The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2022

Volume 17, Pages 136-151

ICRETS 2022: International Conference on Research in Engineering, Technology, and Science

Centrifugal Pump Design: An Optimization

Van Thanh Tien NGUYEN
Industrial University of Ho Chi Minh City

Thi Minh Nhut VO
Thu Dau Mot University

Abstract: A centrifugal pump is an efficient piece of machinery that is often used in the activities of our everyday lives as well as the production of industrial goods. Due to the ever-increasing demands of our contemporary lifestyle, the process of designing a pump is becoming more authoritarian and demanding. In order to assist designers in overcoming these limits, an optimization algorithm would be suggested. This algorithm would help designers use optimum design methodologies and reduce risk throughout the manufacturing stage. ANSYS's Computational Fluid Dynamics (CFD) tool was used to develop numerical models for simulation. These models were created using ANSYS. For the purpose of the multi-objective optimization design, the simulation's best-chosen model was taken into consideration. This algorithm was used throughout the process of designing the ideal solution. Several design models were created by selecting characteristics such as the size of the pump volute casing section, the tongue's length, and the tongue's angle. The findings demonstrate that the provided strategy is viable for resolving the issue with the optimal design. These findings have the potential to serve as an encouraging reference for companies that manufacture centrifugal pumps, as well as researchers who are interested in applying their invention and development to the pump design sector in the future.

Keywords: Centrifugal pump, Optimal design, Volute casing tongue, Intelligent algorithms for design

Introduction

It is safe to say that centrifugal pumps are integral to any system designed to regulate the built environment. Little has changed in the underlying physics and mechanics of pumps in the previous century. However, in recent years, the technology for using pumps has significantly advanced. Pumps are a popular area of focus in projects because of the potential for considerable energy savings that may be uncovered via field inspection and testing of pumps' performance, which is typically underutilized. Energy can be saved by adjusting pump flow rates closer to the load requirements or doing away with redundant pressure drops. Below is an illustration of how decisions made during the design process might affect the building's operation for decades. Centrifugal pumps (Abdolahnejad et al., 2022; Bamberger et al., 2020; Bellary et al., 2016)are essential gear in water treatment plants since they are the ones in charge of transferring water from one section of the plant to another. Therefore, the readers may make the most educated choice regarding the design of their pumping system (Elkholy & Fathy, 2016; Esmaeilian et al., 2019; Jegha et al., 2020). Besides, the authors determined to examine this study's various kinds of pumps and their associated efficiencies. Pumps are devices that transport something from one location to another by directing a flow of fluid via a pipe in order to do so.

A pump may be used for a variety of uses, including the circulation of fluids (Liu et al., 2013; Shim et al., 2018), such as water, oil, gas, and others. Many pump designs are available (Bamberger et al., 2020; Shim et al., 2016). Still, they all have one crucial characteristic: they are highly effective devices that can transfer a large volume of fluid in a short amount of time. The centrifugal pump is among the most efficient (Capurso et al.,

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

2022; Parikh et al., 2022). The circular motion of this sort of pump is used to generate a force that either propels or retracts items as they are moving through a fluid. Centrifugal pumps are used to move a lot of liquids and gases about, but they are beneficial for transporting liquids since they are able to do it swiftly and quietly. Centrifugal pumps are used to move a lot of liquids and gases around. The inability of centrifugal pumps to effectively move solids is one of the drawbacks of using these types of pumps. This is because they do not have sufficient torque to push solid items through the fluid, and as a result, they often need additional equipment to move materials such as earth or boulders. However, despite their drawbacks, centrifugal pumps remain one of the most effective types of pumps that can be purchased. They are an excellent choice for applications that require the rapid transport of liquids or gases.

A pump with its motor is referred to as a tubular pump. Because the tubular pump's input and outlet channels run in parallel, it may be used for emergency mine drainage, water lifting for large-scale water conservation projects, and water supply for tall structures. Because of the intricate nature of the pump's internal flow arrangement, its efficiency (Capurso et al., 2022; Derakhshan & Bashiri, 2018; Derakhshan et al., 2013; Latifi et al., 2021; Lu et al., 2021; Mitrovic et al., 2021)is often poor. The issue of energy consumption (Derakhshan & Bashiri, 2018; Wu et al., 2022; Yildiz & Vrugt, 2019)is gaining more attention due to the fast expansion of the economy and the ongoing rise in the world's population. At this time, the global community is working on a solution to the issue of an inadequate supply of energy (Elkholy & Fathy, 2016; Wu et al., 2022; Zeidan & Ostfeld, 2022; Zhang et al., 2021); excessive use of energy will always result in problems with the environment. The objective of reaching the global carbon peak requires the implementation of many essential strategies, including energy saving and emission reduction. Pumps, which are considered to be multi-purpose pieces of equipment, find widespread use in a variety of economic-related disciplines. According to the available data, the percentage of the world's total power consumption (Yildiz & Vrugt, 2019)that is accounted for by the pumps' electricity is around twenty percent. Therefore, increasing the pump's efficiency is of utmost importance if one wants to achieve energy savings, a decrease in consumption, and relief from energy shortages, due to the fact that they have a high flow pumping capacity. The research objectives of this study are diving tubular pumps. It is of considerable worth to find a strategy that can optimize its performance since there are times when emergency rescue operations need electricity that is in low supply (Wu et al., 2022; Zeidan & Ostfeld, 2022; Zhang et al., 2021).

The study of the creation of entropy that is presented in this article is used to examine the flow loss (Anagnostopoulos, 2009; Ghorani et al., 2020; Lu et al., 2021; Shim et al., 2016)of the first pump. This problem is done to identify the areas of the original pump (Wang et al., 2020; Wang et al., 2017; Wu et al., 2022). As a result, it is possible to disregard the vicious impact dissipation and entropy formation has on flow loss (Anagnostopoulos, 2009; Ghorani et al., 2020; Shim et al., 2016; Wu et al., 2022; Zhang et al., 2021)that diving tubular pumps experience. Production of entropy at the wall and the entropy of turbulent kinetic energy generation are two significant contributors to the flow loss that diving tubular pumps participate in. The ensuing investigation concentrates its primary attention primarily on wall entropy formation as well as turbulent kinetic energy entropy creation. The purpose of this kind of optimal design for pumps is to give an analysis of possible future applications or future research areas.

