

Lightweighting of a Centrifugal Pump Casing Through Structural Re-engineering and Simulation

Amit Patil^{1,*}, Dr. Mukundrao Kadam², Dr. Kailasnath Sutar³, Yogesh Saindane⁴,
Manoj Ukhande⁵

^{1*} Bharati Vidyapeeth (Deemed to Be University) College of Engineering Pune, Maharashtra, India

² Department of Mechanical Engineering, Bharati Vidyapeeth (Deemed to Be University) College of Engineering Pune, Maharashtra, India

³ Department of Mechanical Engineering, Bharati Vidyapeeth (Deemed to Be University) College of Engineering Pune, Maharashtra, India

⁴ Engineering Centre India, WILO Mather and Platt Pumps Pvt. Ltd, Pune, Maharashtra, India.

⁵ India Design Engineering Centre (IDEC), WILO Mather and Platt Pumps Pvt. Ltd, Pune, Maharashtra, India

*Corresponding Author: Amit Patil, E-mail : amitpatilemail@gmail.com

Abstract

In today's highly competitive market, there is a growing demand for lightweight, cost-effective designs that do not compromise structural integrity or functional performance. In end-suction centrifugal pumps, the casing wall thickness significantly contributes to the overall weight of the product. The study performs design re-engineering of large size pump used for sewage application which add significant value towards product upgradation. This design gives competitive advantage & results into customer satisfaction. In the existing casing design, it is observed that wall thickness is variable which introduces several challenges including uneven weight distribution, potential stress concentration zones, complex manufacturability, difficult quality inspections, and increased material waste, etc. These factors collectively extend the product development cycle and reduce overall efficiency. The study focuses on structural optimization and weight reduction of pump casing and makes it manufacturing friendly design with consistent wall thickness. This is achieved by using simulation driven approach. Simulations / Analysis carried out for pump casing to study the overall stress distribution in the casing region and identify the critical and the non-critical locations. Complementary analytical calculations were also performed to validate and correlate the simulation results, showing strong agreement between both methods. Based on stress distribution of the existing casing, various design optimization simulations are explored to achieve a uniform wall thickness. Accordingly, design iteration is selected which meets the requirement of stress and factor of safety (FOS) requirements. This study led to 6% reduction (a saving of over half a ton) in casing weight, achieved consistent wall thickness ensuring structural strength and produce a sustainable, environmentally friendly design by using CAD and simulation/analysis tools. This study also demonstrates the application of meshless technology at the designer level to accelerate the design process as compared to conventional processes.

Keywords: Centrifugal pump casing, wall thickness, FEA, weight optimization, design iteration, simulation, SimSolid, Abaqus.

1. Introduction

A centrifugal pump includes casing or housing, impeller, shaft, and bearing housing. Fluid enters through the suction nozzle, and the motor-driven impeller increases its speed and pressure. As the fluid moves through the volute and diffuser, its velocity drops, converting kinetic energy into pressure. [1]. The pump and its parts must function with reliability and with zero leaks. The casings are typically designed as volute shells that include two nozzles, one for fluid intake and the other for discharge. The volute casing is divided along its perimeter into regions that handle varying flow capacities, with some areas designed for high flow and others for low flow [2].

It plays a vital and crucial role in pump assembly. So, the strength of casing is important to ensure its safe operation, especially when it is exposed to several working conditions. Hence, the centrifugal pump's structure must be sufficiently robust to preserve its strength and functionality during its working operation condition. Also, the structure of the centrifugal pump must be strong enough to maintain the pump functionality [3]. Therefore, choosing the optimal thickness for the pump casing is important for its performance and to avoid failure during performance test & other operating conditions. Conducting a burst/hydro pressure test on pumps offers critical insights for developing emergency response protocols and accident preparedness. It also helps pinpoint potential failure zones within the system. By estimating burst/hydro pressure, engineers can identify vulnerable components and assess how much safety margin exists between the system's design limits and its actual breaking point.[4]

In most cases large pump casings are manufactured by sand casting process. Sand casting is a process where a pattern is used to make a cavity in sand, into which molten metal is poured. After cooling, the sand mold is broken to retrieve the solidified metal part. This method is widely used for producing complex metal components due to its low cost and versatility [5]. Casing (or casting) thickness plays a crucial role in ensuring casting quality and mold longevity. Uniform wall thickness helps achieve consistent solidification, reduces the risk of shrinkage cavities, and minimizes temperature differences that can lead to premature mold failure. Avoiding abrupt changes in section thickness and using smooth transitions like generous fillets not only improves metal flow and producibility but also extends mold life. Therefore, maintaining nearly uniform thickness throughout the casting is essential for optimal performance and durability. [5][6] Non-uniform wall thickness can lead to stress concentrations, making the casting more liable to fatigue cracking/failure and other structural issues [7]

Current competitive market demands economical pump. To achieve this, weight reduction of pump components will play imperative role and especially lightweighting of pump casing. By optimizing the pump wall thickness, we can reduce material usage by around 6% [8] Optimization method plays a vital role in improving component performance while reducing both weight and cost. By applying optimization techniques, material usage and consequently material costs can be minimized, which often represent a significant portion of the total budget. For greater accuracy, it is more effective to analyze material costs separately during the optimization process.[9]. The major factors contributing to increased weight include overdesign, customer requirements, casting feasibility, and operating conditions. Design optimization techniques aims at achieving a robust design that satisfies product weight and the fatigue life requirements. It considers manufacturing constraints such as casting wall thickness, draft allowances, and metal flow radius under starter operating conditions.[10]

The findings from Paper [2] indicate that an optimized design of the pump volute casing was achieved, focusing on critical structural regions. In Paper [3], finite element-based software was employed to successfully analyze the impact of thickness on the mechanical properties of centrifugal pump casing designs, highlighting casing thickness as a pivotal design parameter affecting structural integrity. Paper [7] conducted fatigue life analyses on three enhanced pump structures under actual operating conditions, concluding that structural design flaws contribute to fatigue cracking in the pump head body. According to Paper [8], the maximum equivalent stress in the pump body structure occurs at the tongue, measuring 36.843 MPa with a 6 mm grid cell size. The study notes that reducing grid cell size increases both the maximum equivalent stress and the number of units, while an appropriately selected wall thickness can save material and meet structural performance requirements.

