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Design Validation of Hub Stream Pump Impeller using Computational Fluid Dynamics

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Abstract: The Technology used in Pumps is a proved, applications and usage are universal. Hub stream pump is a machine designed to convert mechanical vitality into fluid energy by rotational motion of an impeller. The axial flow pump (Low Head and High Flow) is chosen because it is widely used in Power Transformers for cooling Purpose (Recirculation oil in closed loop). The reason for this paper is to compute the plan computation of hub stream pump impeller which can deliver Fluid vitality by lifting activity of the pump impeller blades. In this paper, the flow rate and head of hub stream flow pump are 0.0 3m^3/sec and 2.5 Mts. The rotation speed is 1500 rpm. The paper, especially involves the design calculation of propeller type impeller running in a Suction casing of the pump. The result data of impeller are outlet diameter is 152 mm, the hub diameter is 98.8mm. The number of blades is five. The clearance between impeller and pipe or casing is 0.152mm. The designed hub stream flow pump satisfies the requirements of Power Transformer.

Keywords: *Axial Flow Pump, Blade Design, Fluid Flows, Impeller, Number of Blades, Rotational Speed.*

1. Introduction

Hub stream flow pumps are commonly used when there is a low head and high flow rate requirement. The Axial flow pump consists of a propeller-type of impeller with Different No of Vanes running in a casing driven by electric motor. The impeller is mounted on a common shaft which is supported by bearings and driven by electric motor. The pump includes the electric Motor and pump shaft with impeller covered by suction and delivery casings together to prevent external leakage. The advantage of a hub stream pump is its compact construction. The flow area is the same at Suction and Delivery. Axial flow pump generation of head is influenced by rotational moment of the rotating wheel called impeller. It has most noteworthy the explicit specific speed, low head, low rpm and large flow capacities.

Typically, the absolute velocities of the fluid in a hub stream pump are quite low. Typical velocities for a pump have 477 specific speed. The Velocity Triangle approach is a popular tool for turbo machine pump design for the past decades. In this, Paper utilizes the Voznesenski mean camber line profile design approach using circulation. With the input of flow rate, head requirement, other parameters like vane velocity, tip and hub radius, twist angle, stagger angle blade profile at different radius can be determined.

Discharge from the hub stream machine is moderately smooth and consistent during typical activity. Hub stream pumps can be mounted vertically, evenly, or at different angles to discharge the fluid. This Particular hub stream pumps are available that can handle Insulating oils.

2. Specification Data

Axial Flow Pump with the following specifications requirements to be designed:

Capacity, Q = 0.03 m^3/Sec

Pump Head, H = 2.5 m

Rotational Speed, N = 1500 rpm

Density of Transformer oil, ρ = 896.3 kg/m^3

Acceleration due to gravity, g = 9.81m/s^2

3. Methodology

In Design specifications requirements to be calculate:

Specific Speed $N_s = \frac{3.65.N\sqrt{Q}}{(H)^{0.75}}$ (1)

Hub Ratio $D_d = 26.8X(N_s) - 0.603$ (2)

Hub ratio can also be obtained from cordier diagram

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No of Blades (Z) can be Decide Depend on Specific Speed (Ns) Versus Hub ratio (D_d).

Specific Speed(RPM) N_s	400	600	800	1000	1200
Impeller Hub Ratio (D_d)	0.6	0.55	0.50	0.45	0.40
No of vanes (Z)	6	5	4	3	2

Table 1. No of Blades Selection

Calculating the Impeller Diameter (D):

$$\text{Flow Velocity } V_Z = (0.07)X\ {}_3\sqrt{QXN}^2 \qquad (3)$$

$$D = 2X\sqrt{\frac{Q}{\pi X V_Z X(1-D_d^2)}} \qquad (4)$$

(or)

$$D = 4.3\sqrt{\frac{1}{(1-D_d^2)}}X_3\sqrt{\frac{Q}{(N)}} \qquad (5)$$

Diameter of impeller can be optimized depend on pipe Diameter.