Efficiency, Head, And Output Power Theory

The Efficiency of the Centrifugal Pump

There are pump efficiency η = 65.5%, volume efficiency $\eta_v = 94\%$, hydraulic $\eta_h = 80\%$ and machinery efficiency $\eta_m = 83\%$

$$\eta = \frac{\rho g H Q}{T . \omega}$$

where is:
η: efficiency (%)
gH : specific energy of the centrifugal pump ($m^2 s^{-2}$)

ρ : fluid density (kg/m^3)
Q: flow rate (kg/s)
T: torque (Nm)

ω: angular velocity(rad/s)

$$Q_t = \frac{Q}{\eta_v} = \frac{1}{(60 \times 0.94)} = 0.018 m^3 / \sec$$

Head And Output Power of the Centrifugal Pump

$$H_{th} = \frac{H}{\eta_h} = \frac{33}{0.84} = 39.3m$$

P = T.ω
Specific speed

$$n_s = \frac{n\sqrt{Q}}{H^{3/4}} = \frac{1750\sqrt{1}}{33^{3/4}} = 127(m, m^3 / \min, rpm)$$
$$n_s^{'} = kn_s = 6.67 \times 127 = 847(ft, gpm, rpm)$$

Angular velocity

$$\omega = \frac{2\pi n}{60} = \frac{2\pi \times 1750}{60} = 183.16 rad / \sec$$

Pump shaft diameter

$$d = k\sqrt[3]{\frac{L_m}{n}} = 125\sqrt[3]{\frac{11}{1750}} = 23.1mm$$

k=125, d =38mm, $D_s = 35\ mm$

Impeller boss diameter

$$D_b = 1.4 d_s = 1.4 \times 35 = 50mm$$

Impeller inlet velocity

$$k_{mo} = 0.1 + 0.00023 n_s = 0.1 + 0.00023 \times 127 = 0.129$$
$$v_{mo} = k_{mo}\sqrt{2gH} = 0.129\sqrt{2 \times 9.8 \times 33} = 3.29 m / \sec$$

Empirical equation

$$v_{mo} = \frac{\sqrt[3]{Qn^2}}{60}$$
$$v_{mo} = \frac{\sqrt[3]{1 \times 1750^2}}{60} = 2.42 m / \sec$$

Impeller outlet velocity

$$D_s = \sqrt{\frac{4Q_t}{\pi v_{mo}} + D_b^2} = \sqrt{\frac{40 \times 0.018}{\pi(3.29 \sim 2.42)} + 0.05^2} = 0.097 \sim 0.109m$$

Choose

$D_s = 100\ mm$, Area at impeller outlet position

$$A = \frac{\pi}{4}(D_s^2 - D_b^2) = \frac{\pi}{4}(0.1^2 - 0.05^2) = 0.006m^2$$

$$v_{mo} = \frac{Q}{A} = \frac{0.018}{0.006} = 3m/\sec$$

Impeller discharge dimensionless

$$\psi = \frac{gH}{u_2^2}, \beta_e = 27^0, n_s = 127, \psi = 0.57$$

⇨ Select Ψ =0.52

where Ψ is Head coefficient, a dimensionless parameter; β_e is average outlet angle.
The necessary impeller peripheral velocity and the impeller outlet diameter were calculated from

$$u_2 = \sqrt{\frac{gH}{\psi}} = \sqrt{\frac{9.8 \times 33}{0.52}} = 24.9m/\sec$$

$$D_2 = \frac{60u_2}{\pi n} = \frac{60 \times 24.9}{\pi \times 1750} = 0.272$$

➔ $D_2 = 0.272\ m$

Impeller outlet width

$$H_{th} = a\frac{u_2^2}{g}\left\{h_0 - h_v \frac{v_{m2}}{u_2}(\cot\beta_e + \cot\alpha_1)\right\}$$

where is a = 0.95, $\alpha_1 = 90^0$, $u_2 = 24.9\ m/$sec, $\beta_e = 27^0$,

Busemann factor number is 7, $\beta_2 = 27^0, h_0 = 0.805, h_v = 1$

Thus,

$$39.3 = 0.95\frac{24.9^2}{9.8}\left\{0.805 - 1\frac{v_{m2}}{24.9}(\cot 27^0)\right\}$$

$$v'_{m2} = 1.918 m/\sec$$

$$t_2 = \frac{272\pi}{7} = 122mm,$$

$$\frac{t_2}{t_2 - s_2} = 1.1$$

$$\delta_2 = s_2 \sin\beta_2 = 11 \sin 27^0 = 5mm$$

The impeller outlet width was given by

$$b_2 = \frac{Q_t t_2}{(t_2 - s_2)(2\pi r_2 v'_{m2})} = \frac{0.018 \times 0.122}{(0.122 - 0.011)(2\pi 0.136 \times 1.918)} = 0.012m$$

Impeller profile

Table 1. Impeller profile of the designed pump

D(mm)	D×b(mm^2)	b (mm)	D (mm)	D×b(mm^2)	b (mm)
272	3264	12.00	160	2474	15.46
260	3179	12.23	140	2333	16.66
240	3038	12.66	120	2192	18.27
220	2897	13.17	100	2051	20.51
200	2756	13.78	80	1910	23.88
180	2615	14.53	75	1875	25.00

Methodology

Design Structures and Unstructured Models

The geometry model was designed following the parameters calculated above by using CATIA.

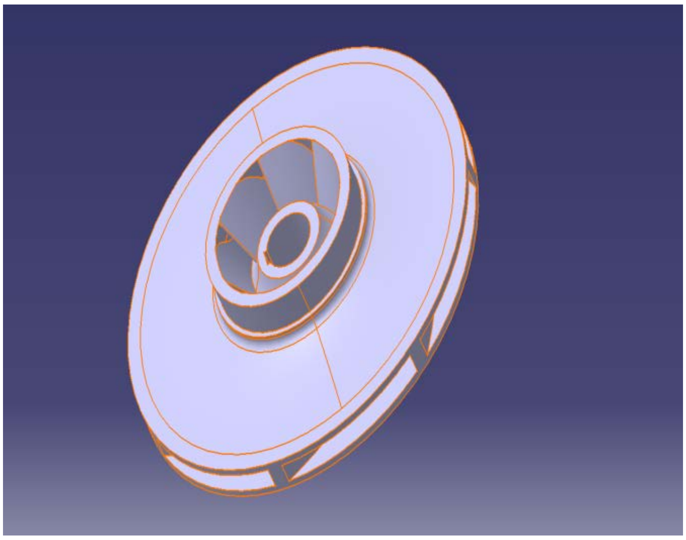

Figure 1. Designed impeller by using Catia

Figure 2. Unstructured designed volute by using Catia

Table 2. Boundary conditions

Specification	Option
Working fluid	water
Turbulence model	SST
Boundary condition	Inlet: total pressure Outlet: Mass flow
Interface type	Fluid-Fluid
Analysis type	Steady-state
Frame change/mixing model	Frozen Rotor and None
Residual target	10^{-5}

Numerical Methods

It looked at how "the solution of the three-dimensional incompressible Navier-Stokes" equation affects the pressure and flow fields via the impeller (Anagnostopoulos, 2009; Bellary et al., 2016; Derakhshan & Bashiri, 2018; Shim et al., 2016; Wang et al., 2017). İn addition, the disturbance is simulated using the standard k-model (Bamberger et al., 2020; Farokhzad et al, 2012). This equation's solution leads to the formation of the pressure and flow fields. The simulations are carried out with the help of the commercial CFD code (Benini & Cenzon, 2010; Capurso et al., 2022; Fracassi et al., 2022; Siddique et al., 2022)known as Fluent®, which has a history of successful use in the field of turbine engineering. The pressure-velocity coupling is carried out with the use of an algorithm (Anagnostopoulos, 2009; Bellary et al., 2016; Capurso et al., 2022; Derakhshan, Mohammadi, & Nourbakhsh, 2009; Derakhshan et al., 2013; Elkholy & Fathy, 2016)known as SIMPLE.

