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Conceptual Framework of Centrifugal Pumps towards Industrial Revolution

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Abstract-In recent years, researchers have put a considerable effort to increase the efficiency in a centrifugal pump .The current scenariointhe impeller design interest has considerably increased in recent years in various publication, statingthe pump efficiency, pump performance, impeller design, modification the vane angle through CFD analysis has consideration to elaborate the conceptual frame work of a centrifugal pumps.

Key words- Centrifugal pumps, CFD, Efficiency, Failure analysis, Impeller design, Numerical analysis, Optimization

Introduction-S.C.M. Yu(2000) Investigated the flow patterns within the impeller passages of a centrifugal blood pump of which different types of blade geometry have been tested including the radial straight blade and backward swept blade designs. Both designs can achieve a head of about 100 mm Hg at the design point **Jong-Soo Choi(2005)** experimented large-scale flow instabilities in a pump rotor and the process of noise generation on the unsteady flow field and mechanism of a centrifugal turbomachine has been performed.The jet-wake flow pattern found in the impeller blade passages induces a strong vorticity field near the trailing edge of each blade.The rotating discharge instability in the impeller discharge is very similar in its behavior to the phenomenon known as rotating stall found in centrifugal impellers and diffusers. The surface pressure spectrum measured at the trailing edge of each blade revealed a cluster of peaks, which were identified with integer mode numbers. **Ismaier (2009)** proposed Centrifugal pumps generate in piping systems noticeable pressure pulsations of which the dynamic interaction between water hammer and pressure pulsations was presented. Different measurements at this testing facility show that pulsating centrifugal pumps can damp pressure surges generated by fast valve closing.Centrifugal pumps generate especially in part load and at high pump speed noticeable pressure pulsations.

These pressure pulsations can interact with pressure waves caused for example by fast valve closing **AhNemdlh.Dieter-Heinz Hellmann(1999)** stated the application of a centrifugal pump for desalination and power plants, and the energy usage and the maintenance costs during the operation of the pump was reduced .**Daniel Wolfram(2010)**observed that low circumferential Mach number the sound of isolated centrifugal fan impellers was dominated by distinctive tones at blade passing frequency (BPF) and integer multiples. This led to the preliminary conclusion that the BPF related tones are exclusively flow-induced. Based on hot-wire and blade pressure fluctuation measurements and a subsequent correlation analysis, coherent flow structures different from those associated with the principal azimuthal flow pattern due to the blades were detected. More likely the vortex structure detected here is related to the draft tube vortex found in water turbines or in the intake of pumps. **PunitSingh (2010)**concluded that a methodological approach has to be employed for using the optimization routine in field projects and to collect accurate operational data. **R.Barrio (2011)** experienced a significant radial load when operating at off-design conditions. Its average magnitude can be reasonably estimated at the design stage by existing formulas.The total radial load on the impeller of centrifugal pumps under different operating conditions can be reasonably estimated by means of the numerical simulation of the unsteady flow with an appropriate CFD code. It was observed that the maximum amplitudeof the unsteady torque can reach a magnitude of about 45% of theaverage value when operating at the lower flow rates). **Ramazanbavindir (2011)** explained the design of water pumping control system in the production plants and implemented an experimental setup in a laboratory. These plants contain harsh environments in which chemicals, vibrations or moving parts exist that could potentially damage the cabling or wires that are part of the control system.The proposed architecture and results demonstrate the feasibility of using IWLAN protocols to communicate effectively with PLCs. The system was tested using an industrial application and it had a very satisfactory performance. **R. Spence(2009)** proposed numerical model

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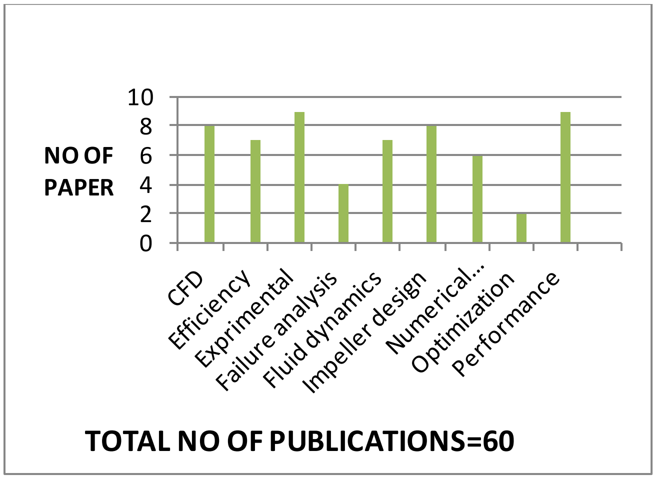
of an entire double entry, double volute centrifuge pump to conduct a parametric study covering four main geometric parameters.