Calculating Hub Dia $D_{h=}D_d X D_{opt}$ (6)

Calculating the Radius at various Sections:

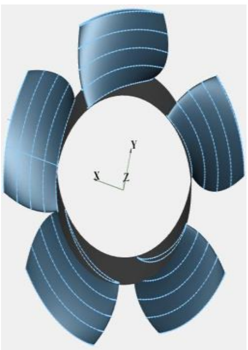
$$r_{1=}(D_h)/2 + (0.02)D_{opt} \qquad (7)$$

$$r_{5=}D_{opt}/(\ 0.02)D_{opt} \qquad (8)$$

$$r_3 = (r_1 + r_5)/2 \qquad (9)$$

$$r_2 = (r_1 + r_3)/2 \qquad (10)$$

$$\mathbf{r_4 = (r_3 + r_5)/2} \qquad (11)$$



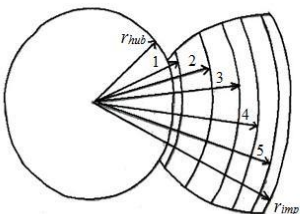


Fig 1. Axial flow pump impeller FIG 2. Impeller Radius

Details /Section	I	II	III	IV	V
Radius in mm r	52.4	57.6	62.7	67.8	72.9
Flow Velocity (V_Z) inm/s $(0.07)X\ {}_3\sqrt{QXN}^2$	2.85				
Peripheral Velocity in m/s $\mu = \frac{\pi DN}{60}$	8.24	9.04	9.85	10.6	11.4
Inlet Vane Angle in deg $\beta_1 =$ Arc tan $(\frac{V_Z}{\mu})$	19.1	17.4	16.1	14.9	13.9
Absolute Velocity in m/s $\mu_2 = \frac{g\ H}{n_h \mu}$	3.72	3.39	3.11	2.88	2.67
outlet Vane angle in deg $\beta_2 = \text{Arc tan}\ (\frac{V_Z}{\mu - \mu_2}$	32.2	26.7	22.9	20.1	17.9
Vane Curvature in deg $\Delta\boldsymbol{\beta} = \beta_2 - \beta_1$	13.18	9.26	6.79	5.15	4.01
Head Coefficient $K_H = \frac{H}{(\frac{N}{60})^2\ X\ D^2}$	0.038	0.035	0.032	0.029	0.027
Solidity l/t for β_2 & $\Delta\boldsymbol{\beta}$⋆ from Howell Chart	1.0	0.566	0.50	0.50	0.50
Solidity (l/t)Peri for Papir chart Or $5.95K_H$	0.226	0.208	0.190	0.172	0.160
Vane Spacing (Pitch) in mm $t = 2\pi r/Z$	65.89	72.34	78.79	85.30	91.68
Chord length in mm l = (l/t)X t in mm	65.89	40.94	39.39	42.65	45.84
To=t/l (or) 1/(l/t)	1	1.766	2.0	2.0	2.0
Circulation Speed per blade in m²/s $\Gamma_1 = \frac{60Xg\times H}{NXZX\eta_{hyd}}$	0.245	0.245	0.245	0.245	0.245
Total Circulation in m²/s $\Gamma = ZX\Gamma_1$	1.225	1.225	1.225	1.225	1.225
Av Velocity of Tangential Comp of Relative	6.376	7.748	8.292	9.216	10.12

Velocity in m/s $W_{u\,ave} = u - [\frac{\mu_2}{2}]$					
Av Value of velocity Vane Angle in deg β_{ave} (ά) $= \arctan\left(\frac{V_Z}{W_{u\,ave}}\right)$	24.08	20.20	18.97	17.18	15.72
Average Value of relative Velocity in m/S $W_{ave} = \frac{W_{u\,ave}}{\cos\beta ave}$	6.98	7.819	8.768	9.646	10.51
Δα in deg $\arctan\left(\frac{w_{ave}}{(180/\pi)(\mu}\right)$	1.545	1.383	1.302	1.240	1.195
α in deg =άX Δα	37.20	27.94	24.70	21.30	18.78