Quadratic wind arbitrary is used for convection and central difference for diffusion. There is only one slab in the computational domain (Bamberger et al., 2020). The logarithmic-based wall functions are used on all solid walls and periodic boundary conditions (Luan et al., 2016; Myrzakhmetov et al., 2020) are implemented. It is ensured that there will be no slip circumstances at any stable, stationary, or rotating surface and that there will be uniform inflow conditions as well as free-flow conditions at the inlet and outflow of the flow, respectively. The computational grid (Bamberger et al., 2020; Peng et al., 2022)is structured, and the Fluent preprocessor Gambit is the tool used to construct it. This is made possible by the fact that the domain as a whole is divided into multiple domains or subregions. The precision and the computing cost are considered. And an alphanumeric grid with around 4.5 million cells is deemed sufficient for the computations. Figure 2a depicts an image that suggests the mesh around the blade, and Figure 2b depicts a close-up view of the blade's leading edge. The algorithm (Abdolahnejad et al., 2022; Almasi et al., 2022; Bamberger et al., 2020; Bellary et al, 2016; Derakhshan et al., 2009)begins with a modest rotational speed and progressively increases it until it achieves its nominal speed of 3000 rpm. This is done for stability reasons. Box and Wilson presented the Reaction Surface Methodology (RSM) in 1951; it is a technique for estimating the combined effect of several independent variables that do not require the performance of factorial design experiments for all of the independent variables at each level. RSM (Liu et al., 2019; Meng et al., 2022)is a technique that can be found in the field of chemical engineering.

There are at least two different categories of variables that are being looked at, and an estimation of the functional relationship that exists between the response variables and the independent variables is being used to make a prediction about the variation that occurs in response to changes in the values of the independent variables. from data. An optimization procedure (Benini & Cenzon, 2010; Derakhshan & Bashiri, 2018; Fracassi et al., 2022)is used to determine the values of the independent variables for which the response should be optimized. This is based on the information provided above. Among the various kinds of reaction surfaces, experiments are the two-level factorial arrangement method and the three-level factor arrangement method, both of which are utilized when the estimation equation for the reaction surface is a first-order equation. Other types of reaction surface experiments include the factorial arrangement method. the design approach and the Box-Behnken method (Meng et al., 2014)are used in the estimation process. estimated is a quadratic, central composite. Within the scope of this investigation, an optimization strategy that makes use of central synthesis was implemented. Carrying out the job of impeller optimization (Abdolahnejad et al., 2022; Bamberger et al., 2020; Bellary et al., 2016; Derakhshan & Bashiri, 2018; Derakhshan et al., 2013; Ghadimi, Nejat, Nourbakhsh, & Naderi, 2019) was studied. The goal value and the column of the pump were set to 33 meters. And the efficiency was set to the utmost value possible while considering the significant margin and the loss because the pump being studied has a current that fits the intended specification. Figures 1-2 depict the unstructured models for the centrifugal pump which was employed for predicting the optimal propeller model that satisfies the selected target value. In this case, a numerical analysis is done on the optimization model, and the performance of the optimized model is compared with the performance of the basic model, as shown in Figures 1-2 and Tables 1-2; this allows for an accurate evaluation of the performance of the propeller optimization model. The performance result value for this propeller-optimized model is raised by around 0.5 meters compared to the standard model, but the efficiency is decreased by about 0.1 percent. When beta two is raised to meet the goal value for the head, as shown by the findings of the impact analysis of the design variable, it is expected that the efficiency would suffer a minor drop in order to accommodate the new value. On the other hand, the impeller optimization model (Abdolahnejad et al., 2022; Bellary et al., 2016; Fang et al., 2020; Ghorani et al., 2020) was created using specified response surface engineering since it was determined that this efficiency drop quite tinily and does not substantially impair the pump performance. is the most comprehensive model for the optimization of impellers.

Results and Discussion

The numerical model first determines the flow field in a 3000-rpm conventional impeller, and this impeller has regular-height blades with a single casing. Therefore, the nominal flow rate and other impeller properties follow the lab model pump, showing informative numbers. Figures 3-4 present the design variables of x_1 (variable angle) and x_2 (impeller-tongue gap, which is the gap between the impeller and the volute casing). Besides, Figure 5-6 shows the design variable ignored for the above variables mentioned in Figures 3-4. It could be seen how a leading-edge affects the intake radius. This study discusses non-twisted blade geometry. The impeller with a blade edge angle of 30^o has 11% poorer hydraulic efficiency but better BEP flow rates. In the context of this investigation, we try to construct the area of the cross-section. The Stepanoff hypothesis is used in the execution of horizontal arcs.

As a consequence of this, the rate of flow inside the chain was determined to be 12.5 meters per second, and the distribution of the cross-sectional area. The constant value used in calculating the internal flow rate of the voltage is practical, and it is impossible to identify which deal is the best one to use to compute the flow rate. This was explained before. Four more cross-sectional area distributions were picked on top of the cross-sectional area distributions computed using Stepanoff's theory as the center. In this case, the open duct connecting to the impeller output is 90 millimeters in width—additional considerations for the design. Final answer is x(0.0; -1.0)

