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Design and Analysis of Centrifugal Pump for Backward Blades with CFD Simulation

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Abstract -- In this research paper describes the design and analysis of centrifugal pump for backward blades with CFD simulation. It is the frequently useful mechanical rot dynamic machine in dynamic works which widely used in domestic irrigation, industry, large plants and river water pumping system in our country. The centrifugal pump has two components, impeller (rotating part) and casing (stationary part). The head and flow rate of this pump are 6.096m and 0.00315 m^3/s and the motor speed is 2000 rpm. The result data of backward inclined centrifugal pump are shown in table. And then, detail graph of backward impeller with different inlet blades angles are described by using Matlab Program and CFD software

Indexed Terms: Backward, impeller, velocity, centrifugal pump, forward impeller

I. INTRODUCTION

The Brazilian soldier and historian of scientist, the first machine that could be characterized as a centrifugal pump was a lifting machine which appeared as early as 1475.A pump which rises water or liquid from a lower level to a higher level by centrifugal force is known as a centrifugal pump. Centrifugal force is defined as the action that causes something to move away from its center of rotation. In centrifugal pump, water enters axially through the impeller eyes and water exits radials. The pump casing is to guide the liquid to the impeller, converts into pressure the high velocity kinetic energy of the flow from the impeller discharge and leads liquid away of the energy having imparted to the liquid comes from the volute casing.

Impeller forces the liquid into a rotary motion by impelling action, and the under a higher pressure. The impeller is mounted on a shaft which is supported by bearings and driven through a flexible or rigid coupling by a driver. The casing has to be packed around the shaft to prevent external leakage. Closely fitted rings called wearing rings are mounted on the impeller and fitted in the casing to restrict leakage of high pressure liquid back to the pump suction.

Liquid is directed to the impeller eye by the suction nozzle and is brought into a circular motion by the impeller vanes. The impeller vanes and impeller side walls form the impeller channels. The centrifugal pumps are found in such services as steam power plants, water supply plants, oil refineries, chemical plants, steel mills, food processing factories etc.

II. CENTRIFUGAL PUMPS

centrifugal pump is a rotodynamic pump that uses a rotating impeller to increase the pressure and flow rate of a fluid. Centrifugal pumps are the most common types of pump used to move liquids through a piping system. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller flowing radials outward or axially into a diffuser or volute chamber, from where it exits into the downstream piping system. Centrifugal pumps are typically used for large discharge through smaller heads.

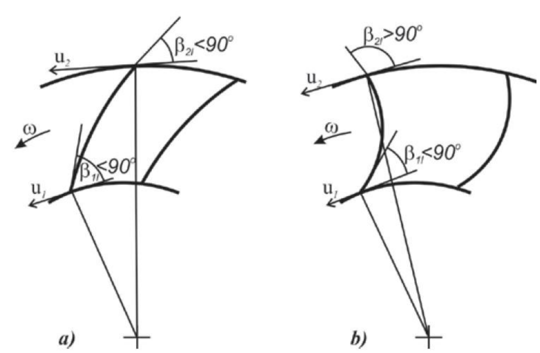

Fig.1. Centrifugal Fan Runner:

a) with backward-curved blades ($\beta_{2l}<90°$),
b) with forward-curved blades ($\beta_{2l}>90°$) [2]

Centrifugal pump runners with backward-curved blades (a) and forward-curved blades (b) are shown in Figure 1. Centrifugal pump impellers are always made with backward-curved blades, are manufactured centrifugal fans with forward-curved blades, and where these fans are applied.

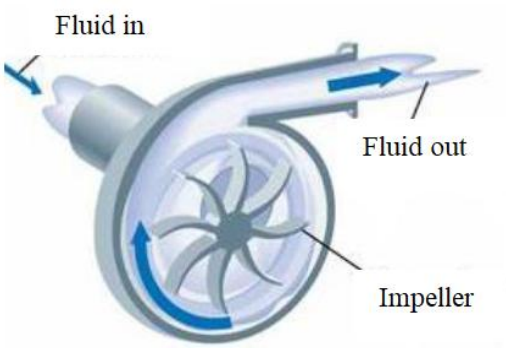

Fig. 2: Centrifugal pump [3]

Centrifugal pumps are widely used for irrigation and are most common where pumping from surface water supplies such as rivers, lakes and streams. Moreover, they are also used extensively in the chemical industry because of their suitability in practically any service and are mostly used in many applications such as water pumping project, domestic water raising, industrial waste water removal, raising water from tube wells to the fields.

