxy proposed and Kevlar29/epoxy composites along with conventional steel of grade SM45. The ANSYS R14.5 is employed for FEA and found Kevlar29/epoxy composites reduced weight by 81.05%, 0.22% reduction of traditional stress and 57.1% increased buckling capacity than conventional steel.

This research focuses on such complicated design for guide vanes. The guide vanes are a number of fixed blades that arranged between two parallel covers and normal to the turbine shaft. By adjusting them the flow rate can be varied. The impingement type cooling is widely used on the leading edge of the airfoils and in the mid-chord of the vane where the heat loads are extremely high. The Figure 1 exhibits a jet impingement that located throughout the cross-section of an inlet guide vane. According to their findings film cooling performance can be improved by adding showerhead with fan-shaped holes. An optimal cooling design depends on many factors such as state of approaching flow, blowing ratio, hole shape, the number of cooling rows and cooling type. This investigation is focused with showerhead cooling in the place of the impingement cooling type.

MATERIALS AND METHODS

Nickel Alloy 901/ Nimonic 901

The preferred material for this guide vane is Nickel Alloy 901/ Nimonic 901 which is often encountered in high temperature applications like gas turbine engine shafts, discs, rings, seals, and casings. Nimonic 901 is one of the nickel based super alloy. The chemical composition of the Nimonic 901 furnished in Table 1.

Table 1 Chemical Composition of Nickel Alloy 901/ Nimonic 901

Weight%	S	C	Al	Si	Mn	Cu	Co	Ti	Mo	Cr	Ni	Fe
Composition	0.03 max	0.1 max	0.35 max	0.4 max	0.5 max	0.5 max	1.0 max	2.9	5.75	12.5	42.5	Bal

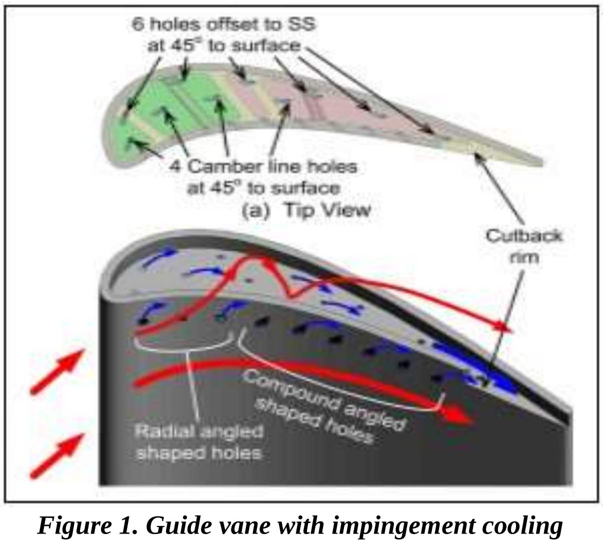

Figure 1. Guide vane with impingement cooling

It contains Aluminium and Titanium for precipitation hardening and molybdenum for solid-solution strengthening. It exhibits high strength (high yield strength and creep resistance) at elevated temperature 600°C. Apart from this it has a substantial iron content which enables it to combine strength with good forging characteristics. Nomonic 901 is solution treated in the temperature range of 1100 °C -1125°C for 2 hrs and then allowed to cool at room temperature. Then it is heat treated for stabilization at a temperature range of 790°C - 820°C then allowed to cool at room temperature. After that it is precipitated hardened at 735°C - 764°C for 24 hours and then allowed to cool in the oil medium. The physical and mechanical properties were tabulated in Table 2.

Table 2. Physical and Mechanical Properties of Nickel Alloy 901/ Nimonic 901

Property Description	Property Value
Hardness	302-388 HBN
Tensile Strength	1034 N/mm^2 or Mpa
Yield Strength	689 N/mm^2 or Mpa
Young's Modulus at 1000°C	126000 Mpa
Poisson's ratio at 1000 °C	0.24
Elongation in 4D	12%
Reduction of Area	15%
Melting Range	1280 °C - 1345 °C
Density at 1000 °C	0.00000814 kg/mm^3
Mean coefficient of linear thermal expansion	19.9µm/m•°C

STRUCTURAL ANALYSIS

MODELLING

The impingement cooling and showerhead coolings were considered for investigation and their dimensional particulars are illustrated with Pro/ENGINEER (Pro/E) sketches in Figure1. The modeling task performed with Pro/ENGINEER (Pro/E).