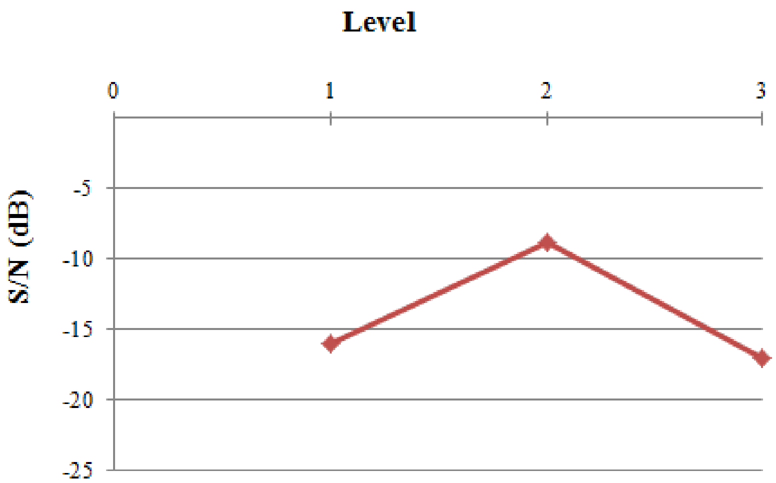

Figure 3. Design variable x_1

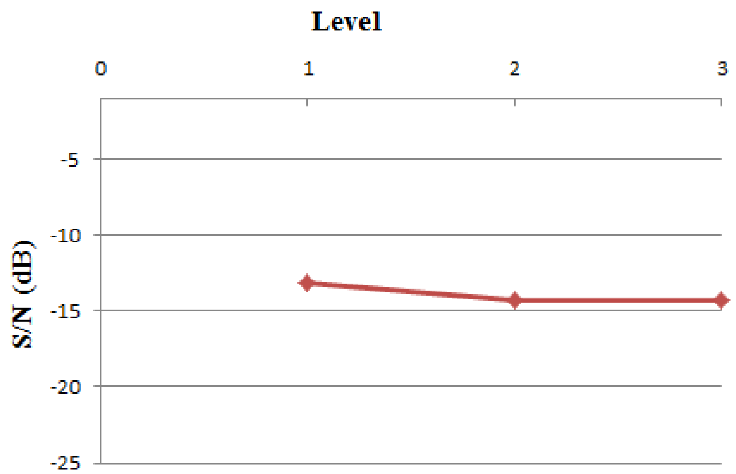

Figure 4. Design variable x_2

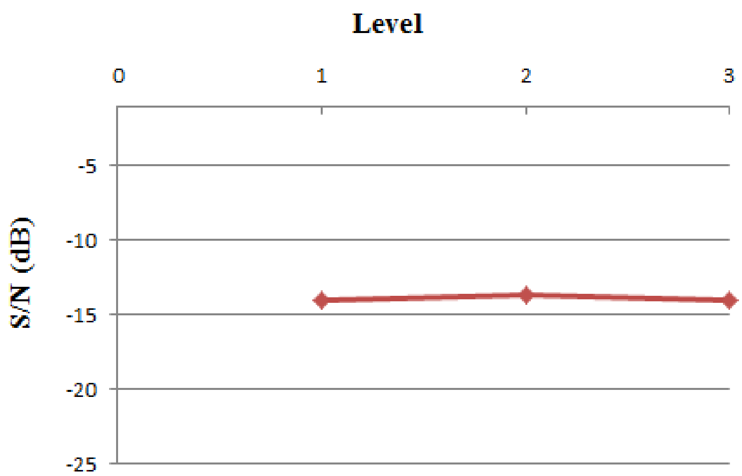

Figure 5. Design variable Ignored 1

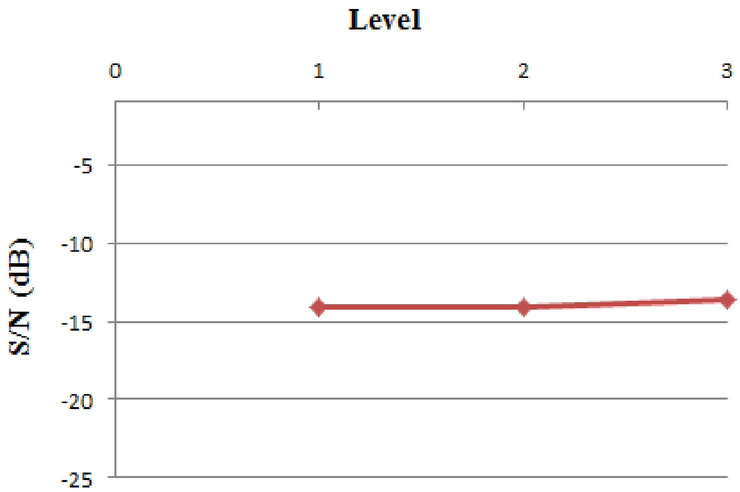

Figure 6. Design variable Ignored 2

From the results, it is easy to see that the optimum values of factors and their levels selected are x (0; 2.7) $x_1 = 0^0, x_2 = 2.7\ \%$. After optimization, the variable angle and impeller-tongue gap are $X_1 = 0^0$ $X_2 = 3.67\ mm$, respectively. These are the best parameters for centrifugal pump design, particularly volute tongue length.

