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THEORETICAL ANALYSIS ON EFFECT OF BLADE DISCHARGE ANGLE ON DEGREE OF REACTION FOR BACKWARD CURVED VANE, RADIAL OUTWARD FLOW TURBO MACHINE

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ABSTRACT

In this research work, the theoretical analysis is made on radial outward flow turbo machine. Based on the literature survey results it is found that radial outward flow turbo machines are power absorbing turbo machines with centrifugal type, centrifugal effect at outlet is twice that of inlet and flow velocity is constant throughout the flow. Based on this conditions and taking inlet blade angle(β_1) as 45° the results shows that, for different values of blade discharge angle(β_2):- i) $\beta_2 < 26.5°$, machine acts like turbine, ii) $\beta_2 = 26.5°$ there is no change in static pressure head, iii)$26.5° \leq \beta_2 \leq 153.5°$, machine acts like power absorber, reaction type.

Keywords: Degree of Reaction(R), Centrifugal type, Blade discharge angle (β_2), Power absorber, Turbine

1. INTRODUCTION

The degree of reaction is defined as the ratio of Energy transfer due to change of static pressure in the rotor to the Total energy transfer in the rotor. In an impulse type machine, if the fluid enters and leaves the rotor at different radii a change of static pressure occurs due to centrifugal effects in one direction. An equal amount of change in static pressure is produced in the opposite direction. A machine with any degree of reaction must have the rotor enclosed in order to avoid expansion of fluid in all directions, this is called a reaction machine. In a machine with zero degree of reaction, the rotor can be open type, i.e. an open jet of fluid with no connection with the rotor.

The radial outward flow machines are centrifugal type and are power absorbers like centrifugal compressor or centrifugal pump these are the devices which converts mechanical energy into pressure energy, for centrifugal machines there is no inlet guide blade, i.e tangential component of absolute velocity at inlet is zero, the centrifugal effect at outlet i.e, outlet blade velocity is twice that of inlet, and flow velocity is constant throughout the flow of working fluid.

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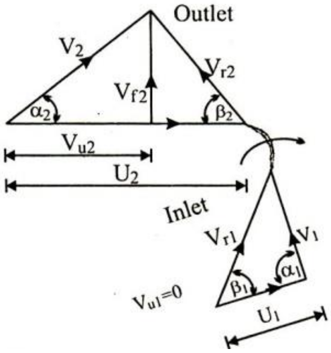
2. METHODOLOGY

2.1 Expression for Degree of Reaction for radial outward flow turbo machine in terms of blade discharge angle (β_2).

The velocity triangle for radial outward flow backward curved vane turbo machine is given by,

Where,

V_1 = absolute velocity of the working fluid at inlet.
V_2 = absolute velocity of the working fluid at outlet.
V_{r1} = relative velocity of the working fluid at inlet.
V_{r2}= relative velocity of the working fluid at outlet.
V_{f1} = flow velocity of the working fluid at inlet.
V_{f2} = flow velocity of the working fluid at outlet.
V_{u1} = tangential component of absolute velocity of the working fluid at inlet.
V_{u2} = tangential component of absolute velocity of the working fluid at outlet.
U_1 = absolute velocity of the blade/runner at inlet.
U_2 = absolute velocity of the blade/runner at outlet.
α_1 = fluid angle at entry/ Inlet nozzle angle.
α_2 = fluid discharge angle at outlet.
β_1 = blade angle at inlet.
β_2 = blade angle at exit.
g_c = Newton's proportionality constant = 1 (kg- m) / (N- sec^2)



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Conditions for radial outward flow machine,

i) $V_{u1} = 0$
ii) $V_{f1} = V_{f2} = V_f$
iii) $U_2 = 2\times U_1$
iv) $\beta_1 = 45°$

Now,

From the definition of Degree of reaction

$$R = \frac{\text{Energy transfer due to change of static pressure in the rotor}}{\text{Total energy transfer in the rotor}} = \frac{\acute{E}S}{\acute{E}} \quad \text{.......(1)}$$

Energy transfer due to change of static pressure in the rotor ($\acute{E}_S$) = $(u_1\text{-}u_2)^2/\ 2g_c + (v_{r2} - v_{r1})^2/\ 2g_c$ ....(2)