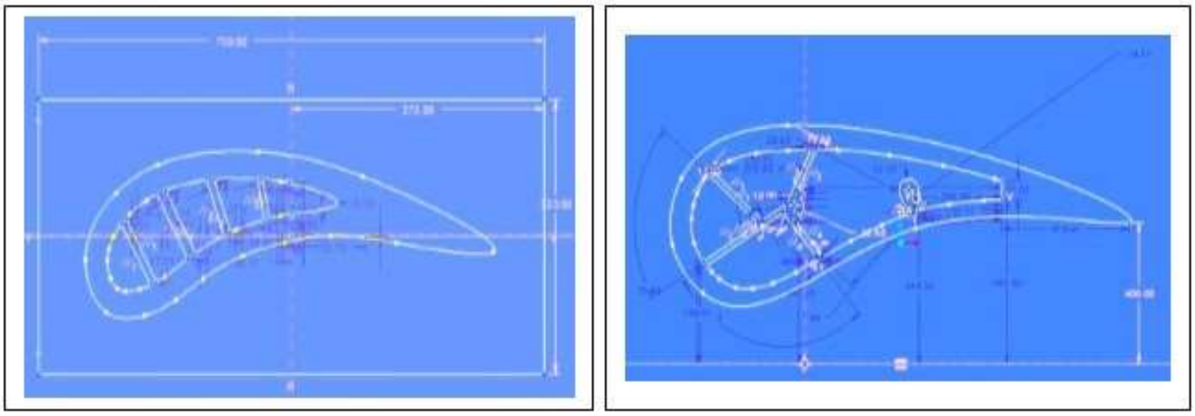

Figure 2 Profile and Dimensions of Impingement (Left) showehead (Right) Cooling type Guide Vanes

FINITE ELEMENTAL ANALYSIS

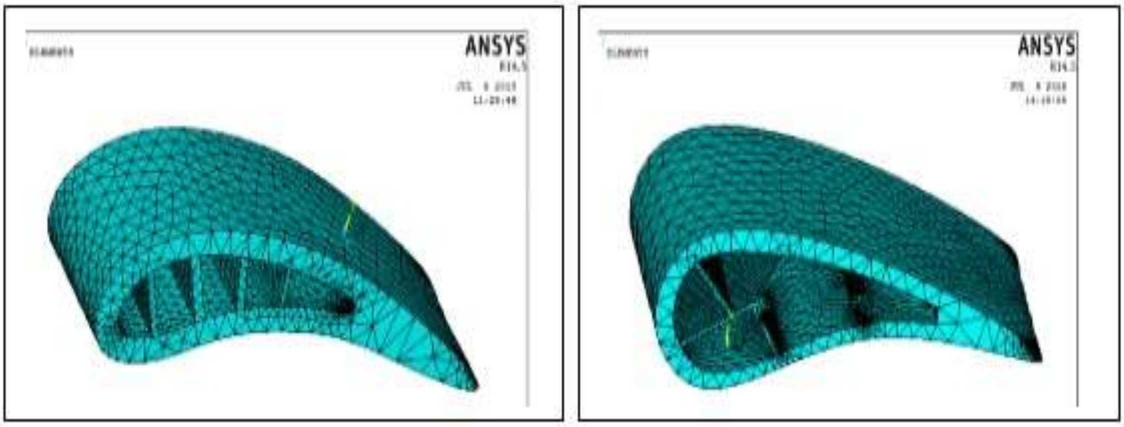

Figure 2 Meshed model of Impingement (Left) showehead (Right) Cooling type Guide Vanes