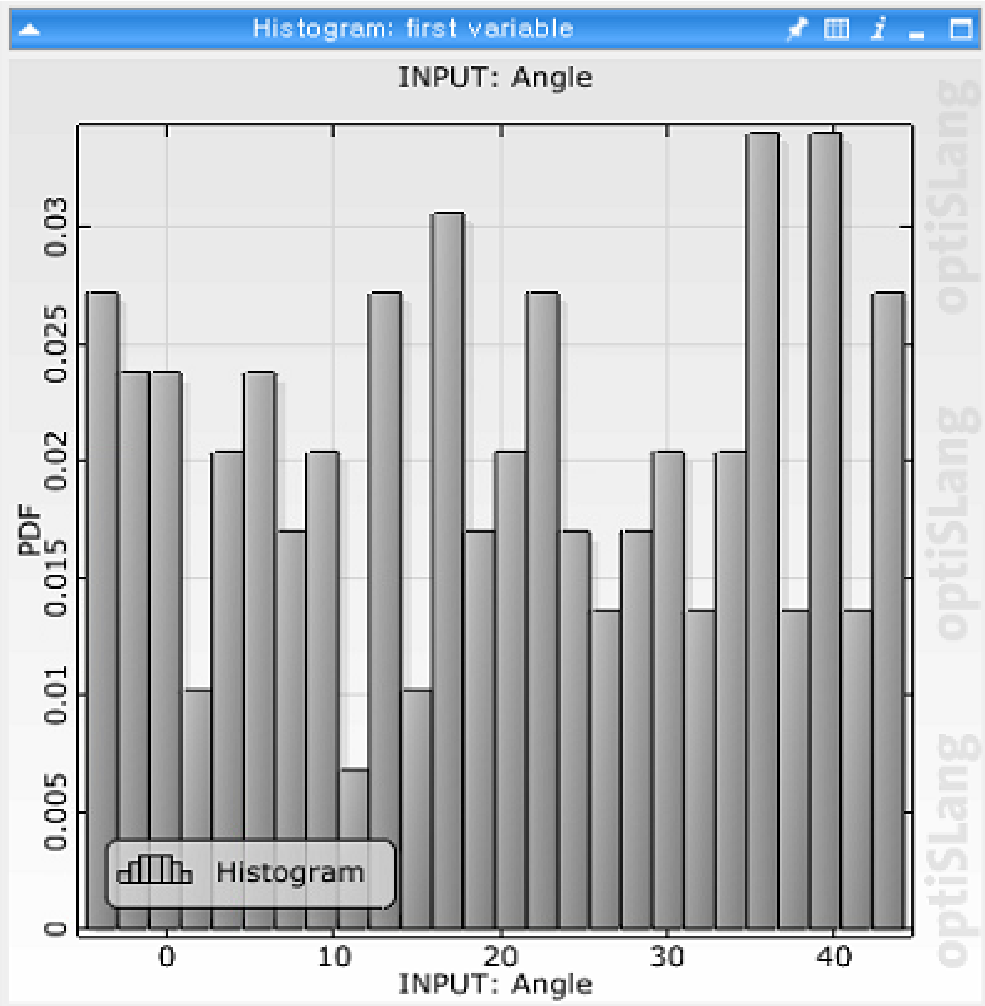

Figure 7. Histogram of first variable

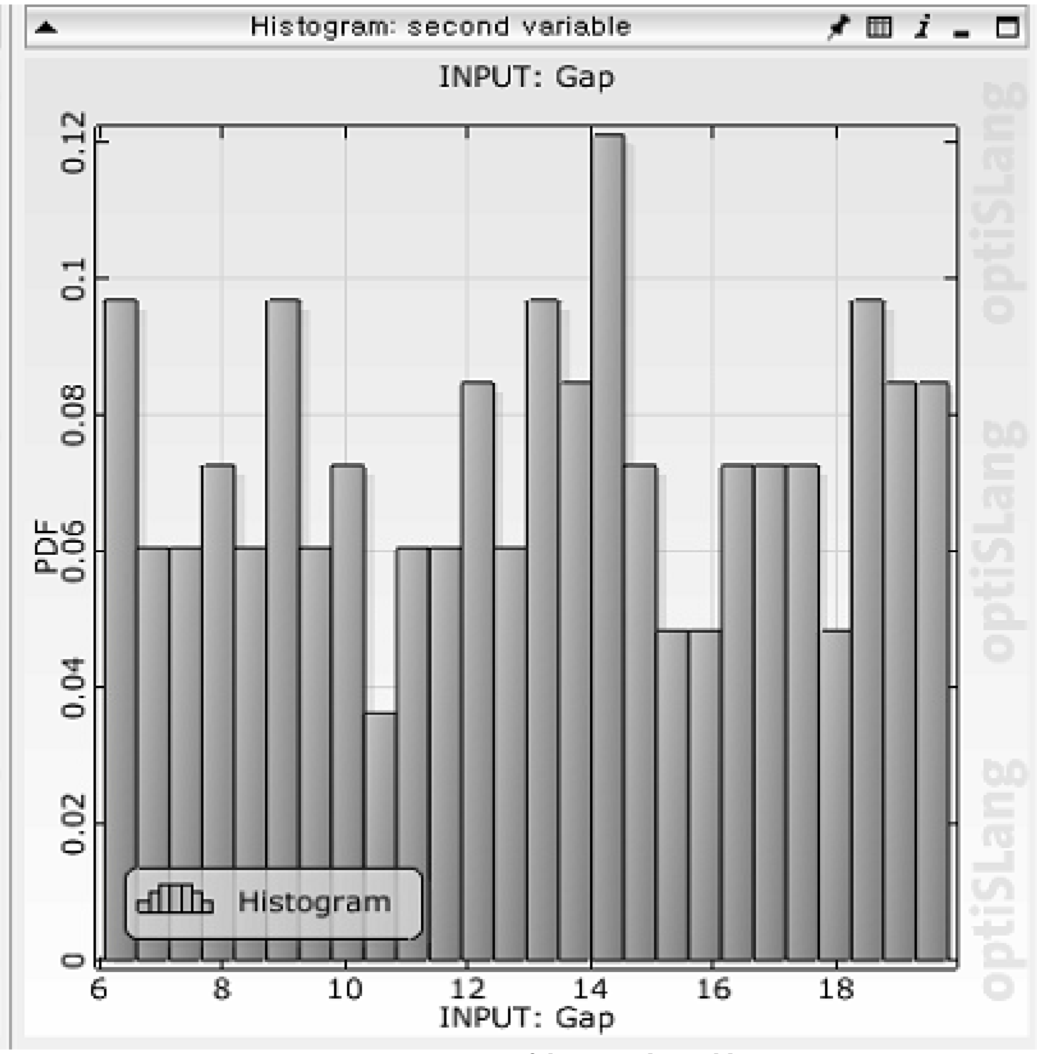

Figure 8. Histogram of the second variable

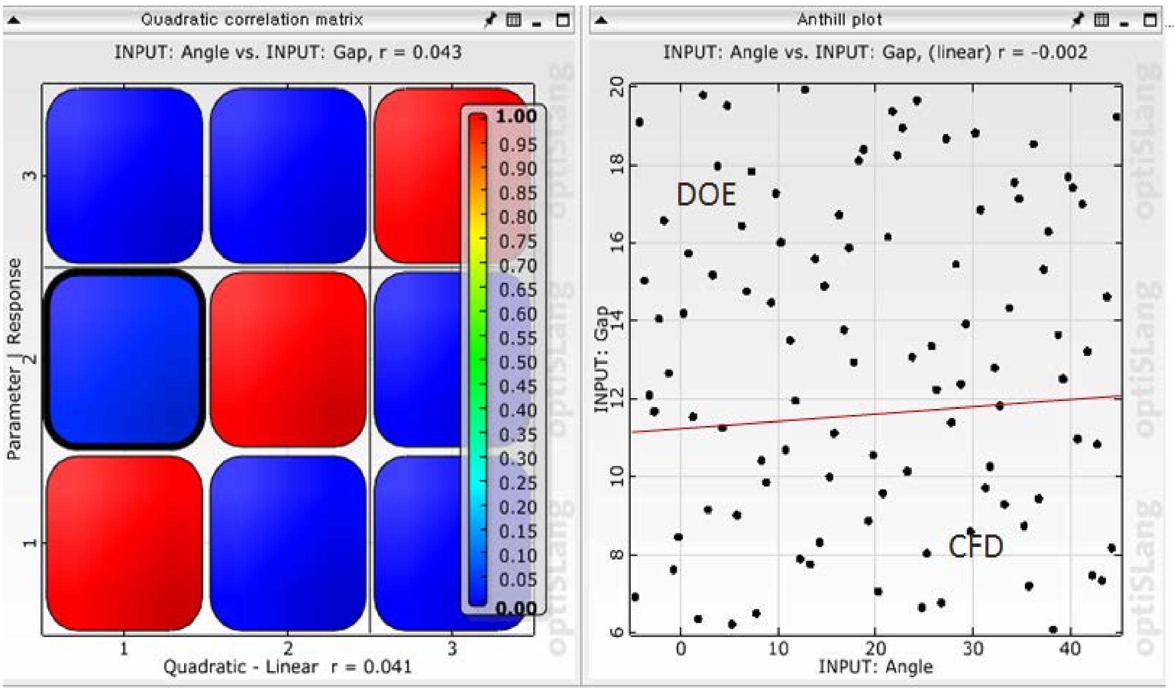

Figure 9. Quadratic correlation matrix

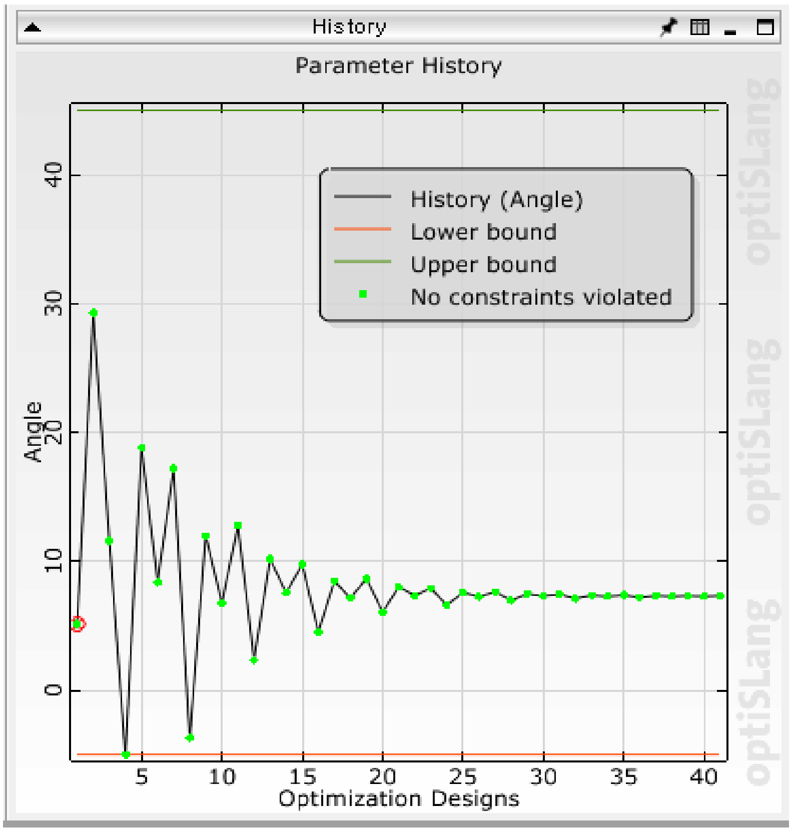

Figure 10. Parameter history

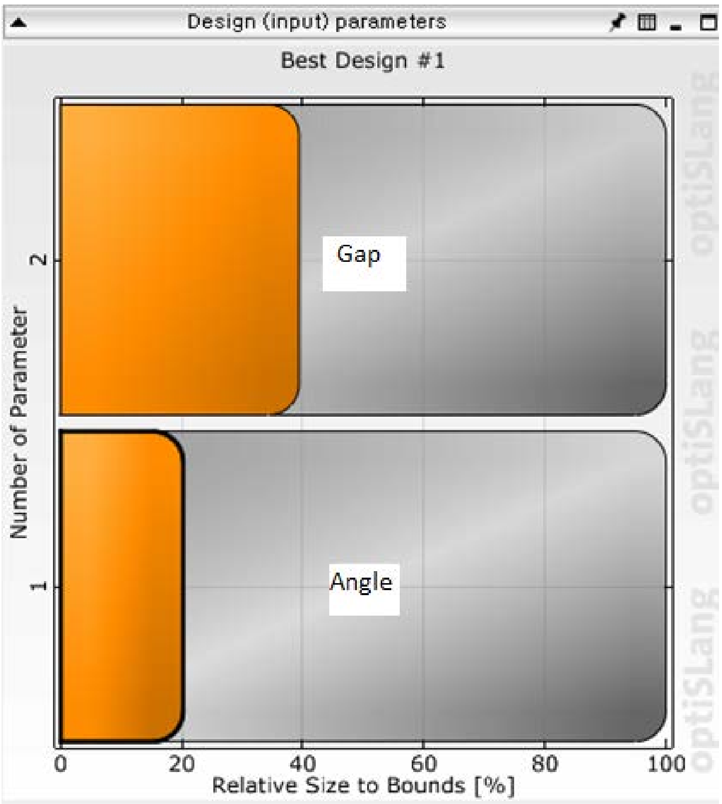

Figure 11. Design input parameters (Best Design #1)

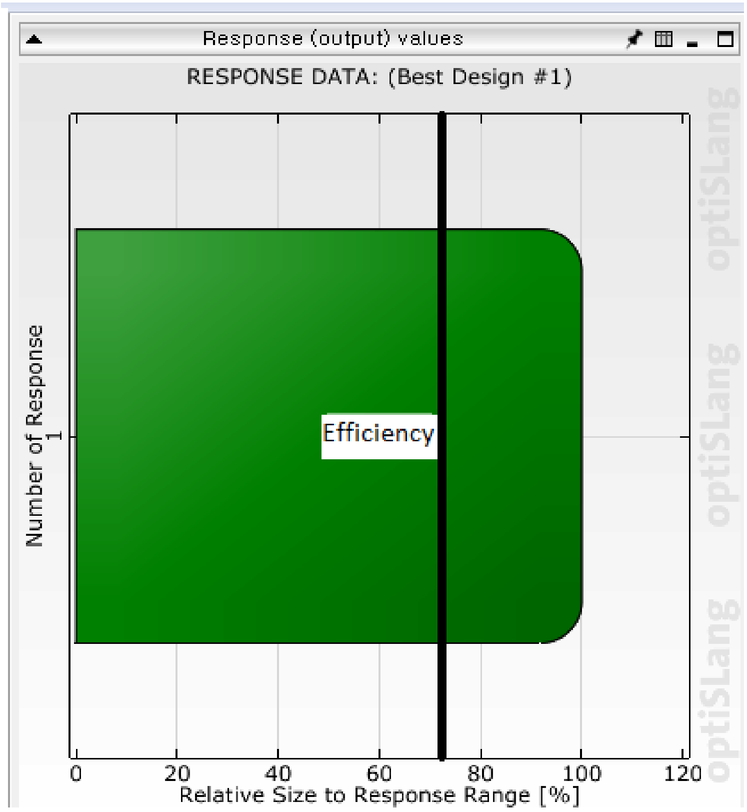

Figure 12. Response data (Best Design #1)

Optimal Design Stage

In order to discover the optimal blade form that maximizes, the two geometric parameters discussed before make up the free design variables. These geometric parameters may be adjusted within certain constraints. This research resulted in the presentation of a centrifugal pump design that was capable of meeting the desired parameters. In order to accomplish this objective, the propeller's optimum design work was carried out using response surface engineering and CFD. Additionally, a voltage matching proposal for optimally designed propellers was developed via the application of Stepanoff's theory. 1) Based on the study's findings that analyzed each variable's impact, it was discovered that the exit angle of the impeller has the most significant impact on the life force and the efficiency of the impeller. 2) The response surface method calculates the propeller optimization model. The performance of the calculated optimization model was compared to the performance of the basic model. As a consequence of this comparison, the performance of the computed optimization model was slightly lowered (about 0.3 percent) to 98.2 percent, but the top of 64.5 m, approximately 2.5 m. Elevate to a level that will fulfill the goal value. As a consequence of this, the final propeller optimization model will be the target model that was chosen. 