According to [11], the higher stress values in the existing pump casing are localized and occur mainly at junction regions. By increasing the thickness at these critical points and reducing it elsewhere, the overall stress levels can be maintained below the allowable stress intensity, resulting in material savings. Paper [12] emphasized the need for a systematic approach to pressure application, suggesting additional experimental work to monitor stress and strain variations using strain gauges for achieving an optimized pump casing design. It also suggests that to minimize the overall cost of the pump, it is essential to optimize the casting components. This optimization can be achieved through weight reduction without compromising the pump's performance, made possible by modern simulation tools and advanced manufacturing processes. Study [14] focused on the design and structural evaluation of volute casings for liquid rocket turbopumps. Iterative 3D modelling and finite element analyses were

conducted, considering factors such as internal pressure, casing stiffness, and mounting forces while aiming for weight reduction. The casings were then manufactured through metal casting and validated via burst/hydro tests, where measured strains were compared with predicted results.

While some studies explore transitioning from uniform to non-uniform wall thickness, there is limited research addressing the shift from non-uniform to uniform casing thickness for weight reduction.

Pumps with variable wall thickness have their own drawbacks such as uneven weight distribution, chances of stress concentration, manufacturing difficult design, hard quality checks and material wastage etc. This results in longer product development cycle time. The optimized design structure of pump casing is also capable of meeting the structural performance requirements. Re-engineered design is verified with simulations/analysis. The correlation between analytical calculations & simulations is carried out.

The existing pump casing belongs to a large-capacity sewage pump, originally designed many years ago with a high safety factor. So the lightweighting of the casing was necessary. This paper deals with the weight optimization of existing centrifugal pump casing by design re-engineering from non-uniform thickness casing to uniform thickness. The pump casing's thickness changes linearly with stress, while its displacement and strain show a polynomial relationship with each other [3]. An increase in the casing thickness at some critical regions whereas reduction in thickness at non-critical locations in the pump casing helps to maintain stress in all regions of pump casing lower than allowable stress intensity of the material [11]. This is possible with simulation tools and the latest manufacturing techniques [12]. A structural analysis needs to be carried out for the fluid pressure to evaluate the stress distribution and deformation of the casing also the analysis and simulation is helpful for casing optimization [13][14]. With the help of finite element analysis, we identify the stress location and verify that maximum equivalent stress is lower than or equal yield strength/ultimate tensile strength of material, if yes then casing design is reliable [15] [16]. In this analysis, the pump housing is treated as a rigid structure with fixed boundary constraints [17]. To find circumferential stress, thin cylinder concept can be used, if its wall thickness is less than one-tenth to one-fifteenth of its diameter it is called thin cylinder [18,19,20]. To ensure that the pump can withstand the load factor of safety should be calculated and should be greater than or equal to Target factor of safety. It can be evaluated with the help of Ultimate tensile strength and design or maximum stress and is defined as the ratio between the load required to cause failure and the maximum load expected during actual use [10] The Factor of safety helps in reducing safety hazards [21,22].

The culmination of this research was the finalized 3D CAD model, which successfully met all required weight, stress criteria, and factor of safety standards. The foundational objectives guiding this study were multifaceted. Initially, the research focused on conducting an FEA simulation of the existing pump casing design to thoroughly examine the overall stress distribution and determine its factor of safety (FOS). This simulation's results were then correlated with an analytical method to validate the existing design's performance. The study then proceeded to an optimization phase, implementing iterations on the existing design, primarily by reducing and making the casing thickness uniform. A core objective was to systematically study the stress distribution in these various design iterations and evaluate their factor of safety. Ultimately, the goal was to select the optimum design iteration based on several key criteria: ensuring the target stress level remained below the Ultimate Tensile Strength (UTS) value of 250 MPa specified for the material EN-GJL-250; achieving a final design factor of safety (FOS) that met or exceeded the target value of 1.5 realizing a target weight reduction of greater than 5% with uniform thickness and ensuring the manufacturing friendly final design.

2. Optimization Problem and Methodology

2.1 Optimization Problem

The optimization problem as formulated in Table 1

Table 1: Parameters of optimization problem formulation

Parameter	Description
Objective Function	Minimize the total weight of the pump casing by at least 5% compared to the existing design.
Design Variables	Casing Thickness
Constraints	Maximum stress should be below ultimate tensile strength (UTS) of material.
	Factor of Safety (FOS) ≥ 1.5
	Manufacturing constraints: Minimum wall thickness ≥ 50 mm, ensuring uniform wall thickness and castability.
	Geometry and assembly interfaces must remain compatible with the existing pump layout.

Based on problem definition, pump casing weight reduction achieved by varying design variable (casing thickness). Accordingly, a series Simulation/Analysis iterations performed to evaluate the effect of thickness variation on stress, strain, deformation, and overall weight. Design iteration meeting all the constraints mentioned above is finalized as optimum design.

2.2 Methodology

As mentioned, this study focuses on the weight optimization of existing pump casing with non-uniform thickness using CAD & simulation/analysis tools such as Altair SimSolid and Abaqus.

To achieve this objective, the methodology illustrated in Figure 1 has been adopted. The flowchart provides an overview of the process followed for finalizing the modified design.

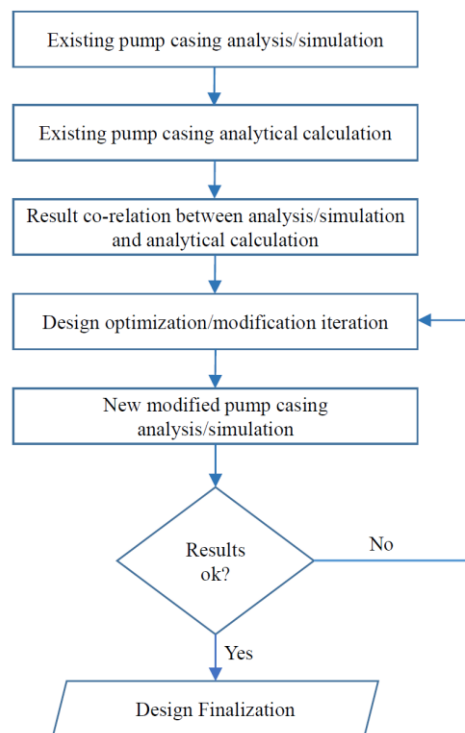


Figure 1: Methodology Flow chart

To optimize weight, uniform thickness applied to casing. The CAD and simulations were performed on the casing. The CAD model modified as per the results obtained by simulation. The simulations carried until the target stress & weight is achieved. Refer Table 2 for Casing thickness and software tools used during iteration process.

Table 2: Casing thickness and software used during iteration process.