Conceptual investigation



CFD Analysis

A.D Gosman(1998)CFD codes to effectively harness the power of the new generation in parallel computers[19]. **A. Lucius(2010)** et al calculate rotating stall in a pump for part load conditions. Which is a state of the art eddy viscosity model[50]. **K.K. Singh(2007)** et al simulated continuous flow pump-mixer employing top shrouded Rushton turbines with trapezoidal blades. Which concluded that CFD simulations can closely predict the single-phase head and power characteristics of pump-mixer. An insight has been provided into the pumping action of the impeller[12]. **R. Spence(2009)** et al studied double volute centrifugal pump to conduct a parametric study four main geometric parameters[1]. **Wei Zhang(2010)** et all analyzed of transportation equation of turbulence fluctuant velocity in the rotating frame intrinsic mean spin tensor is instead of mean vorticity tensor. Considering the transportation of fluctuation velocity and Reynolds stress [9]. presented advancement numerical solvers, physics modeling, user interfaces, CAE integration and computer hardware.

Governing equations

Katharine H(2011)et all the Navier–Stokes equations using CFD fluent , where ρ is the fluid density, it is the velocitycomponent in solved the xidirection (i=1,2), p is the pressure, τij is the stress tensor, and repeated indices were equated as

$$\frac{\partial ui}{\partial xi} = 0$$

$$\rho\left[\left(\frac{\partial ui}{\partial t}\right) + \frac{\partial}{\partial xj(uiuj)}\right] = -\frac{\partial p}{\partial xi} + \partial\tau ij/\partial xj$$

These are solved using a commercial CFD package Fluent 4[10]

Pump efficiency

Khin Cho Thin (2008) et al determine the power efficiency required to shaft using
The hydraulic efficiencies where

$$\eta_r=1-\frac{0.42}{(\log D0-0.172)^2}\textbf{[54]}$$

E. M. Kraeva(2010)compared the density for the magnitude power consumption of pump due to the [52]

$$N = \frac{Kp\rho NnomV^{0.05}}{(Kp\ nom\ \rho nom\ Vnom)^{0.05}}$$

the pump efficiency determined was changes of fluid viscosity with the normal parameters

$$\eta=\frac{\boldsymbol{\rho Nnom}\eta\mathrm{nomKp}}{\boldsymbol{\rho nomN}}$$

Antonio de la Torre(2008)define the difference between total absolute pressure in the pump suction flange and the vapour pressure of the pumped liquid based is onset of cavitation, head drat 0% to 3% and formulated cavitation criteria NPSHRvalues can be defined as follows:[21]

pump performance

The performanceflows a significant role in order to plot the efficiency curve in order to compare the theoretical and experimental calculating considering various losses **J.P. Boylan(1998)**innovated solar pump system using a modular centrifugal pump with variable speed and number of activated stages (DSP) has been proposed [34]. . **Khin Cho Thin (2008)** et al showedlooses of centrifugal pump with the valuesQ and H determine various operating points. Centrifugal pumps are fluid-kinetic machines designed for power increase within a rotating impeller Somelooses of centrifugal pump with the values Q and H are determined for the various operating points. [54]. **P. Thanapandi and Rama Prasad(1995)** studied to theoretical and experimental on the transient characteristics of a centrifugal pump during starting and stopping periods. Which experiments were conducted on a volute pump for normal starting and stopping transients for two cases. Dynamic characteristics of the pump during the operating transients have been studied and the nature of change of parameters during transients was conducted [11]. **Wen-GuangLi(2000)**tested centrifugal pump performances using water and viscous oil as working fluids of which centrifugal pump's performance goes down when the pump handles high viscosity working fluid. The flow patterns near the impeller outlet are less affected by the viscosity of the fluids in best efficiency and part loading points, but the flow patterns near the impeller inlet are greatly affected by the viscosity's.[20]. **TahsinEngin(2006)** et al designed to three centrifugal fan impellers made of ceramic materials Experiments have been conducted on a specifically designed test facility allowing that gases with temperatures up to 1050 ºC. The effect of impeller geometry, shaft speed, gas temperature, and the tip clearance on the overall performance of the tested impellers have been investigated [55].

N. Tauveron, I. Dor(2010) investigated various technologies centrifugal circulators with a vane less diffuser when have significant properties in term of simplicity, cost, ability to operate over a wide range of conditions (according to general consideration and historical development and choices)[42]. **N. Tauveron, I. Dor(2010)**experimented and simulated results of internal and external characteristics at steady operation from shutoff condition to design condition, DES and sliding mesh were used to explore the transient characteristic of the process when valve was rapidly opened [48].