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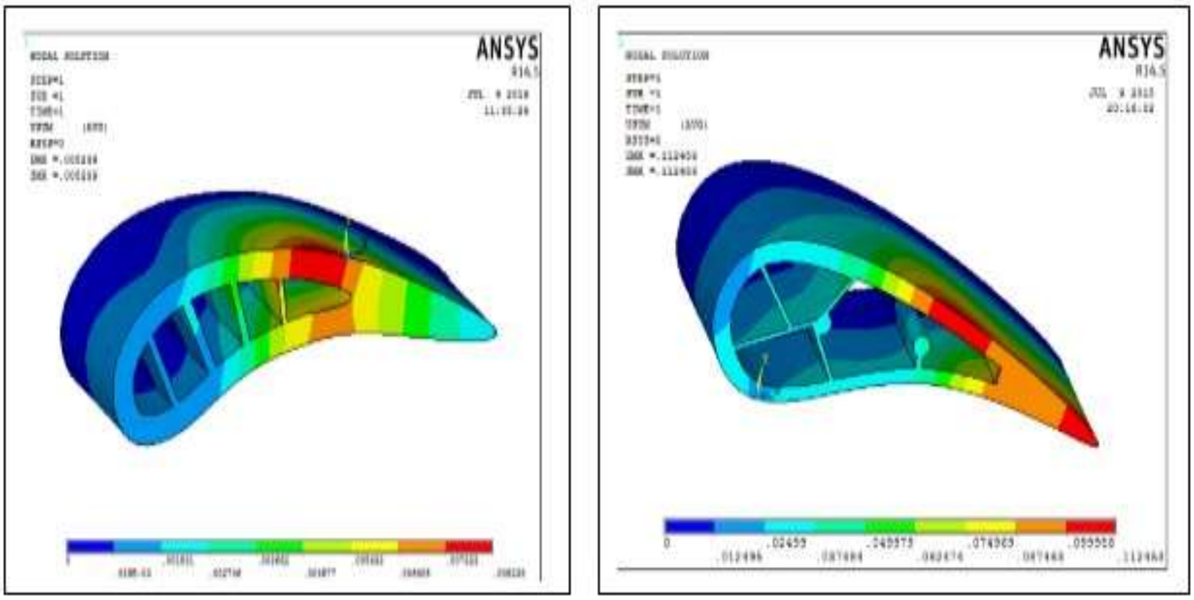

Figure 3 Displacement analysis for Impingement (Left) showehead (Right) Cooling type Guide Vanes

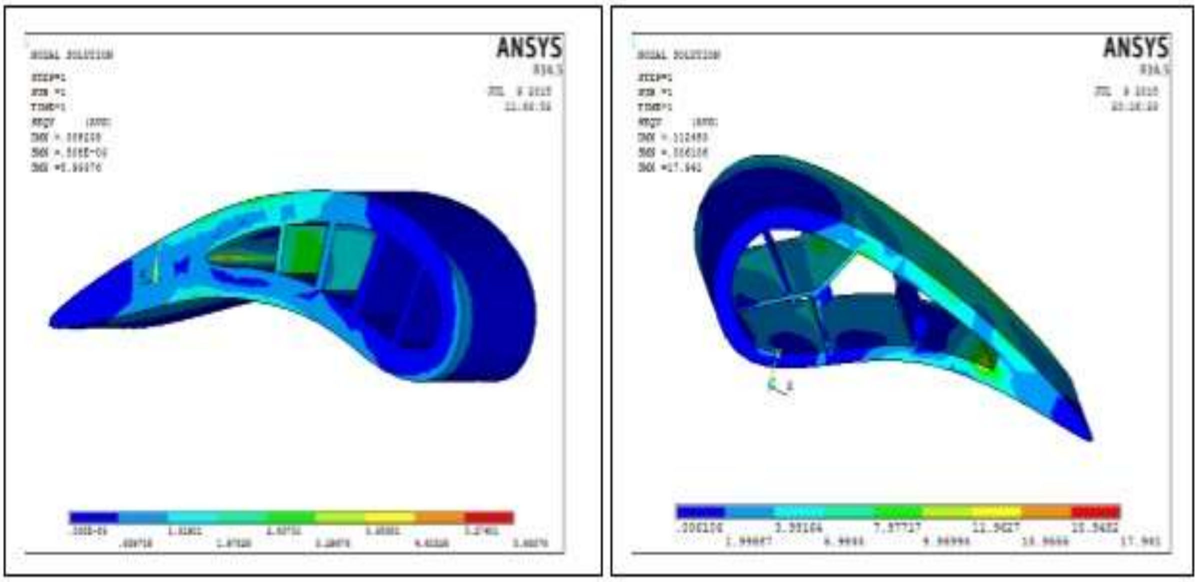

Figure 4 Stress analysis for Impingement (Left) showehead (Right) Cooling type Guide Vanes

The ANSYS release14 is employed for this analysis part. The mechanical and physical properties were used in the model with 186 nodes. The meshed models of conventional and improved designs are shown in Figure 2 for impingement and showerhead cooling type guide vanes. The load and displacement analysis results are displayed in Figure 3 for impingement and showerhead cooling type guide vanes. The stress analysis (Figure 4 for impingement and showerhead cooling type guide vanes) and strain analysis (Figure 5) for impingement and showerhead cooling type guide vanes) were also investigated.