Pump Casing	Casing Thickness	Thickness Uniformity	CAD software	Analysis Software
Existing Design	35mm to 70mm	Non-uniform	Unigraphics NX	Altair SimSolid
Modified Design-I	65mm	Uniform	Unigraphics NX	Altair SimSolid
Modified Design-II	53mm	Uniform	Unigraphics NX	Altair SimSolid, Altair HyperMesh (For Meshing) and Abaqus

To optimize the centrifugal pump, structural analysis was performed. A 3D CAD model of the pump body was developed, followed by simulation and analysis also it serves as a theoretical foundation for the optimization design of the centrifugal pump body. [8]. In practice, testing every casing during regular production is not feasible; therefore, an alternative approach is necessary to evaluate the reliability of the casing. Here enters Finite Element Analysis and simulation approach [12].

The analysis helps identify regions susceptible to fatigue failure, enabling more effective design improvements and maintenance planning to extend the component's service life, also the analysis and simulation results act as essential inputs for the design and modelling process. [23]. For this purpose, Altair SimSolid and Abaqus software tools were utilized.

Computer Aided Design (CAD) and Computer Aided Engineering (CAE) are intrinsic parts of modern engineering. CAE simulation tools are extremely important because they allow for performance validation and optimization of a product design before the product is physically created. Today this is typically done using software based on Finite Element Analysis (FEA) [27]

SimSolid is a fast, meshless simulation tool that allows engineers to analyze multiple design optimization iterations and gain insights into stress distribution in a quicker manner which reduces significant design iteration life. It is employed to perform comprehensive finite element analysis (FEA) of the component's structural behavior [24][25]. In short SimSolid is a structural analysis software developed specifically for upfront assessment. It eliminates geometry simplifications and meshing, the two most time consuming and expertise extensive tasks done in traditional FEA [26].

Modern FEM tools such as ANSYS and ABAQUS support coupled mechanical, thermal, and fluid simulations, enabling engineers to assess strength, vibration, cavitation, wear, and noise. These tools help visualize stress and deformation, identify failure-prone areas early, and facilitate design improvements that lead to cost savings, enhanced performance, and improved safety [27].

Casing material EN-GJL-250 is used for all the design iterations. Its mechanical properties are summarized as in Table 3.

Table 3: Material properties of pump casing

Material	Young's Modulus	Poisson's Ratio	Density	Ultimate tensile strength (UTS)
EN-GJL-250	115000 MPa	0.26	7.2 E-9 ton/mm3	250 MPa

Simulations for all three designs were performed by applying boundary conditions and a required internal pressure of 0.6 Mpa on the pump casing surface. According to the available pump standards IS:5120, the hydrostatic test pressure is specified as 1.5 times the maximum allowable working pressure [12][28]. Since the pump's operating pressure is 0.4 MPa, the corresponding hydrostatic test pressure will be $0.4 \times 1.5 = 0.6$ MPa. Casing foot faces fixed to restrict its movement, and the entire casing is sealed with blind flanges by creating the required connections to carry out the pressure test simulation referring Figure. 2. Accordingly, results analysis carried out.

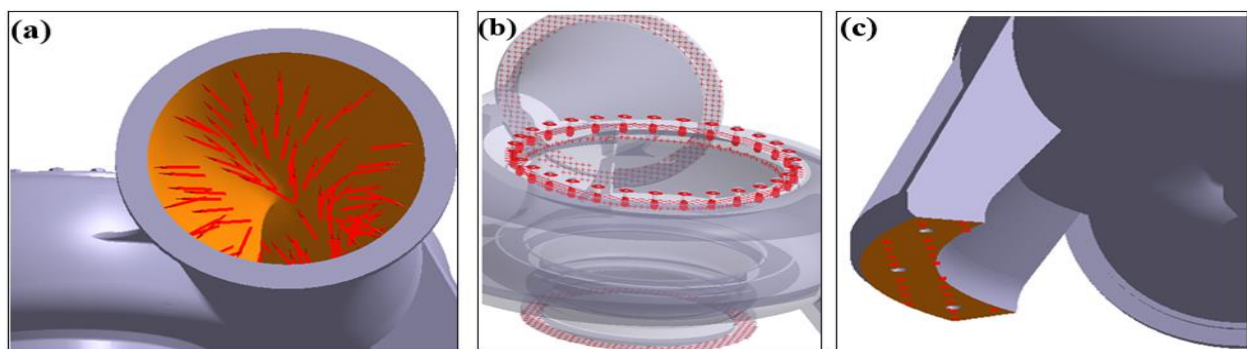


Figure 2: a. Pressure applied; b. Connections created between parts; c. Foot faces fixed in Altair SimSolid

With modified design Iteration-II expected results were achieved in Altair SimSolid. As Altair SimSolid tool works on Rapid and meshless technology, hence before design finalization results has to be verified with conventional established FEA tools like Abaqus. Accordingly modified design iteration-II detail analysis carried out with Abaqus solver whereas meshing carried out using Altair HyperMesh tool. Casing geometry is meshed with higher order tetrahedron element [12]. Critical areas are meshed with fine elements whereas remaining areas are meshed with 20 mm mesh size as shown in Figure. 3. Appropriate loads and constraints are applied on the casing as per test conditions requirements.

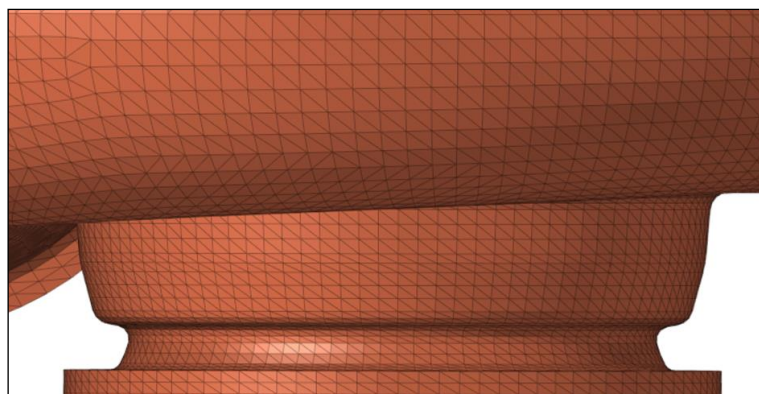


Figure 3: Mesh model of pump casing in Altair HyperMesh.

After solving model in FEA using Abaqus, post-processing is carried out to check stress and results. Based on stress levels observed in FEA model, factor of safety evaluated for modified design -II.

