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CFD ANALYSIS OF EFFECT OFBLADE ROUGHNESS

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Abstract: ***A computational study has been conducted for different inlet velocities in linear axial flow Compressor Cascade focusing mainly on analysis of the effect of blade roughness with different velocities on the aerodynamic performance of the Cascade. Measurement of pressure loss was carried out with different roughness on the blades of Cascade. Initially, both surfaces of the blades of the cascade are kept as smooth and total pressure loss is analyzed for the different velocities like 250m/s, 300m/s and 350m/s. Different roughnesses are given on the Suction and Pressure surfaces and Percentage Profile losses are Found for different inlet velocities as 250m/s, 300m/s, and 350m/s.***

NOMENCLATURE:

ρ	***Density (kg/m3)***
P	***Static Pressure (Pa)***
E	***Energy term***
h	***Enthalpy (kj/kg-k)***
mj	***Mass fraction (kg)***
M	***Mach number***
P2s	***Static pressure at outlet (Pa)***
Po1	***Total pressure at inlet (Pa)***
Po2	***Total pressure at outlet (Pa)***
γ	***Ratio of specific heats for air***
ζy	***Local energy loss Coefficient***
S	***Span (mm)***
Y	***Distance along pitch (mm)***

KEY WORDS: **Cascade, Stagger angle, Pitch, Chord length**

I. INTRODUCTION

Cascade of blades

Blades of a desired size and shape are assembled in a straight line or annular according to the cascade required. For assembling the blades, pitch(s) and stagger angle (γ) is defined. Blades of equal lengths are used in constructing a cascade. Sometimes blades are made hollow to reduce the quantity of material and the weight of the blade.

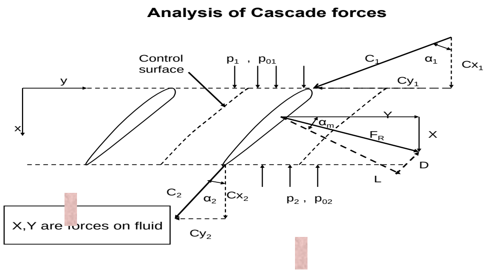

Fig 1: Analysis of Cascade Forces(S MYAHAH)

In the figure 1 inlet and outlet velocity triangles on the blade surfaces are shown. The absolute inlet velocity is C1 and absolute outletvelocity is C2. The components of C1 and C2 velocities in axial and perpendicular directions are Cy1, Cx1 and Cy2, Cx2 respectively.

II. LITERATURE REVIEW

Shao-Wen Chen and Shi-jun-sun [2] studied an effect of boundary layer suction on the flow characteristic in a highly loaded Compressor cascade with a stator clearance experimentally. They applied hole type suctions with different locations and distributions on the end wall to control Clearance flow and losses. The result shows that the clearance flow is improved and the losses reduced when boundary layer suction is adopted and the maximum loss reduction with clearance is 32%.

They observed that with a short clearance the same flow separation obtains in the corner of the suction surface as that with no clearance.

In another research GuoShuang and Chen Shaowen [4] studied the effect of boundary layer suction position on the compressor cascade performance. Results shows that with higher suction flow rate and the suction position closer to the trailing edge reduces the losses and the maximum reduction in the total pressure loss is 16.5%. The effect of suction position is more than the suction flow rate in affecting the total pressure loss.

JIA Hurxia, XI Guang, Wen Shurping [12] worked on effects of Deposition Models on Deposition and Performance Deterioration in Axial Compressor Cascade.He found that total pressure loss co-efficient for three angle of attack -4.30, 00, and 6.70. Total pressure loss co-efficient increases with increase in positive angle of attack and is maximum for 6.70 angle of attack.

Singoria, and Samsher [5] studied the effect of surface roughness on the secondary losses in an axial flow compressor cascade. They found that with the increase of surface roughness the percentage pressure loss decreases. The percentage of secondary losses was 5.26, 5.13 and 5.06 for the roughness of 250μm is applied on suction and pressure surfaces individually and both the surfaces together while the percentage of secondary losses for the smooth blade cascade was 5.33 %, 5.17% and 5.15%.