3) As a result of carrying out a performance assessment through numerical analysis and establishing each design voltage in the vane optimization model, it was determined that it should be built with the internal cross-sectional area distribution. When the chain model is used, it can be shown that the head is around 32 meters, and the efficiency is improved, demonstrating that the model produces the best results. As a result, the target curve model is provided as an alternate line design appropriate for the impeller optimization model. Figures 7-8 present the histograms of the first variable (x_1) and the second variable (x_2). The chart image shows that in variable 1, the concentration amplitude deviates to the right, tends to increase from low to high, and has an average value of about 0.018. Figure 8 shows that the highest values are concentrated in the center on the left and right sides (with an average value of 0.06). Figure 9 depicts the quadratic correlation matrix shown to be highly correlated in optimization with r=0.043. The red line divides the two experimental domains, DOE and the CFD simulation domain, and the selected experimental values are arranged fairly evenly in these two domains. Figure 10 shows the convergence history of parameters with lower bound, upper bound, and no constraints violated for the first variable. In this study, our preliminary results are drawn and presented in Figures 11-12. These two figures illustrate design input parameters (Best Design #1) and response data (Best Design #1). In this result, the optimal value is chosen for the designed pump at 74%. However, the optimization problem is to solve the problem by a trade-off. This result may not be very high, but it is consistent with the hypothesis.

Production Process Development

In developing the processes of production, based on the assumption of small and medium-sized organizations, three ideas were kept in mind, casting philosophical foundations, namely

✓ While the principles and language of design may be universal, their application in the redesign of goods cannot be. The miniaturized variant of a substantial marketable item

✓ The success or failure of a company cannot be attributed to the quality of its production system; nonetheless, a system that is insufficient or gives the wrong impression might prevent even the most promising enterprise from reaching its full potential.