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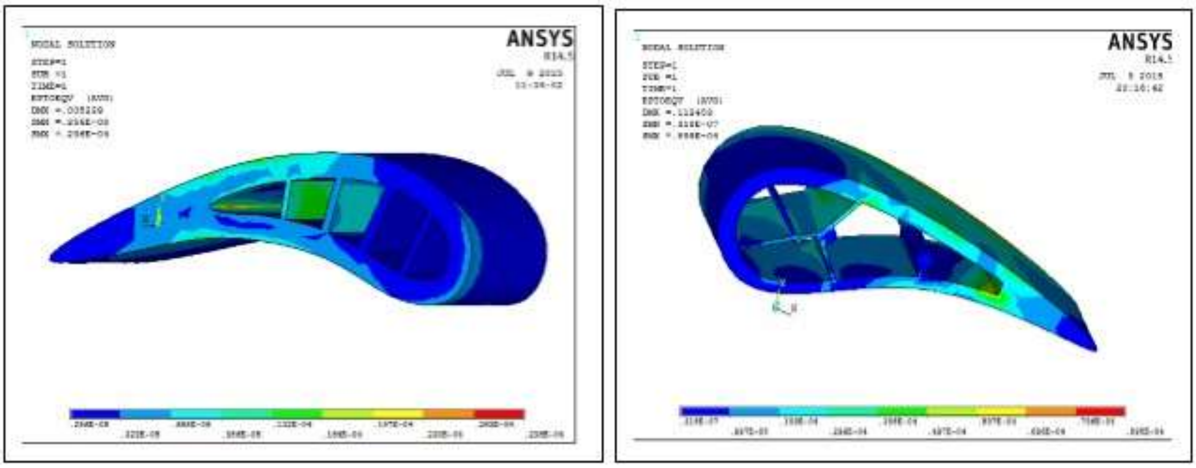


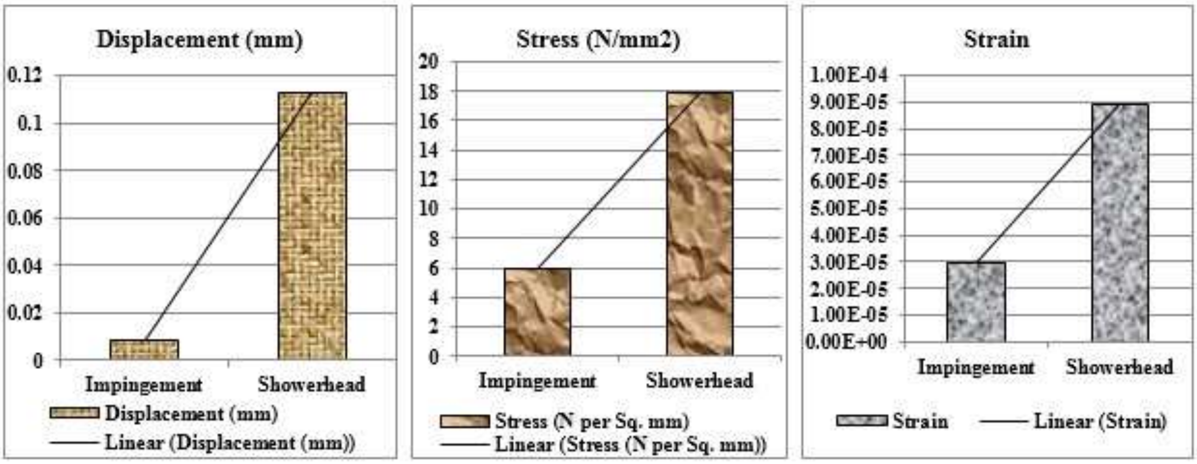
Figure 4 Strain analysis for Impingement (Left) showerhead (Right) Cooling type Guide Vanes

RESULTS AND DISCUSSION

The structural analysis line displacement analysis, stress analysis and strain analysis were carried out and their results are tabulated in Table 3 and graphically compared with respect to displacement (left), stress (middle) and strain (right) in figure 5. The guide vane designed with showerhead cooling type is yielded higher value than impingement type. The impingement type of cooling is conventional type. The sowerhead cooling is improved

Table 3 Results of structural analysis of showerhead and impingement type cooling type guide vanes

Guide vane with impingement cooling Design			Guide vane with showerhead cooling Design		
Displacement (mm)	**Stress (N/mm^2)**	**Strain**	**Displacement (mm)**	**Stress (N/mm^2)**	**Displacement (mm)**
0.008239	5.93376	0.296e-4	0.112453	17.941	0.895e-4



Design. The improved design, i.e., showerhead cooling on the Nimonic 901 made guide vane is more flexible and withstand the applied load.