III. METHODOLOGY

The 2D modeling scheme was adopted in GAMBIT and it was analyzed using FLUENT. A compressor cascade model with zero degree flow angle of incidence was designed. A two dimensional model of the profile was created, with the help of Gambit®. Dimensions of

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the cascade & flow parameters are shown in Table. The compressor cascade used for research contains five blades and formed four complete passages, however only one passage is used for the recording and documentation of data. Chord of all the blades are 37mm and the pitch is 31.07mm. The following table summarizes the geometric properties of the compressor cascade.

Table 1: Cascade Parameter

1	Aspect ratio (c/h)	0.987
2	Chord length(c)	37 units
3	Pitch of the cascade(s)	31.07 units
4	Solidity (c/s)	1.19
5	Inlet velocity	250m/s, 300m/s, 350m/s
6	Viscous models	K-epsilon
7	Software used	Gambit and Fluent
8	Type of analysis	Computational 2D
9	No of blades	5
10	No of flow channels	4
11	Working fluid	Air

Measuring plane

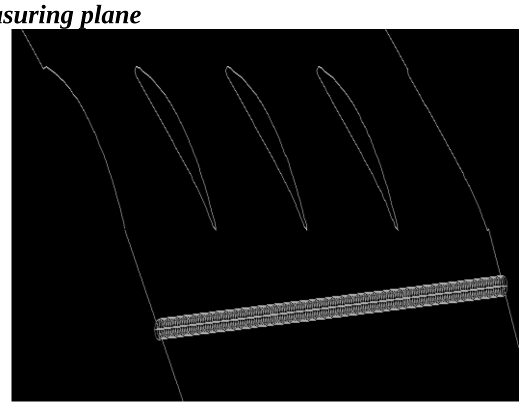

Fig 2: Measuring plane at 0.4 chord.

All various co-ordinates of blade profile are plotted using vertex command in Gambit®. By using the edge command all the co-ordinates are joined to obtain a wire frame model. This gives us a blade of the compressor. Now rotate this blade at the stagger angle. For computational study of effect of roughness different values of roughness are applied to the surfaces.

The pressure loss coefficient ξ is calculated using the relation proposed by Dejc and Trojanovskij, expressed as-

$$----- \xi=\frac{1-\left[1-\left[\frac{P01-P02}{P01-P2S}\right]\left[1-\frac{P2S}{P01}\right]\right]^{\frac{\gamma-1}{\gamma}}}{\left[1-\left[\frac{\square 2S}{P01}\right]^{\frac{\gamma-1}{\gamma}}\right]\left[1-\left[\frac{P01-P02}{P01-P2S}\right]\left[1-\frac{P2S}{P01}\right]\right]^{\frac{\gamma-1}{\gamma}}}$$

IV. RESULTS

From the Figure 3 the percentages profile loss of smoothblades for the inlet velocities 250 m/s, 300 m/s, and 350 m/s are36.46 %, 35.21 % and 33.90 % respectively.

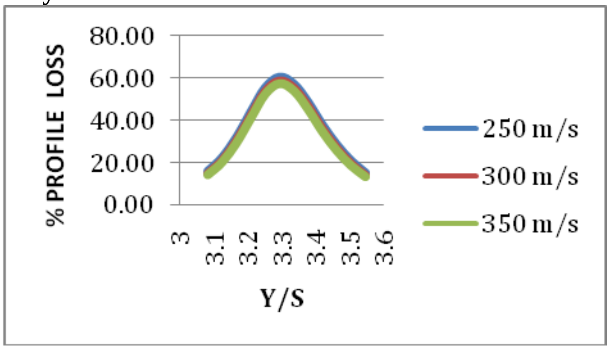

Fig 3: Percentage profile loss Vs. Y/S for smooth blade

Percentages profile loss of both side rough blades

Roughness of 300 m is applied on both surfaces of blades. For the inlet velocities 250 m/s, 300 m/s, and 350 m/s percentage profile losses are 37.0285 %, 35.7663 % and 34.4406 % respectively.