The main component parts of a centrifugal pump are:

i. Impeller
ii. Casing
iii. Suction pipe
iv. Delivery pipe

III. BASIC PARAMETERSOF CENTRIFUGAL PUMP

A. Design of backward impeller centrifugal pump

In this paper, the impeller is designed on the basic of design flow rate, pump head and pump specific speed. So, the design data are required to design the centrifugal pump. For design calculation, the design parameters are taken as follows:

Head, H = 6.096 m
Flowrate, Q = 0.00315 m^3/s
Speed, n = 2000 rpm
density of water, ρ = 1000 kg/m^3
gravitational, g = 9.81m/s^2 acceleration

Specific speed:

$$n_s = 3.65n\frac{\sqrt{Q}}{(H)^{3/4}} \quad (1)$$

The water power is:

$$W_{hp} = \rho g H Q \quad (2)$$

The shaft power is:

$$Shaft\ power = \frac{Water\ power}{\eta_p} \quad (3)$$

Where,

η_p is pump efficiency

The maximum shaft power is:

$$N_{max} = \alpha_1 \frac{\rho g H Q}{\eta_p} \quad (4)$$

Where,

α_1 is safety factoring change condition of the work of pump.

The torsional moment is estimated by:

$$T = 9.75\frac{N_{max}}{n} \quad (5)$$

The shaft diameter at the hub section is:

$$d_s = \sqrt[3]{\frac{T}{0.2\tau}} \quad (6)$$

Where,

τ is allowable shear stress.

The hub diameter is usually 1.5 to 2 times of the shaft. So, the hub diameter is calculated by:

$$D_h = 2d_s \quad (7)$$

The hub length is twice of the shaft. Hub may be sometimes offset to suit conditions. The hub length is:

$$L_h = 2d_s \quad (8)$$

The impeller eye diameter is:

$$D_o = K_o\sqrt[3]{\frac{Q}{n}} \quad (9)$$

The inlet diameter of impeller is:

$$D_1 = 1.1K_o\sqrt[3]{\frac{Q}{n}} \quad (10)$$

where

K_o is the constant parameter which value is chosen as 4.5.

The outlet diameter of impeller is:

$$D_2 = 19.2\left(\frac{n_s}{100}\right)^{1/6}\sqrt{\frac{2gH}{n}} \quad (11)$$

The inlet width of the impeller is:

$$b_1 = \frac{R_o}{2} \quad (12)$$

The outlet width of the impeller is:

$$b_2 = 0.75\left(\frac{n_s}{100}\right)^{1/2}\sqrt[3]{\frac{Q}{n}} \quad (13)$$

The hydraulic efficiency is:

$$\eta_h = 1 - \frac{0.42}{(\log D_o - 0.172)^2} \quad (14)$$

The leakage head is:

$$H_y = H_T - \frac{V_2^2}{2g} - \frac{U_2^2}{2g}\left(1 - \frac{D_y^2}{D_2^2}\right) \quad (15)$$

Where,
H_T and D_y are the pressure head and seal diameter.

The pressure head is:

$$H_T = \frac{H}{\eta_o} \quad (16)$$

The seal diameter is:

$$D_y = D_o + 10 \quad (17)$$

The minimum clearance between the war ring and casing is:

$$\delta = 10^{-3} D_y \quad (18)$$

The leakage flowrate in the passage is:

$$Q_y = \mu\pi D_y \delta\sqrt{2gH_y} \quad (19)$$

The leakage flowrate in the pump is:

$$Q_k = Q + Q_y \quad (20)$$

The volumetric efficiency is:

$$\eta_v = \frac{Q}{Q_k} \quad (21)$$

The mechanical efficiency is assumed as 0.96.
The overall efficiency is calculated by:

$$\eta_o = \eta_v \times \eta_m \times \eta_h \quad (22)$$

The inlet and outlet velocity must be:

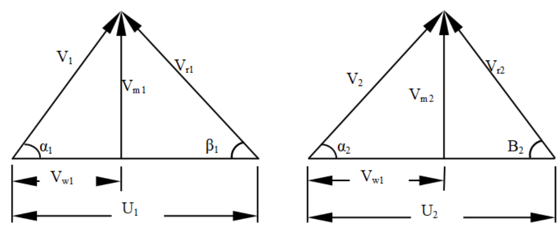

Fig. 3: Inlet and outlet velocity diagram [2]

The inlet velocity is:

$$U_1 = \frac{\pi D_1 n}{60} \quad (23)$$

The outlet velocity is:

$$U_2 = \frac{\pi D_2 n}{60} \quad (24)$$

The inlet flow velocity is:

$$V_{m_1} = \frac{Q_k}{\pi D_1 b_1} \quad (25)$$

The inlet blade angle is:

$$\tan\beta_1 = \frac{V_{m_1}}{U_1} \quad (26)$$

The outlet whirl velocity is:

$$V_{w_2} = \sigma U_2 \quad (27)$$

Where,
σ is the slip factor.