For pump casing existing design, stress results correlation between Altair SimSolid and analytical method carried out. In the analytical method, stresses are evaluated based on thin cylinder theory at lowest and highest casing thickness regions and those stress values compared with Altair SimSolid results at respective locations.

This study also includes an investigation of the effect of thickness variation on stress distribution. To achieve this, the stress experienced at a range of thicknesses was precisely calculated using an analytical approach with the help of thin cylinder concept.

3. Results and Discussion

3.1 Thickness-Stress Relationship

To evaluate stress at various thickness, the concept of thin cylinder can be used, a cylinder is said to be a thin cylinder when cylinder it has smaller wall thickness as compared to its inner diameter. If the wall thickness (t) is less than one-tenth of the shell diameter (d), the vessel is classified as a thin shell or cylinder. Conversely, when the wall thickness exceeds one-tenth of the diameter, it is referred to as a thick shell or cylinder [16][18].

Consider Circumferential/ Hoops stress from thin cylinder theory.

Assumptions:

- Material is Isotropic and homogeneous [19]
- Applied Pressure is uniform through the casing [19]

Where:

σ_c : Circumferential/ Hoops stress

p : Pressure (MPa)

d : Internal diameter of Volute (mm)

t : Thickness of Casing (mm)

In existing pump casing “ d ” is 2645mm and maximum thickness of casing “ t ” is 70mm.

Now

$$\frac{1}{10} \times d = \frac{1}{10} \times 2645 = 264.5mm \quad (1)$$

$$t = 70mm \text{ (maximum thickness)} < 264.5mm$$

Which means,

$$t < \frac{1}{10} \times d \quad (2)$$

Hence, the casing can reasonably be treated as a thin-walled cylindrical structure, as its wall thickness is relatively small compared to its overall diameter. This assumption allows the application of thin-cylinder theory for analytical stress estimation, simplifying the analysis while still providing sufficiently accurate results for design evaluation.

Now for example: Consider Circumferential/ Hoops stress at 35mm thickness:

Where,

p : 0.6 MPa (6 bar)

d : 2645mm

t: 35mm

Equation for Circumferential/ Hoops stress is as below [16]:

$$\sigma_c = \frac{p \times d}{2t} \tag{3}$$

$$\sigma_c = \frac{0.6 \times 2645}{2 \times 35} \tag{4}$$

$$\sigma_c = \frac{0.6 \times 2645}{2 \times 35} \tag{5}$$

$$\sigma_c = 22.67 \text{ Mpa} = 22.7 \text{ MPa} \tag{6}$$

Using the Equation-3 stress for various thickness calculated considering d as 2645mm with graph (refer below Table 4 and Figure 4). The stress is calculated at various thickness ranging from 35mm to 70mm.

Table 4: Stress by analytical method at various thickness

Thickness	Stress by Analytical Method
35	22.7
40	19.8
45	17.6
50	15.9
55	14.4
60	13.2
65	12.2
70	11.3

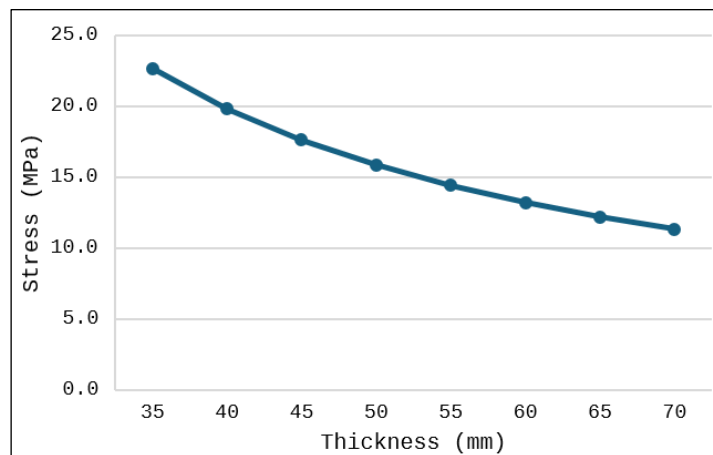


Figure 4: Casing Thickness Vs Stress by Analytical Method

The data illustrates the relationship between component thickness and the resulting stress as calculated by an analytical method. As shown in Table 4 and represented graphically in Figure 4, stress decreases consistently with an increase in thickness. At a thickness of 35 mm, the stress is calculated to be 22.7 MPa while at 70 mm, it reduces to 11.3 MPa. This inverse relationship suggests that regulating the material thickness enhances its ability to withstand applied loads, thereby reaching the required stress value.

Therefore, for existing casing design while achieving weight reduction, maintaining uniform thickness or reducing the wall thickness can both be effective, as long as the resulting stress remains below the ultimate tensile strength (UTS).

3.2 Results correlation between Simulation and analytical calculation

After performing the existing casing simulation using Altair SimSolid, post-processing was conducted to evaluate the stress at lowest (35 mm) and highest (70 mm) thickness regions of the pump casing, as illustrated in Figure 5. The corresponding stress values calculated using the analytical method for the lowest and highest thicknesses are presented in Table 5.

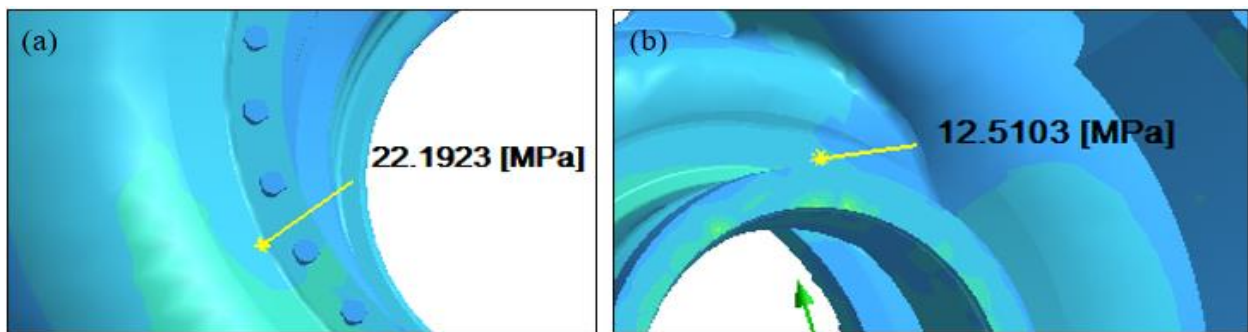


Figure 5: Stress at lowest (a) and highest (b) thickness of pump casing in Altair SimSolid

To correlate the above stress results with the analytical method, both the Altair SimSolid-simulated and analytically calculated stress values must be compared. Stress by analytical method calculated by equation 3.