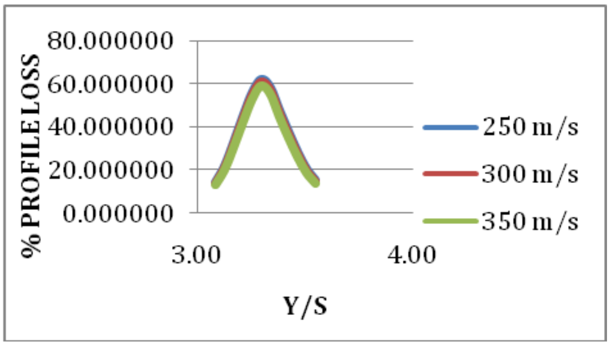

Fig 4: Percentage Profile loss Vs. Y/S for both side rough blades

Profile loss for rough suction surface

Roughness is applied only on the suction surface of the blades and all other boundary conditions and location of measurement plane remained unchanged. From the Figure 5 the percentage profile loss for rough suction surface with roughness 300µm for inlet velocities 250 m/s, 300 m/s, and 350 m/s are 37.0287 %, 35.7662 % and 34.4407 % respectively.

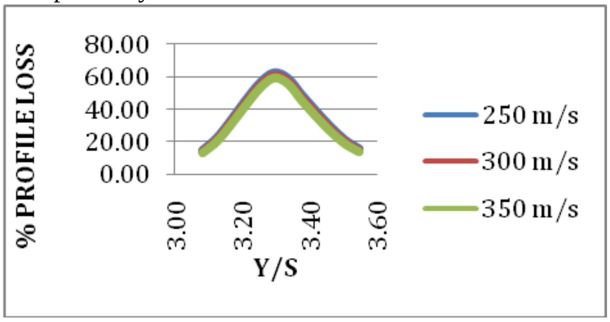

Fig 5: Percentage Profile loss Vs. Y/S for rough suction blade having roughness=300µm

Profile loss for rough pressure surface

Roughness is applied only on the pressure surface of the blades and all other boundary conditions and location of measurement plane remained unchanged. From the

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Figure 6 the percentage profile loss for rough pressure surface with roughness 300µm for the inlet velocities 250 m/s, 300 m/s, and 350 m/s are 37.0284 %, 35.7663 % and 34.4407 % respectively.

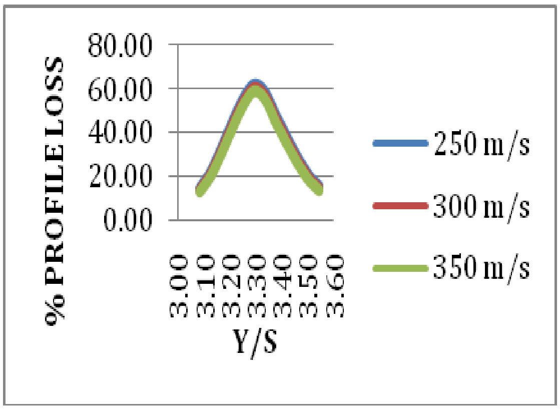

Fig 6: Percentage Profile loss Vs. Y/S for rough pressure blade having roughness=300µm

Flow Visualization

Contour plots of total pressure distribution for different cases

Smooth blades at Inlet velocity 250 m/s.