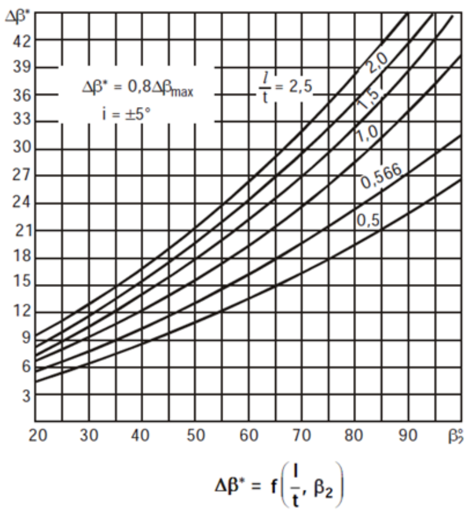


Fig 3. Howell Chart for l/t estimation Tables

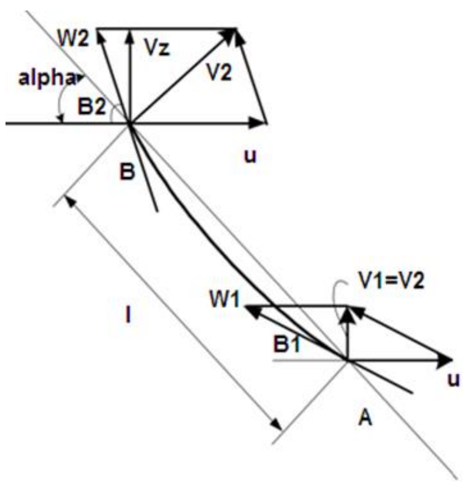


Fig 4. impeller inlet and outlet velocity

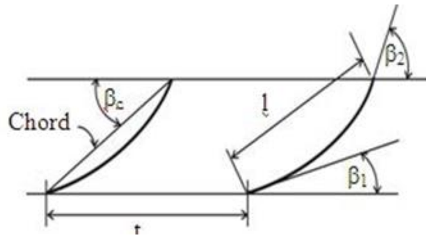


Fig 5. Vane Spacing,Chord,(α=$\boldsymbol{\beta}_c$)

4.Results and Discussions

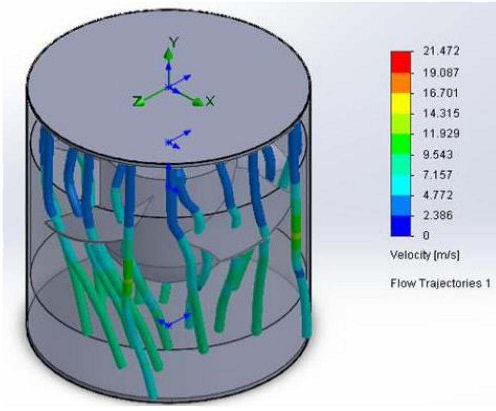


Fig 6. Flow Trajectories

(Velocity Distribution) of impeller

Flow simulation for the input data is done by using solid works software. The calculated value of flow velocity is almost the same with numerical research value.

Design calculations also match with CF Turbo Calculations and Modeling.

Leading edge and Trailing edge Parameters also Matches with Design Calculations.