Total energy transfer in the rotor ($\acute{E}$) = $(v_{u1}u_1 - v_{u2}u_2)/g_c$. ....(3)

from inlet velocity triangle, $V_{u1}= 0$ and $V_1 = V_{f1} = V_{f2} = U_1= V_f$

from outlet velocity triangle, $U_2 = 2\times U_1= 2\times V_f$

Substituting the conditions in equation (2) and equation (3) ,

On simplifying we get,

$\acute{E}_S = V_f^2((\cot \beta 2 - 2) \times (\cot \beta 2 + 2)) / 2\ g_c$ ....(4)

$\acute{E} = 2V_f^2 (\cot \beta 2 - 2) / g_c$ ....(5)

Substituting equation (4) and equation (5) in equation (1), we get

$$\mathbf{R} = \frac{2+\cot \beta 2}{4}$$

This is the equation for degree of reaction for radial outward flow turbo machine in terms of blade discharge angle *(β_2)*.

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2.1.1 Graph of Degree of Reaction for various values of blade discharge angle.

The graph is plotted by taking blade discharge angle along x-axis and degree of reaction along y-axis and the graph obtained is as shown in figure 2.1. From the graph it is observed that the value degree of reaction is greater than unity when blade discharge angle is less than 26.5°, the value degree of reaction is unity when blade discharge angle is equal to 26.5°, the value degree of reaction is 0.5 when blade discharge angle is equal to 90°, the value degree of reaction is 0 when blade discharge angle is equal to 153.5°, and the degree of reaction varies from o to unity when blade discharge angle is between 153.5°≤ β_2 ≤.26.5°.

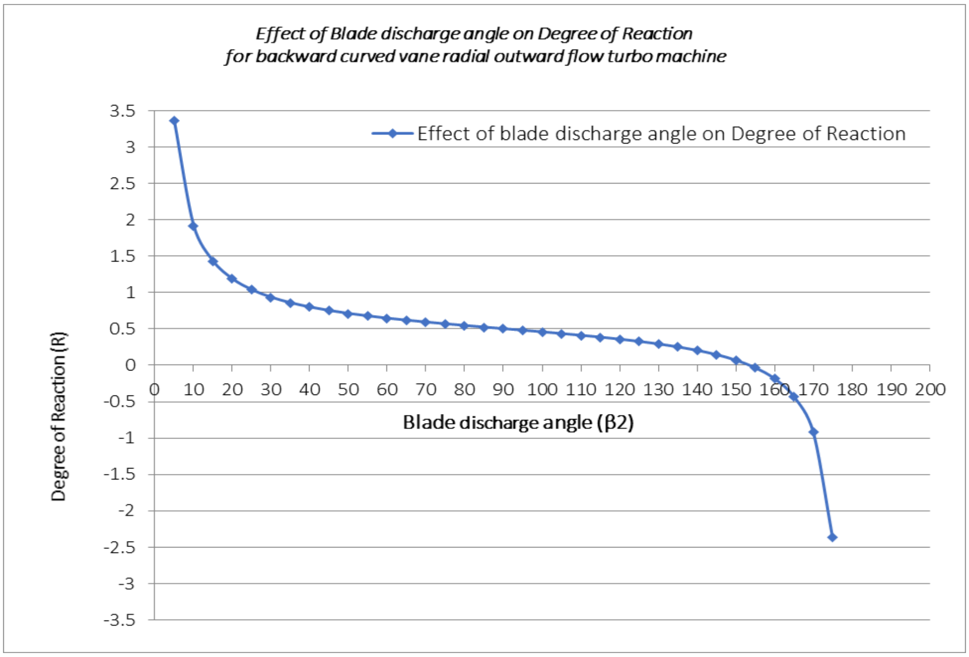

Fig 2.1:- Graph of degree of reaction (R) v/s blade discharge angle (β_2)

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3. RESULTS AND CONCLUSION

Figure 2.1 shows the curve of variation of degree of reaction for various values of discharge blade angle.

Discharge Blade angle (β_2)	**Degree of Reaction (R)**	**Remarks**
i)$\beta_2 < 26.5°$	Positive with greater than unity	Machine acts like turbine, reaction type.
ii)$\beta_2 = 26.5°$	1	Increase in static head due to centrifugal effect is counter balanced by decrease in static head due to increase in relative velocity.
iii)$\beta_2 = 90°$	0.5	Machine is 50% degree of reaction.
iv)$26.5° \leq \beta_2 \leq 153.5°$	$1 \geq R \leq 0$	Machine is power absorbing, reaction type.
v)$\beta_2 = 153.5°$	0	Machine is impulse type.

Table 3.1: - Results and Conclusion

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