Table 5: Stress comparison by analytical method and Altair SimSolid

Casing Thickness (t)	Stress by Analytical Method	Stress by Altair SimSolid
35mm (Lowest)	22.7 MPa	22.2 MPa
70mm (Highest)	11.3 MPa	12.5 MPa

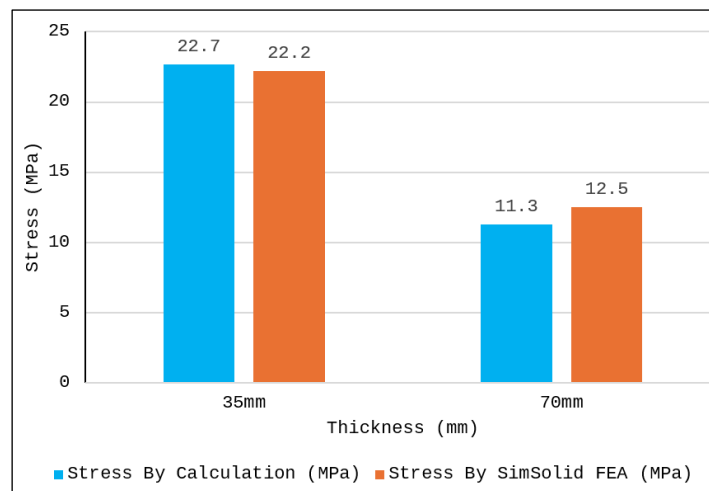


Figure 6: Stress values at thickness

From above Table 5 and graphical representation in Figure 6 it is observed that stress evaluated based on Altair SimSolid analysis match very well with analytical calculations.

3.3 Simulation / Analysis Summary.

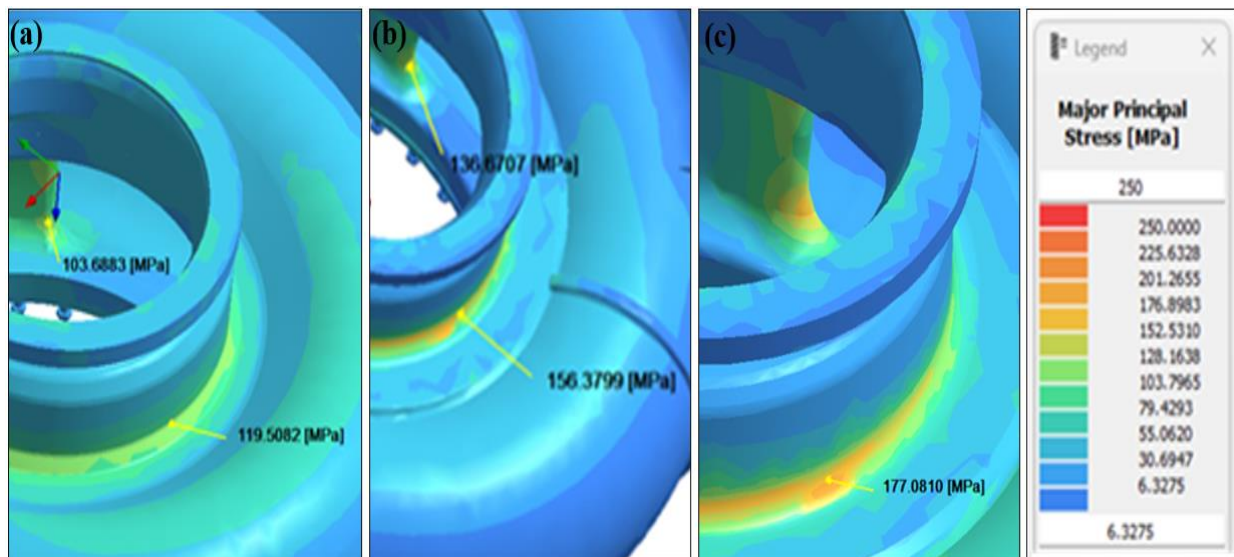


Figure 7: Maximum Stress at Pump Casing with Altair SimSolid in (a) Existing design, (b) Modified Design-I and (c) Modified Design-II

Figure 7 Shows the maximum stress using Altair Simulation at pump casing in existing design, modified Design I & II. Here we can see that stress increases as we reduce the thickness.

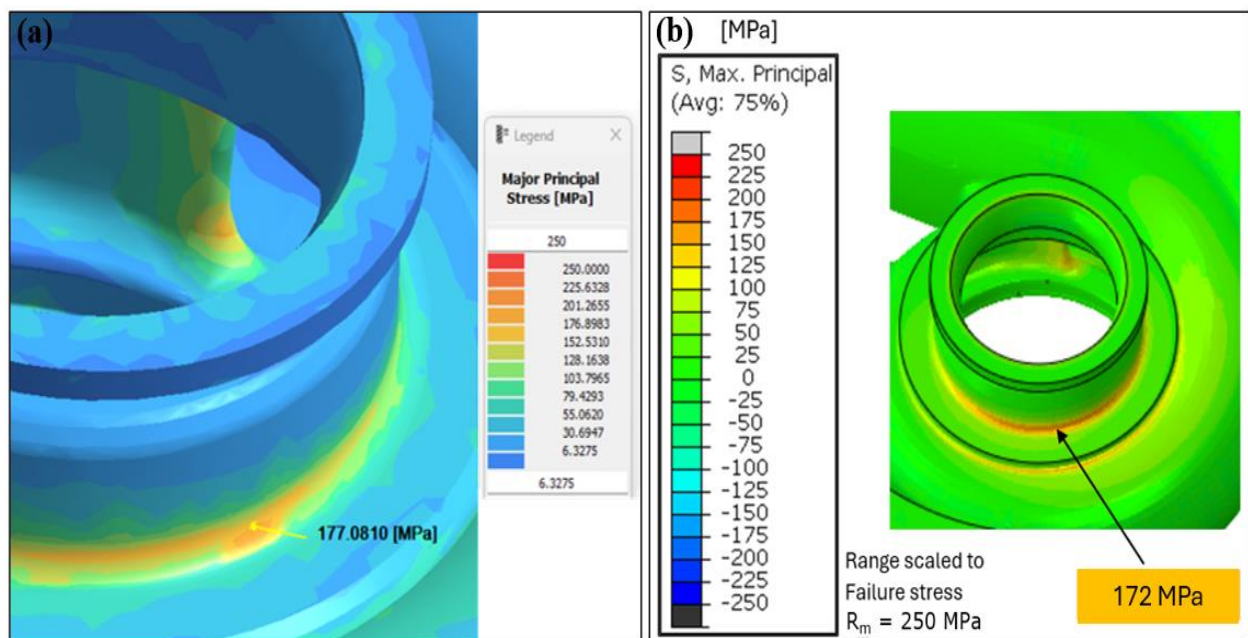


Figure 8 Maximum Stress in Modified Design-II with (a) Altair SimSolid and with (b) Abaqus