Theoretical Head:

N. Tauveron, I. Dor(2010) subjected in the Euler head is determined from zero to maximum theoretically attainable flow using.[54]

The theoretical head: Hth = 1/gU2Vu2 (27)

whereU2and Vu2 are outlet tangential velocity and whirl velocity. Whirl velocity: Vu2 = U2 – Vm2 cotβ2 (28)whereVm2andβ2 are outlet flow velocity and outlet blade angle.

Net Theoretical Head

If the slip factor is known, the net theoretical head may be obtained from Euler's head. It is possible to relate thetheoretical characteristic obtained from Euler's equation to theactual characteristic for various losses responsible for thedifference. The use of the slip factor which varies with flow rate enables the net theoretical head curve to obtained. Atflow rates below design flow rate, separation occurs on thesuction side of the blade.

The net theoretical head is calculated by:

$$\mathrm{Hthn} = \frac{\mathrm{U2Vu2}}{\mathrm{g}}$$

The whirl velocity at the outlet is;

Vu2 = U2σ – Vm2 cotβ2 (30)

where, σ is the slip value. Slip value is obtained by using the following equation Specific speed is used to classify impellers on the basis of their performance, and proportions regardless of their actual size or the speed at which they operate.[54]

Specific Speed: $n_s=3.65n\sqrt{Q}/H^{0.25}$

Experimental

M. J. Tummers(1997) et al measured the mean velocities, Reynolds stresses, and triple-velocity correlations were measured in an adverse pressure gradient wake, using LDA[57]. Ramazanbavindir(2011) explained water pumping control system that is designed for production plants and implemented in an experimental setup in a laboratory. These plants contain harsh environments in which chemicals, vibrations or moving parts exist that could potentially damage the cabling or wires that are part of the control system[6]. **F. JiménezEspadafor(2000)** et al analysed the failure mode of the six impellers of a centrifugal pump in an irrigation system used for street washing for the results show a very high level of torsional vibrations induced by severe pulsations of engine torque.

Daniel Wolfram(2010) et al detected the draft tube vortex found in water turbines based an flow indused[25]. **Daniele Fiaschi(2005)** et al subjected to an innovative solar pumping system using a modular centrifugal pump with variable speed and number of activated stages (DSP) has been proposed and discussed Centrifugal Pump, SCP) [35]. **Chi Nan Pai(2010)** et almeasured the pulsatile flow rate through a maglev CBP during ventricular assistance and developed a disturbance force observer to estimate the radial thrust[41]. **N.R. Sakthivel(2010)** et al deal with the vibration based fault diagnosis an mono block centrifugal pump through six classical statement viz., normal, bearing fault, impeller fault, seal fault, impeller and bearing fault together, cavitation [51].

Failure analysis

OM PRAKASH(1996)et al explained an eight-stage feed pump in a urea-manufacturing plant started showing a high overall vibration level. Chemical examination of impeller material did not show any serious irregularity regarding its chemical composition where as metallographic examination confirmed that the impellers were not subjected to proper heat treatment and formed that high level of vibration was due to the imbalance caused as a result of the breakage of the impellers [28]. **G Das(1999)** et al subjected to an analysed the premature failure of two counter shafts used in centrifugal pumps for lifting slurry thus Chemical analysis, microstructural characterization, fact graph, hardness measurement, tensile and Charpy impact tests were used for the analysis where shafts "consisting of ferrite-pearlite for A and tempered bainite for B were made of EN13 steel The materials did not show significant inclusions or segregation but Shaft B improper heat treatment resulted in low values of strength

[27]. **F. Berndt(2001)** et al contributed towards pump failures indicating the effect of pump performance[60].

Fluid dynamics

B. Baudouy(1998) et al studied the hydraulic characteristics of a variable speed liquid helium centrifugal pump in He I near saturated conditions (4.2 K and 100 kPa) are presented.We have the hydraulic performances of three pump housings, for a simple housing and two inducer housings in He I. The use of an inducer avoids the precipitous decrease in the pressure head at low mass flow rate as exhibited by a simple housing pump [31]. **A. Ismaier(2009)** et al determined the Centrifugal pumps generate in piping systems noticeable pressure pulsations. Thus the dynamic interaction between water hammer and pressure pulsations for which different measurements at this testing facility show that pulsating centrifugal pumps can damp pressure surges generated by fast valve closing. [30]. **Wu Dazhuan(2010)** et al experimental and simulated results of internal and external characteristics at steady operation from shutoff condition to design condition, DES and silding mesh were used to explore the transient characteristic of the process when valve was rapidly opened. [48]. **Jorge Parrondo (2011)**et al subjected to Conventional centrifugal pumps with volute casing generating fluid-dynamic noise particularly at the so-called blade-passing frequency, which is attributed to the interaction of the flow exiting the pump impeller with the volute tongue. **R.Barrio(2011)** et al explained the impeller of a centrifugal pump significant radial load when operating at off-design conditions. Its average magnitude can be reasonably estimated at the design stage by existing formulas.The total radial load on the impeller of centrifugal pumps under different operating conditions can be reasonably estimated by means of the numerical simulation of the unsteady flow with an appropriate CFD code[22].