The outlet flow velocity is:

$$V_{m_2} = \frac{Q}{A_2} \quad (28)$$

The outlet blade angle is:

$$tan\beta_2 = \frac{V_{m_2}}{U_2 - V_{w_2}} \quad (29)$$

The number of impeller blades is:

$$Z = 6.5\frac{D_2 + D_1}{D_2 - D_1} sin\frac{\beta_1 + \beta_2}{2} \quad (30)$$

The require parameters to draw the impeller blade are calculated by the following equations:
The radius of the impeller at outlet is:

$$R_A = \frac{D_2}{2} \quad (31)$$

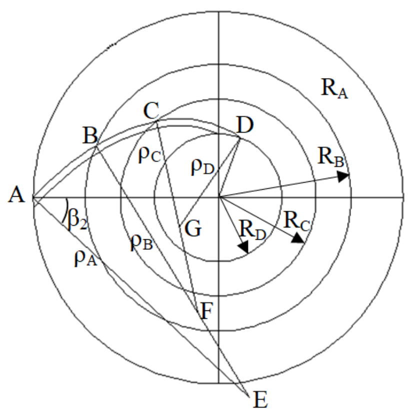

Fig.4: Drawing of backward impeller blade

The value of the radius R_B is assumed as 38 mm which is taken slightly than the radius R_A.

The value of the radius R_C is assumed as 28 mm which is taken slightly than the radius R_B.

Required parameter to layout the impeller blade is:

$$\rho_A = \frac{(R_A^2 - R_B^2)/2}{R_A cos\beta_2 - R_B cos\beta_1} \quad (32)$$

IV. RESULTS OF THE BACKWARD IMPELLER BLADE

The calculated results of the backward impeller are shown in Table I. After that, detail graph of backward impeller with different inlet blades angles by using Matlab Program and CFD simulation are shown in Fig. 5, 6, 7, 8 and 9.

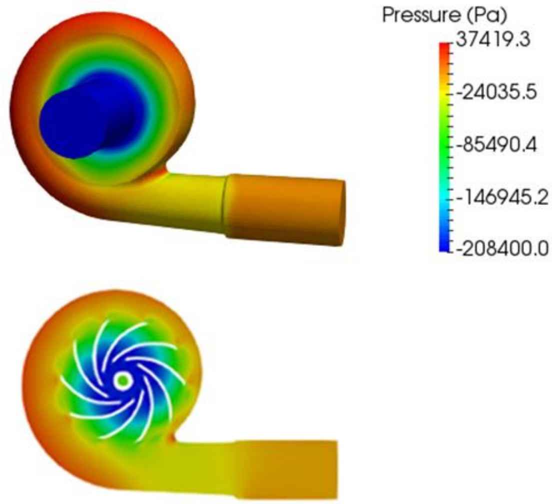

Fig.5. Pressure Effect on the Impeller

A. Flow Parameters

Number of Blades = 11
K-Omega SST Turbulence Model
Steady-State, Incompressible Flow
Multi-Reference-Frame (MRF) Method
Impeller Rotational Velocity = 2000 rpm
Inlet Volumetric Flow Rate = 11.34(m^3/hr)
Volute Casing Outlet Face — Pressure Outlet (0 Gauge Pressure)

B. Pressure contours

The pressure contour results show that the maximum pressure difference (208.4 kPa) between the pump inlet and outlet occurs in the pump with blade outlet angle of 42 degrees and the least at 13 degrees (116.6 kPa), and the pump outlet is set as pressure outlet with fixed value, 0 gauge pressure boundary condition.

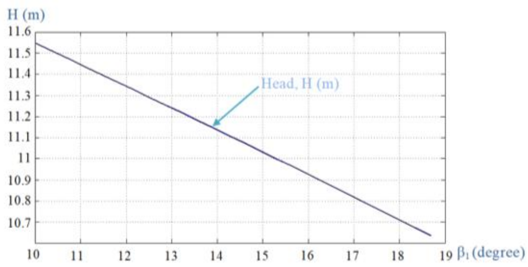

Fig.6 Inlet blade angle versus theoretical head

TABLE I. calculated results of backward impellers

Name	**Symbols**	**Backward Blade**	**Units**
Flow rate	Q	0.00315	m^3/s
Specific Speed	n_s	105.61	RPM
Water Power	WHP	188.376	W
Shaft Power	-	390	W
Shaft Torque	T	2.083	Nm
Shaft Diameter	d_s	7.52	m
Inlet Diameter	D_1	57.6	mm
Outside Diameter	D_2	105.6	mm
Inlet Velocity	U_1	6.032	m/s
Inlet Width	b_1	13	m
Inlet Absolute Velocity	V_{m1}	1.37	m/s
Outlet Absolute Velocity	V_{m2}	1.018	m/s
Outlet Whirl Velocity	V_{w2}	9.981	m/s
Eye Velocity	V_o	20.79	m/s
Efficiency	η_o	77%	-
Inlet Angle	β_1	12.8	Degree
Outlet Angle	β_2	42.6	Degree
Outside Diameter	D_2	13.5	mm
Impeller Width	b_2	42.6	mm
Number of Vanes	Z	10	-