Figure 8 Shows the maximum stress in Modified Design II using both Altair Simulation and Abaqus. The stress obtained from the Altair simulation is 177, while that from Abaqus is 172. This variation arises due to a maximum discrepancy of 4.2% between the target and Altair SimSolid solutions. Despite the benchmarks being intentionally simple, the correlation remains remarkably good, especially considering that the time-consuming meshing process has been eliminated.[26]

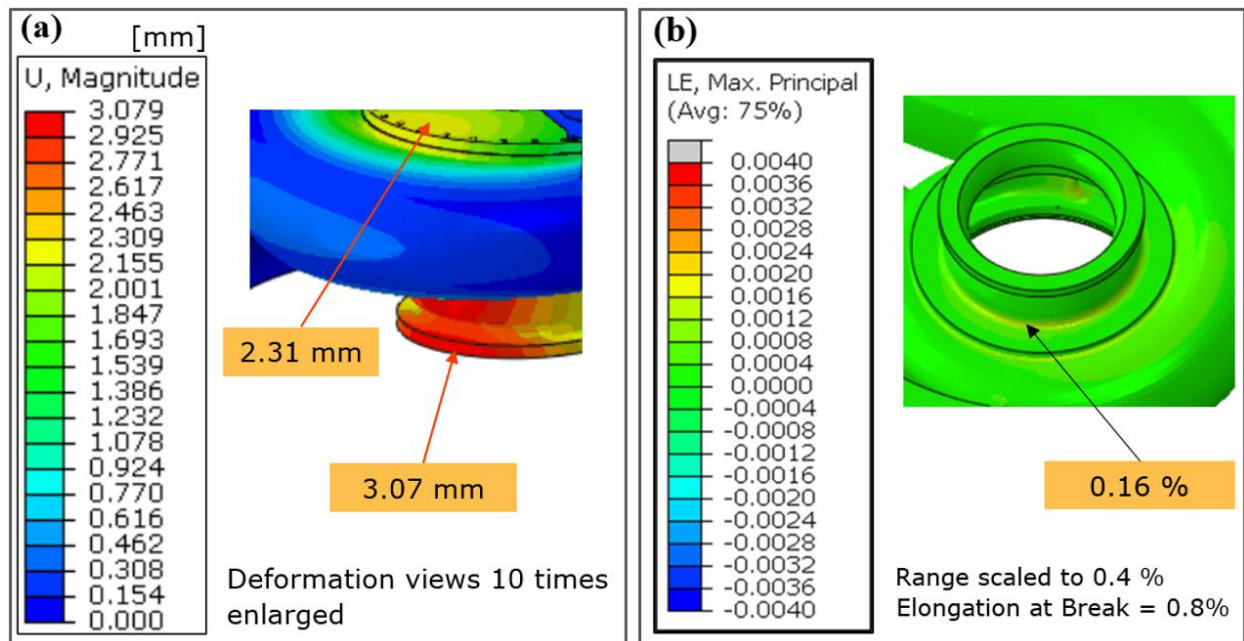


Figure 9: (a) Deformation and (b) Maximum Principal Strain in Modified design II using Abaqus

Figure 9 Shows the Deformation and Maximum Principal Strain in Modified design II using Abaqus. Overall maximum deformation in pump housing is 3.07 mm which is small compared to pump size and maximum principal strain (0.16%) are percentage elongation of material at break 0.8 %.

Existing pump casing thickness consists of variable thickness. To perform weight optimization of this casing, several design modifications and simulations were conducted with different thickness.

During hydrotest, it is expected that, maximum stress generated in the casing should be less than ultimate tensile strength (UTS) (250 MPa) of material. Factor of safety is ratio of ultimate tensile strength to Maximum stress [16]. This shows that we need to maintain stress levels in the pump casing below UTS of material. It means factor of safety should be ≥ 1 . However, by considering risks due to casting defects, fatigue etc. factor of safety maintained about 1.5.

All these results are based on the maximum principal stress theory. As per Table 3, casing material EN-GJL-250 with ultimate tensile strength (UTS) of 250MPa considered for all the iterations. Whereas overall simulation/analysis results are summarized below in Table 6.

Table 6: Simulation/Analysis Results Summary

Simulation	Casing Weights (kg)	Analysis Tool Used	Casing Thickness (mm)	Pressure Applied (bar)	Max. Stress in Simulation (MPa)	Factor of Safety (UTS/Max. Stress)
Existing design	9648	Altair SimSolid	35 to 70	6 (0.6 Mpa)	119.5	2.1
Modified design-I	10285	Altair SimSolid	65	6 (0.6 Mpa)	156	1.6

Modified design-II	9061	Altair SimSolid	53	6 (0.6 Mpa)	177	1.4
		Abaqus	53	6 (0.6 Mpa)	172	1.5