Impeller design

John S. Anagnostopoulos(2009) calculated a numerical methodology of the flow field in a centrifugal pump impeller and predicted of the pump performance curves and developed, regulated, and tested against experimental and statistical data, with encouraging results using Navier– Stokes equations in three dimensions [2]. **AndrzejMisiewicz(2011)** et al showed the influence of large angles of the inlet of impeller on the pump cavitation performance. [53]. **Hongmin Li(2010)** presented a thermal fluid analysis on the air cooling of a permanent magnet electric motor with a centrifugal impeller. Heat transfer analysis on the armature surface shows that the armature body has a flat temperature distribution in the radial direction[15]. **Mario Savar(2009)** et al proposed the method for pump impeller trimming found good experimental confirmation despite some theoretical constraints. Dimensional head-discharge diagrams show a high coincidence when presented in non-dimensional form. The experimental results for a range of seven examined impeller diameters are presented by a single curve with a high head correlation coefficient R2=0.9895[33]. **PunitSingh, Franz Nestmann(2011)** et al developed a subjected to the theoretical model specifically for the PAT optimization study under the background of some assumptions was very useful in isolating the important internal hydraulic variables[36]. **S.C.M. Yu(2000)** et al focused on the flow patterns within the impeller passages of a centrifugal blood pump. Four different types of blade geometry have been tested including the radial straight blade and backward swept blade designs. Both designs can achieve a head of about 100 mm Hg at the design point [44].

Numerical Analysis

M.A.Langthjem (2004) et a relined discrete vortex method for simulation of the flowwith a centrifugal pump is the one of the simplest methods capable of capturing the essential features of this kind of rotational flow. concerned with the simulation of the flow in a flat, 'two-dimensional' laboratory centrifugal pump. [4]. **LI Yao-jun, WANG Fu-jun (2007**) predicted the three-dimensional turbulent flows generated by an axial-flow pump equipped with an inducer simulated using the multiple reference frame approach. The effects of angular alignment of inducer and impeller blades and the axial gap between inducer and impeller have been examined [40]. **RaúlBarrio(2010)** et al simulated numerically unsteady flow (URANS + kepsilon model) with an appropriate CFD code has proven to be a good methodology to investigate the dynamic characteristics of the flow in the near-tongue region of a vane less centrifugal pump [39]. **A. Rossetti et al (2010)**experimented and numerical analyzed two miniature two stage pumps with an overall dimension of 10mm where the innovative design integrated a bladed first stage with a bladeless second stage. The Rotary Shaft Pump design, which integrates the impeller in the shaft, was used as first stage for which the second stage was designed as bladeless centrifugal disk pump [3]. **Amy l. Throckmorton(2010)** et al states Currently available mechanical circulatory support systems are limited for adolescent and adult patients with a Font an physiology. The performance evaluation using CFD, theexperimental testing of a pump prototype, and bloodbag testing in this study indicated an acceptable design from which to build upon and optimize [59]. **Bao-ling Cui(2011)** et al based Navier-Stokes equations and the Spalart-Allmarasturbulence model, three dimensional turbulent flow fields in centrifugal pump with long-mid-short blade complex impeller for calculating and numericallyanalysing. [58]. **Optimization**

M.M.A. Shahin(1990) et al calculated to the optimization technics for centrifugal pump staling

- Slient features of micro computer program
- Data information
- Parametric characteristics
- Relation and interaction of curvature
- Cost estimation

PunitSingh(2010) et al advised for a methodological approaching in order to attend greater accurate [7].

Performance

P. Thanapandi and Rama Prasad(1995) studied to a theoretical and experimental on the transient characteristics of a centrifugal pump during starting and stopping periods. Experiments have been conducted on a volute pump for normal starting and stopping transients for two cases through dynamic characteristics of the pump during the operating transients [11]

Conclusion

The survey very clearly indicates that researchers have shown considerable efforts on centrifugal pumps based on its performance characteristics and efficiency determination, very few papers were published on cfd analysis on pumps and there is no consistent papers on scada applications in pump theory,consider amount of effort has to be made on abrasive slurries, the requirement of longer life and reliability have to be balanced by the constrain of high initial cost and efficiency.

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