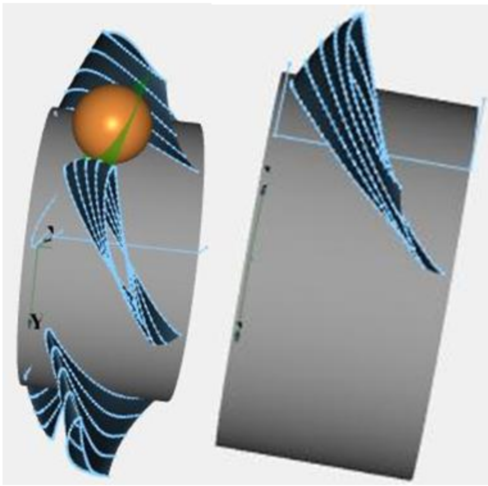


Fig 7. CF Turbo Models Vane Passage

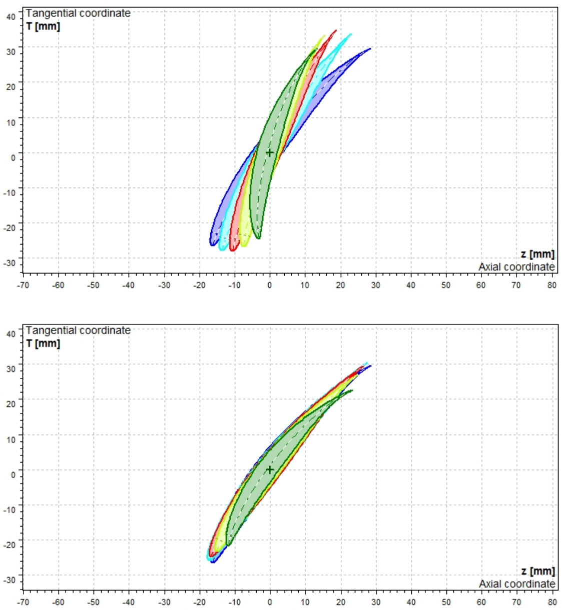


Fig 8. Vane Tangential Coordinates

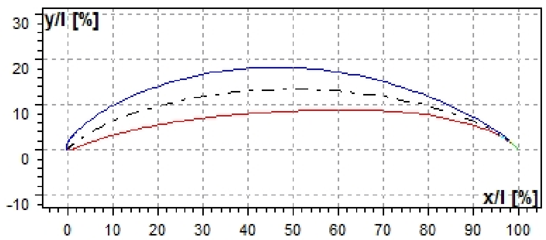


Fig 9. NACA Profile of Vane

	NACA 65-00 Profiles		
xl %	6(yd/l%)	8(yd/l%)	10(yd/l%)
0	0	0	0
0.005	0.004632	0.006176	0.00772
0.0075	0.005592	0.007456	0.00932
0.0125	0.007014	0.009352	0.01169
0.025	0.009444	0.01259	0.01574
0.05	0.01306	0.01742	0.02177
0.075	0.01588	0.02118	0.02647
0.1	0.01824	0.02432	0.0304
0.15	0.022	0.02933	0.03666
0.2	0.02486	0.03314	0.04143
0.25	0.02702	0.03602	0.04503
0.3	0.02856	0.03808	0.0476
0.35	0.02954	0.03939	0.04924
0.4	0.02998	0.03997	0.04996
0.45	0.02978	0.0397	0.04963
0.5	0.02887	0.0385	0.04812
0.55	0.02718	0.03624	0.0453
0.6	0.02488	0.03317	0.04146
0.65	0.02209	0.02946	0.03682
0.7	0.01894	0.02525	0.03156
0.75	0.0155	0.02067	0.02584
0.8	0.01192	0.0159	0.01987
0.85	0.00831	0.01108	0.01385
0.9	0.00486	0.00648	0.0081
0.95	0.001836	0.002448	0.00306
1	0	0	0

5. Conclusions

In This Paper is attempted to design axial flow pump impeller outer diameter and hub diameter, vane angles at different sections and no of vanes.

The Vane was divided into 5 sections from hub to outer diameter of impeller. The results of various vane entrance and discharge angles and curvatures at various sections of profile were described with velocity triangles. And designed parameters were validated with CF Turbo.

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