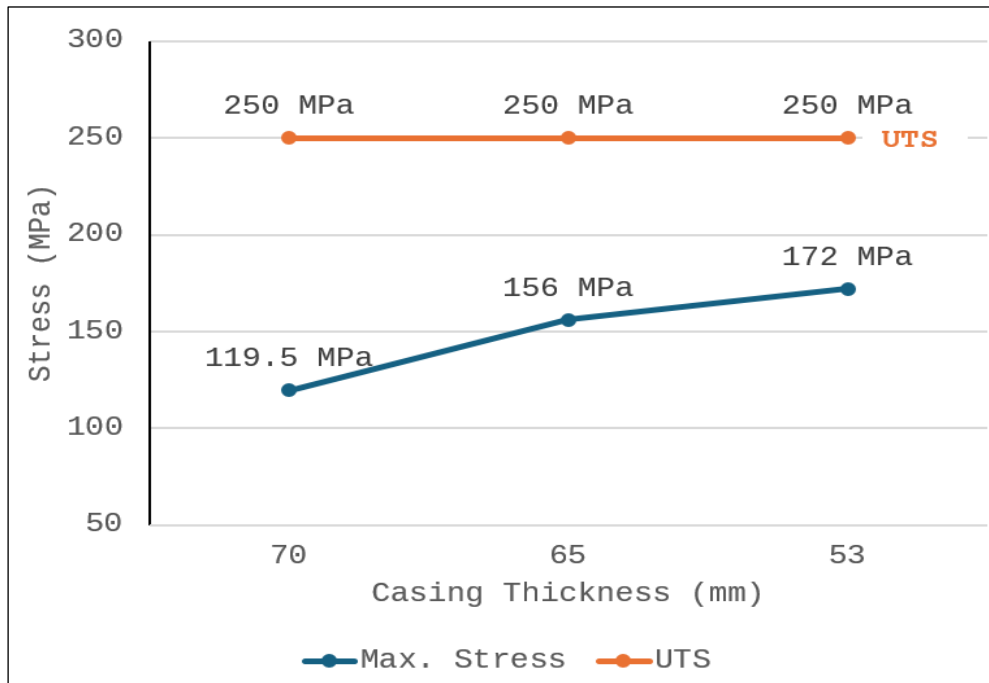


Figure 10: Casing thickness Vs Stress distribution

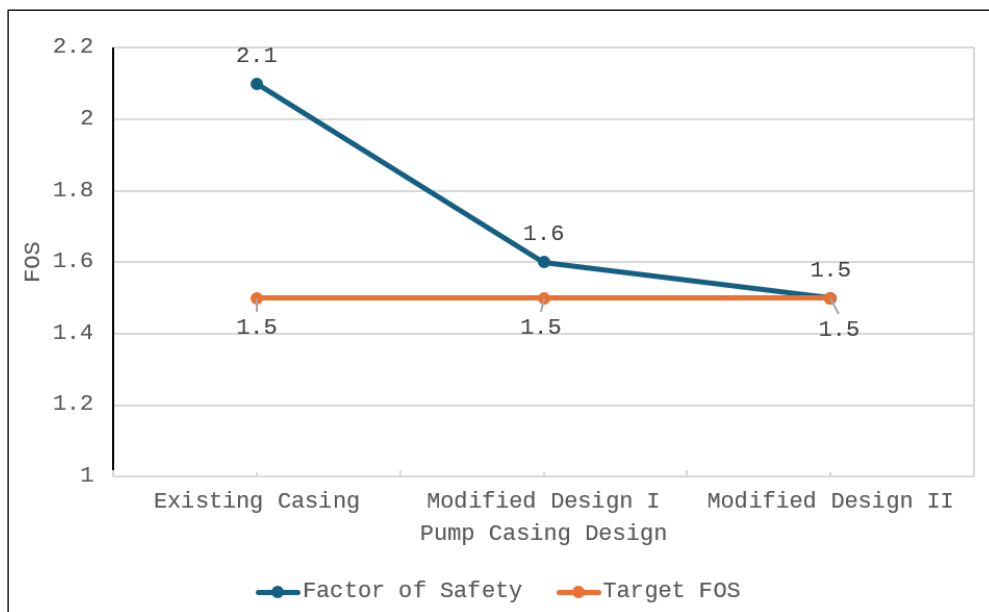


Figure 11: Casing design iterations Vs Factor of safety (FOS)

From the above Table 6 and graphical representation in Figure 10 and Figure 11 following are the observations:

- Factor of safety in existing casing design is 2.1, which indicates optimization feasibility.
- Modified Design-I is heavier than the existing design because it has a consistent wall thickness of 65 mm, whereas the existing design has a varying wall thickness ranging from 35 mm to 70 mm.
- The existing casing has a variable wall thickness ranging from 35 mm to 70 mm. When a uniform wall thickness of 65 mm is applied, the regions with lower thickness (35–60 mm) are increased to 65 mm, resulting in an overall increase in the casing’s weight.
- Modified Design II, with a wall thickness of 53 mm, results in a 6% reduction in weight compared to the current casing design (refer below Table 7 and chart in Figure 12). The weight difference shows that 587kg of material is saved, which lowers material procurement & manufacturing cost. The longer production cycle times and material costs are found to have the greatest influence on the production cost [29]. The greater the weight reduction, the lower the material required during manufacture.[30]. This ultimately improves the cost-efficiency of the design.

Table 7: Pump Casing Weight Comparison

Pump Casing Weight		Weight Difference	Percentage Difference
Existing Design	Modified Design-II		
9648 kg	9061 kg	587 kg	6 %

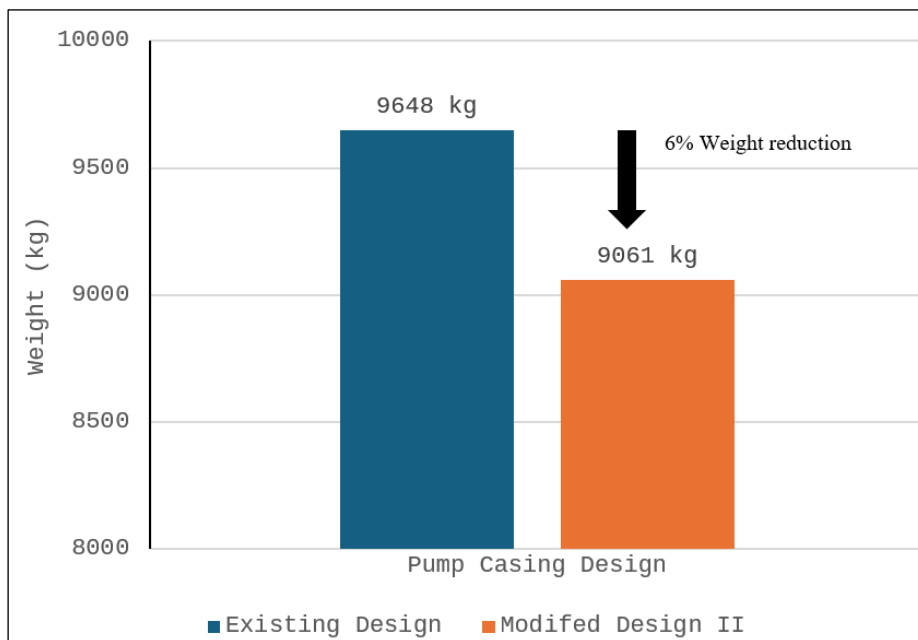


Figure 12: Existing design and Modified design II Pump casing Weight

- Pump casing’s maximum stress in analysis is less than ultimate tensile strength (UTS) of material (250 MPa) for all iterations (refer Figure 10).
- Altair SimSolid analysis shows that, factor of safety (FOS) in modified design-II is 1.4.
- Abaqus analysis shows that, factor of safety (FOS) in modified design-II is 1.5.
- Hence the factor of safety (FOS) of modified design-II is as per acceptance criteria (1.5) (refer Figure 11).