✓ It is preferable to be roughly accurate in redesign procedures than precisely incorrect. In other words, the design was carried out to achieve target performance requirements (Head H and Discharge Q for a contemplated speed N)

Design for manufacturing and assembly was the approach taken in the design of this product. It includes considerations of manufacture and assembly during the design stage. Less time is needed to get the product to market, a smoother transition to the market, fewer parts in the final product, easier assembly, lower production costs, a better product, and happier customers. The resulting sized parts were then tested for assembly. With the tolerances specified, the designs were assembled using CATIA software to check if it was possible to create the product. The dimensions were adjusted to ensure a good design consistent with the design requirements for assembly. Moreover, material properties were also checked.

Conclusions

The current technique can readily manage more free design factors, and it is anticipated that integrating these variables would enhance the impeller design differently. Multi-objective optimization is also a possibility. Right now, it is planned to make an impeller that improves performance and efficiency while being built in a way that costs less. This study found that changing the shape of the volute tongue makes pumps work better. The velocity vector density and the vortex core region of case studies are lower than in previous designs. The smaller the gap between impeller and volute, the better the pump's performance. The impeller outlet blade angle strongly affects the pump performance; the pump performance was improved the most with $\beta_2=34^{o}$.

Initial research has yielded many exciting results. However, the results presented in this paper are subject to further examination and study in the future. The optimization just stopped at the initial development stage. We have many phases of research in-depth, and that will change, but results are uncertain when the empirical analysis is conducted. The limitations of this study are that the final results have not been finalized, the research time is limited, the equipment has not been manufactured and tested, and the funding for the research is relatively modest and self-sufficient. We will complete the CFD simulation steps in the following research direction and conduct careful optimization based on machine learning with optimization algorithms. Then we will collect the optimal result based on the initial design of the CFD data value. After choosing the best model, we will proceed to fabricate the centrifugal pump sample and bring it to the test. The pump manufacturer will verify the experimentally collected deals and suggest future improvements.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Acknowledgements or Notes

This article was presented as an oral presentation at the International Conference on Research in Engineering, Technology and Science (www.icrets.net) conference held in Baku/Azerbaijan on July 01-04, 2022.

References

Abdolahnejad, E., Moghimi, M., & Derakhshan, S. (2022). Optimization of the centrifugal slurry pump through the splitter blades position. *Proceedings of the Institution of Mechanical Engineers Part C-Journal of Mechanical Engineering Science, 236*(1), 191-207. doi:Artn 09544062211027608 10.1177/09544062211027608

Almasi, S., Ghorani, M. M., Haghighi, M. H. S., Mirghavami, S. M., & Riasi, A. (2022). Optimization of a vacuum cleaner fan suction and shaft power using Kriging surrogate model and MIGA. *Proceedings of the Institution of Mechanical Engineers Part a-Journal of Power and Energy, 236*(3), 519-537. doi:Artn 09576509211049613 10.1177/09576509211049613

Anagnostopoulos, J. S. (2009). A fast numerical method for flow analysis and blade design in centrifugal pump impellers. *Computers & Fluids, 38*(2), 284-289. doi:10.1016/j.compfluid.2008.02.010

Bamberger, K., Carolus, T., Belz, J., & Nelles, O. (2020). Development, Validation, and Application of an Optimization Scheme for Impellers of Centrifugal Fans Using Computational Fluid Dynamics-Trained Metamodels. *Journal of Turbomachinery-Transactions of the Asme, 142*(11). doi:Artn 111005 10.1115/1.4048022

Bellary, S. A. I., Adhav, R., Siddique, M. H., Chon, B. H., Kenyery, F., & Samad, A. (2016). Application of computational fluid dynamics and surrogate-coupled evolutionary computing to enhance centrifugal-pump performance. *Engineering Applications of Computational Fluid Mechanics, 10*(1), 172-182. doi:10.1080/19942060.2015.1128359

Bellary, S. A. I., Samad, A., Couckuyt, I., & Dhaene, T. (2016). A comparative study of kriging variants for the optimization of a turbomachinery system. *Engineering with Computers, 32*(1), 49-59. doi:10.1007/s00366-015-0398-x

Benini, E., & Cenzon, M. (2010). Development of a multi-objective optimization method for aerospace turbopump design. *International Journal of Turbo & Jet-Engines, 27*(3-4), 219-250.

Capurso, T., Bergamini, L., & Torresi, M. (2022). A new generation of centrifugal pumps for high conversion efficiency. *Energy Conversion and Management, 256*. doi:ARTN 115341 10.1016/j.enconman.2022.115341

Derakhshan, S., & Bashiri, M. (2018). Investigation of an efficient shape optimization procedure for centrifugal pump impeller using eagle strategy algorithm and ANN (case study: slurry flow). *Structural and Multidisciplinary Optimization, 58*(2), 459-473. doi:10.1007/s00158-018-1897-3

Derakhshan, S., Mohammadi, B., & Nourbakhsh, A. (2009). Efficiency Improvement of Centrifugal Reverse Pumps. *Journal of Fluids Engineering-Transactions of the Asme, 131*(2). doi:Artn 021103 10.1115/1.3059700

Derakhshan, S., Pourmahdavi, M., Abdolahnejad, E., Reihani, A., & Ojaghi, A. (2013). Numerical shape optimization of a centrifugal pump impeller using artificial bee colony algorithm. *Computers & Fluids, 81*, 145-151. doi:10.1016/j.compfluid.2013.04.018

Elkholy, M. M., & Fathy, A. (2016). Optimization of a PV fed water pumping system without storage based on teaching-learning-based optimization algorithm and artificial neural network. *Solar Energy, 139*, 199-212. doi:10.1016/j.solener.2016.09.022

Esmaeilian, H., Mohammadi, E., Fadaeinedjad, R., Bakhshai, A., & Rahnama, M. (2019). Design methodology to optimise induction machines based stand-alone electrical wind water pumping systems. *Iet Electric Power Applications, 13*(12), 2058-2069. doi:10.1049/iet-epa.2019.0210

Fang, H., Ma, J. F., Zhang, W., Yang, H., Chen, F., & Li, X. J. (2020). Hydraulic Performance Optimization of Pump Impeller Based on a Joint of Particle Swarm Algorithm and Least-Squares Support Vector Regression. *Ieee Access, 8*, 203645-203654. doi:10.1109/Access.2020.3036913

Farokhzad, S., Ahmadi, H., Jaefari, A., Abad, M. R. A. A., & Kohan, M. R. (2012). Artificial neural network based classification of faults in centrifugal water pump. *Journal of Vibroengineering, 14*(4), 1734-1744.