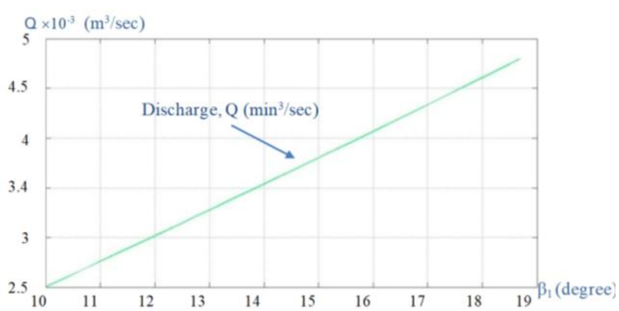

Fig.7 Inlet blade angle versus discharge (Q)

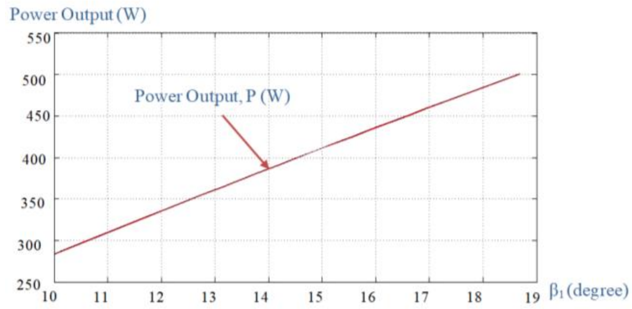

Fig.8 Inlet blade angle versus power output (W)

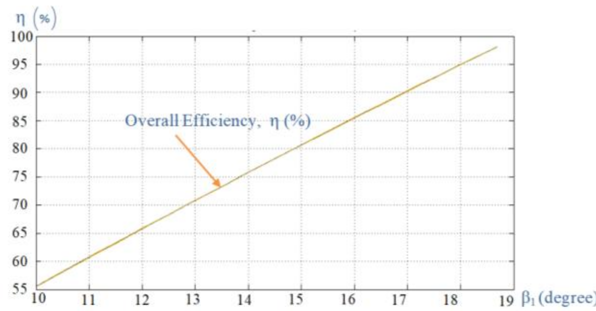

Fig.9 Inlet blade angle versus overall efficiency (%)

V. CONCLUSION

In this research paper, the design head is 6.096 m and the discharge is 0.00315 m^3/s. The pump can run at 2000 rpm. The impeller inlet is 57.6 mm and outlet diameter is 105.9 mm. The inlet blade angle for backward impeller has 12.8˚and the outlet blade angle has 42.6˚. The impeller thickness is 2 mm to layout the impeller blade. The pump efficiency is 77% in this design. The inlet blade angle for forward has 12.8˚ and outlet blade angle of impeller has 95˚. And also draw the figure of discharge, head, power and efficiency with different inlet blade angles with Matlab Program.

REFERENCES

[1] Chen-Kang Huang, Mu-En Hsieh, 2009. "Performance analysis and optimized design of backward curved airfoil centrifugal blowers", HVAC & Research, 15: 461-488.

[2] Choon-Man Jang, Jong-Sung Lee and Sang-Ho Yang, 2013. "Performance Evaluation of a Centrifugal Blower Using Optimal Design Method", Journal of Mechanisms,

Transmissions and Automation in Design, 30(3): 44.

[3] Fowlkes, W.Y., C.M. Creveling, 1995. “Engineering methods for robust product design, Using Taguchi Methods in technology and product development”, Addison-Wesley Publishing Company.

[4] JieJina Ying Fan, Wei Han, Jiaxin Hu, 2012. “Design and Analysis on Hydraulic Model of The Ultra - low Specific-speed Centrifugal Pump”, International Conference on Advances in Computational Modeling and Simulation, 31: 110-114.

[5] Li Chunx, Wang Song Ling and JiaYakui, 2009. “The performance of a centrifugal fan with enlarged impeller”, Journal of Sound and Vibration, 4(8): 87.

[6] Shojaeefard, M.H., M. Tahani, M.B. Ehghaghi, M.A. Fallahian, M. Beglari, 2012. “Numerical study of the effects of some geometric characteristics of a centrifugal pump impeller that pumps a viscous fluid”, Computers & Fluids, 60: 61-70.