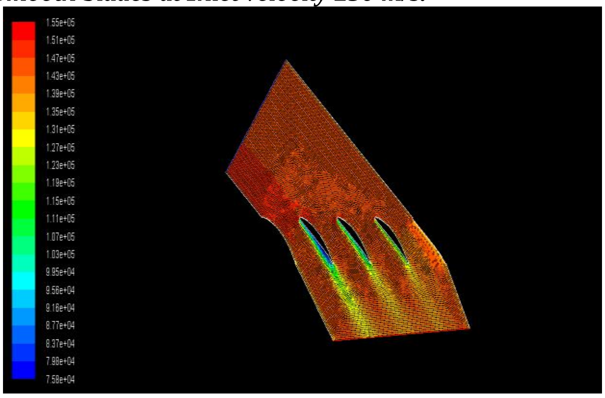

Fig. 7: Contour of total pressure for smooth blades for inlet velocity 250 m/s.

Wholly rough blades having roughness 300µm

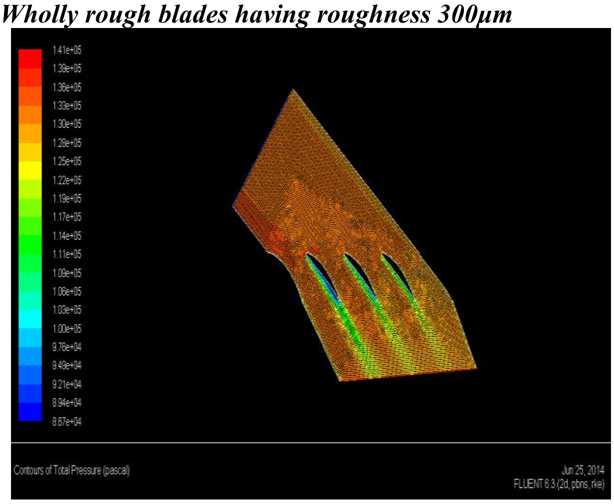

Fig 8: Contour of total pressure for wholly rough blades having roughness 300µm (VEL=250m/s)

Rough suction surface of blades having roughness 300µm at Inlet velocity 250 m/s.

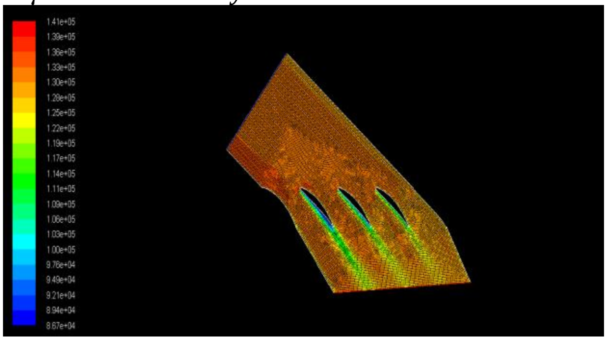

Fig 9: Contour of Total pressure for rough suction surface of blades having roughness 300µm (VEL=250 m/s)

Rough pressure surface of blades having roughness 300µm at Inlet velocity 250 m/s.

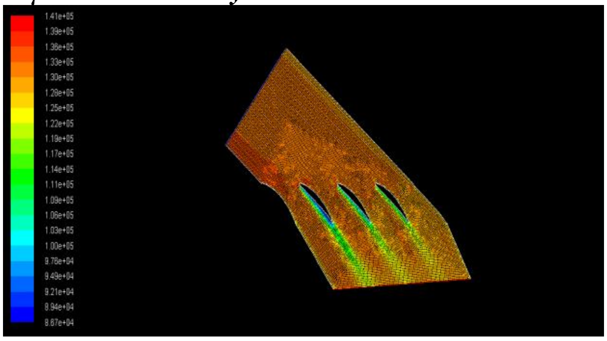

Fig 10: Contour of Total pressure for rough pressure surface of blades having roughness 300µm (VEL=250 m/s)

V. CONCLUSION

It is concluded from the computational study of the effect of blade roughness that with the increase of inlet velocity Profile loss co-efficient decreases.

It is observed that for the smooth blades Profile loss co-efficient decreased by 7.02 % with the increase of inlet velocity from 250 m/s to 350 m/s.

For the constant velocity for the wholly rough blades having roughness 300µm, 500µm, 750µm profile loss decreases approximately by 6.98 %.

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