Fracassi, A., De Donno, R., Ghidoni, A., & Congedo, P. M. (2022). Shape optimization and uncertainty assessment of a centrifugal pump. *Engineering Optimization, 54*(2), 200-217. doi:10.1080/0305215x.2020.1858075

Ghadimi, B., Nejat, A., Nourbakhsh, S. A., & Naderi, N. (2019). Multi-Objective Genetic Algorithm Assisted by an Artificial Neural Network Metamodel for Shape Optimization of a Centrifugal Blood Pump. *Artificial Organs, 43*(5), E76-E93. doi:10.1111/aor.13366

Ghorani, M. M., Haghighi, M. H. S., & Riasi, A. (2020). Entropy generation minimization of a pump running in reverse mode based on surrogate models and NSGA-II. *International Communications in Heat and Mass Transfer, 118*. doi:ARTN 104898 10.1016/j.icheatmasstransfer.2020.104898

Jegha, A. D. G., Subathra, M. S. P., Kumar, N. M., & Ghosh, A. (2020). Optimally Tuned Interleaved Luo Converter for PV Array Fed BLDC Motor Driven Centrifugal Pumps Using Whale Optimization

Algorithm-A Resilient Solution for Powering Agricultural Loads. *Electronics, 9*(9). doi:ARTN 144510.3390/electronics9091445

Latifi, M., Moghadam, K. F., & Naeeni, S. T. (2021). Pressure and Energy Management in Water Distribution Networks through Optimal Use of Pump-As-Turbines along with Pressure-Reducing Valves. *Journal of Water Resources Planning and Management, 147*(7). doi:Artn 0402103910.1061/(Asce)Wr.1943-5452.0001392

Liu, H. L., Wang, K., Yuan, S. Q., Tan, M. G., Wang, Y., & Dong, L. (2013). Multicondition Optimization and Experimental Measurements of a Double-Blade Centrifugal Pump Impeller. *Journal of Fluids Engineering-Transactions of the Asme, 135*(1). doi:Artn 01110310.1115/1.4023077

Liu, X. W., Li, H. C., Shi, X. X., & Fu, J. F. (2019). Application of biharmonic equation in impeller profile optimization design of an aero-centrifugal pump. *Engineering Computations, 36*(5), 1764-1795. doi:10.1108/Ec-08-2018-0378

Lu, R., Yuan, J. P., Wei, G. J., Zhang, Y., Lei, X. H., & Si, Q. R. (2021). Optimization Design of Energy-Saving Mixed Flow Pump Based on MIGA-RBF Algorithm. *Machines, 9*(12). doi:ARTN 36510.3390/machines9120365

Lu, Y. M., Wang, X. F., Liu, H. R., & Li, Y. Y. (2020). Investigation of the effects of the impeller blades and vane blades on the CAP1400 nuclear coolant pump's performances with a united optimal design technology. *Progress in Nuclear Energy, 126*. doi:ARTN 10342610.1016/j.pnucene.2020.103426

Luan, H. X., Chen, Q. G., Weng, L. Y., Luan, Y. Z., & Li, J. (2016). Numerical computation of the flow noise for the centrifugal pump with considering the impeller outlet width. *Journal of Vibroengineering, 18*(4), 2601-2612. doi:10.21595/jve.2016.16656

Meng, F. N., Dong, Q. L., Wang, P. F., & Wang, Y. (2014). Multi-objective Optimization for the Impeller of Centrifugal Fan Based on Response Surface Methodology with Grey Relational Analysis Method. *Advances in Mechanical Engineering*. doi:Artn 61458110.1155/2014/614581

Mitrovic, D., Morillo, J. G., Diaz, J. A. R., & Mc Nabola, A. (2021). Optimization-Based Methodology for Selection of Pump-as-Turbine in Water Distribution Networks: Effects of Different Objectives and Machine Operation Limits on Best Efficiency Point. *Journal of Water Resources Planning and Management, 147*(5). doi:Artn 0402101910.1061/(Asce)Wr.1943-5452.0001356

Myrzakhmetov, B., Sultabayev, A., & Toktamissova, S. (2020). Substantiation of the methodology for modeling and calculating the optimal operating modes of a tandem pumping installation when mining uranium. *Mining of Mineral Deposits, 14*(4), 59-65. doi:10.33271/mining14.04.059

Parikh, T., Mansour, M., & Thevenin, D. (2022). Maximizing the performance of pump inducers using CFD-based multi-objective optimization. *Structural and Multidisciplinary Optimization, 65*(1). doi:ARTN 910.1007/s00158-021-03108-6

Peng, C. C., Zhang, X. D., Gao, Z. G., Wu, J., & Gong, Y. (2022). Research on cooperative optimization of multiphase pump impeller and diffuser based on adaptive refined response surface method. *Advances in Mechanical Engineering, 14*(1). doi:Artn 1687814021107294410.1177/16878140211072944

Shim, H. S., Afzal, A., Kim, K. Y., & Jeong, H. S. (2016). Three-objective optimization of a centrifugal pump with double volute to minimize radial thrust at off-design conditions. *Proceedings of the Institution of Mechanical Engineers Part a-Journal of Power and Energy, 230*(6), 598-615. doi:10.1177/0957650916656544

Shim, H. S., Kim, K. Y., & Choi, Y. S. (2018). Three-Objective Optimization of a Centrifugal Pump to Reduce Flow Recirculation and Cavitation. *Journal of Fluids Engineering-Transactions of the Asme, 140*(9). doi:Artn 09120210.1115/1.4039511

Siddique, M. H., Samad, A., & Hossain, S. (2022). Centrifugal pump performance enhancement: Effect of splitter blade and optimization. *Proceedings of the Institution of Mechanical Engineers Part a-Journal of Power and Energy, 236*(2), 391-402. doi:Artn 0957650921103740710.1177/09576509211037407

Wang, W. J., Li, Y. P., Osman, M. K., Yuan, S. Q., Zhang, B. Y., & Liu, J. (2020). Multi-Condition Optimization of Cavitation Performance on a Double-Suction Centrifugal Pump Based on ANN and NSGA-II. *Processes, 8*(9). doi:ARTN 112410.3390/pr8091124

Wang, W. J., Yuan, S. Q., Pei, J., & Zhang, J. F. (2017). Optimization of the diffuser in a centrifugal pump by combining response surface method with multi-island genetic algorithm. *Proceedings of the Institution of Mechanical Engineers Part E-Journal of Process Mechanical Engineering, 231*(2), 191-201. doi:10.1177/0954408915586310

Wu, T. X., Wu, D. H., Ren, Y., Song, Y., Gu, Y. Q., & Mou, J. G. (2022). Multi-objective optimization on diffuser of multistage centrifugal pump base on ANN-GA. *Structural and Multidisciplinary Optimization, 65*(6). doi:ARTN 18210.1007/s00158-022-03278-x

Yildiz, V., & Vrugt, J. A. (2019). A toolbox for the optimal design of run-of-river hydropower plants. *Environmental Modelling & Software, 111*, 134-152. doi:10.1016/j.envsoft.2018.08.018

Zeidan, M., & Ostfeld, A. (2022). Hydraulic Ram Pump Integration into Water Distribution Systems for Energy Recovery Application. *Water, 14*(1). doi:ARTN 2110.3390/w14010021

Zhang, R. H., Chen, X. B., & Luo, J. Q. (2021). Knowledge mining of low specific speed centrifugal pump impeller based on proper orthogonal decomposition method. *Journal of Thermal Science*, *30*(3), 840-848. doi:10.1007/s11630-020-1356-5

Author Information

Van Thanh Tien Nguyen
Industrial University of Ho Chi Minh City
12, Nguyen Van Bao, Go Vap, Ho Chi Minh City, Vietnam
Contact e-mail: *thanhtienck@ieee.org*

Thi Minh Nhut Vo
Thu Dau Mot University
Binh Duong, Vietnam

To cite this article:

Nguyen, V. T. T., & Vo, T. M. N. (2022). Centrıfugal Pump Design: an Optimization. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 17,* 136-151