CONCLUSION

The cooling Design on the gas turbine guide vane is considered for structural investigation. The conventional impingement cooling design is compared with improved showerhead cooling design. The structural analysis like displacement analysis, stress analysis and strain analysis were carried out. The result shows that the improved design has highly suitable for the application. This paper ensured the structural stability of Nimonic 901 made guide vane with showerhead cooling design. The research be extended to conduct the CFD analysis to ensure the cooling performance.

REFERENCES

1. I.G. Amos, T. Jablonowski, E. Rossi, D. Vogt and P. Boncinelli, “Design and off-design optimization of highly loaded industrial gas turbine stages”, APPLIED THERMAL ENGINEERING, VOL. 24, 2004, pp. 1735–1744.
2. JC. Han, “Recent studies in turbine blade cooling”, INTERNATIONAL JOURNAL OF ROTATING MACHANICS, VOL.10, 2004, pp. 443-57.
3. JC Han, and M. Huh, “Recent studies in turbine blade internal cooling”, HEAT TRANSFER RESEARCH, VOL.41, 2010, pp.803-28.
4. Luca Andrei, Antonio Andreini, Bruno Facchini and Lorenzo Winchler, “A decoupled CHT procedure: application and validation on a gas turbine vane with different cooling configurations” ENERGY PROCEDIA, VOL. 45, 2014, pp.1087 – 1096.
5. Emad Elnajjar, Mohammad O. Hamdan and Yousef Haik, “Experimental Investigation of Internal Channel Cooling Via Jet Impingement”, FDMP, VOL.9, NO.1, 2013, pp.77-89.
6. Öztekin, Ebru, Orhan Aydin, and Mete Avcı. "Hydrodynamics of a turbulent slot jet flow impinging on a concave surface." INTERNATIONAL COMMUNICATIONS IN HEAT AND MASS TRANSFER, VOL.39. NO.10, 2012, pp.1631-1638.
7. Öztekin, Ebru, Orhan Aydin, and Mete Avcı., “Heat transfer in a turbulent slot jet flow impinging on concave surfaces”, INTERNATIONAL COMMUNICATIONS IN HEAT AND MASS TRANSFER, VOL. 44, 2013, pp. 77-82.
8. Hamdan M. O. Elnajjar E., Haik Y., “Measurement and Modeling of Confined Jet Discharged Tangentially on a Concave Semi cylindrical Hot Surface” J. Heat Transfer, December 2011, Volume 133, Issue 12, 122203 (7 pages) doi:10.1115/1.4004529.
9. Yang, Yue-Tzu, Tzu-Chieh Wei, and Yi-Hsien Wang. "Numerical study of turbulent slot jet impingement cooling on a semicircular concave surface" INTERNATIONAL JOURNAL OF HEAT AND MASS TRANSFER, VOL. 54, NO.1, 2011, pp.482-489.
10. M.K. Isman, E. Pulat, A.B. Etemoglu, and M. Can, Numerical investigation of turbulent impinging jet cooling of a constant heat flux surface, NUMERICAL HEAT TRANSFER, PART A, VOL.53, 2008, pp.1109–1132.
11. R. Saravanan, R. Pugazhenthi, P. Vivek and M. Santhanam, “Design and Simulation of a Two-Wheeled Inverted Pendulum - a Balanced, Easy Moving Vehicle for the Material Handling”, AMERICAN-EURASIAN JOURNAL OF SCIENTIFIC RESEARCH, VOL .11, NO 3, 2016, pp.189-198,
12. R Saravanan, P Vivek, T Vinod Kumar, “Is Kevlar29/Epoxy Composite an Alternate for Drive Shaft?”, JOURNAL OF ADVANCES IN MECHANICAL ENGINEERING AND SCIENCE, VOL2, NO 3, 2016, pp.1-13.