Therefore, Modified Design-II, featuring a uniform wall thickness of 53 mm, has been chosen as the optimal design iteration.

4. Conclusion

The primary contributing factor of end suction centrifugal pump casing weight is wall thickness. The original casing design was developed years ago without the aid of simulation technology. This casing was heavier than required due to a conservative approach with a high safety margin and inconsistent/variable wall thicknesses. To optimize this, we analyzed the stress patterns in the existing casing and performed multiple design iterations to achieve a uniform wall thickness. Accordingly, a design iteration meeting the requirement of target weight, stress & factor of safety is selected. Simulations are carried out using Altair SimSolid and Abaqus tools.

A uniform casing wall thickness ensures even weight distribution throughout the structure, which improves the balance and mechanical stability of the pump. It also enables simplified and more accurate quality inspection, since dimensional and thickness variations are minimized. Moreover, maintaining consistent wall thickness reduces the likelihood of localized stress concentrations, thereby enhancing the structural integrity of casing.

The existing casing weight is 9648 kg, whereas the weight of redesigned casing (Modified Design-II) is 9061 kg, resulting in a material reduction of about 587 kg. This saving of over half a metric ton (6%) of material is significant for the cost optimization of product. Such a reduction not only decreases overall manufacturing costs but also contributes to savings in raw material procurement, machining effort, and handling, ultimately improving the cost-efficiency of the design. Moreover, maintaining uniform casing thickness ensures even weight distribution, simplifies quality checks, and minimizes chances of stress concentrations, thereby enhancing structural reliability and extending service life of the pump. From a life-cycle perspective, the optimized design contributes to sustainability and cost efficiency by reducing raw material usage, minimizing manufacturing waste, and lowering the carbon footprint associated with casting, transportation, and operation.

The experimental validation of pump casing is carried out at testing lab. During test 6 bar (0.6 Mpa) hydro pressure is applied on casing, and it was observed that there is no leakage or cracking on the casing structure. The hydrostatic pressure test was successfully completed, validating the FEA results and confirming a strong correlation between the actual test performance and the simulation outcomes.

Altair SimSolid is a good option for design / CAD engineers for rapid design analysis to evaluate critical stress locations in the design stage itself. This will help to reduce the number of design iterations loop with FEA team & accelerate the design process. However, final design iteration validated by using conventional FEA tools like Abaqus.

References

- [1]. Johann Friedrich Gülich, (2010), Centrifugal Pump, Springer International Publishing
- [2]. Mona Golbabaie Asl, Rouhollah Torabi, S. Ahmad Nourbakhsh, Experimental and FEM failure analysis and optimization of a centrifugal-pump volute casing. *Engineering Failure Analysis*, 16(6), (2009) 1996-2003.
<https://doi.org/10.1016/j.engfailanal.2009.02.006>
- [3]. C.Y. Khor, M.A.M. Nawawi, Muhammad Ikman Ishak, Z.K. Ooi, M.U. Rosli, S.N.A. Ahmad Termizi, Simulation Analysis of The Thickness Effect Towards Mechanical Aspects in The Design of Centrifugal Pump Casing. *IOP Conference Series: Materials Science and Engineering*, 864(1) (2020) 1-7.
<https://doi.org/10.1088/1757-899X/864/1/012192>
- [4]. Ihn Namgung, Nguyen Hoang Giang, Investigation of Burst Pressures in PWR Primary Pressure Boundary Components, *Nuclear Engineering and Technology*, 48(1), (2016) 236-245.

- <https://doi.org/10.1016/j.net.2015.11.001>
- [5]. Manufacturing Engineering and Technology, (2014), Pearson Publication.
- [6]. ASM andbook Casting, (2008), ASM Internation Publication
- [7]. ZheDu,Jijun Xue, Fracturing pump head body failure analysis and improvement measures. Engineering Research Express, 6(2), 2024 1-16
- [8]. Wu Lan-Ying, Wang Yan-Lin, Study on Optimization and FEM Analysis of Centrifugal Pump Body Structure. Advanced Materials Research, (154-155) (2011) 1744-1747. <https://doi.org/10.4028/www.scientific.net/AMR.154-155.1744>
- [9]. Sheng Xiong, Chunlong Nie , Yixuan Lu and Jieshu Zheng, Research on Price Prediction of Construction Materials Based on VMD-SSA-LSTM. Applied Sciences, 15(4), (2025) 1-21. <https://doi.org/10.3390/app15042005>
- [10]. Varatharaj Neelakandan, Thulasirajan Ganesan, Praveen Chakrapani Rao,Weight Optimization of Housing Bracket for Electrical Starter Motor using FEA. 2nd International Conference on Structural Integrity and Exhibition, 14, (2018), 345-353. <https://doi.org/10.1016/j.prostr.2019.05.043>
- [11]. S.S Mulik, V.J Shinde, M.S Rohokale, Mugdha Dokhale, Stress Analysis of Centrifugal Pump Casing by using FEM for Minimization of Casing Thickness. Proceedings of National Conference On Computer Applications In Manufacturing Processes (2008) 78- 81.
- [12]. Ashok Ramteke, Ajeet Baraskar, Predicting Crack Initiation Time In Cast Iron Pump Casing with Finite Element Analysis. International Journal of Mechanical and Production Engineering (IJMPE), 6(12) (2018) 85-90. https://iraj.in/journal/journal_file/journal_pdf/2-527-155809392585-90.pdf
- [13]. Peng Guangjie, Wang Zhengwei, Yan Zongguo, Liu Ruixiang, Strength analysis of a large centrifugal dredge pump case. Engineering Failure Analysis,16(1), (2009) 321-328. <https://doi.org/10.1016/j.engfailanal.2008.05.015>
- [14]. Suk-Hwan Yoon, Seong Min Jeon, Jin Han Kim, Burst Test of Volute Casings for Liquid Rocket Turbopump. The KSFM Journal of Fluid Machinery, 14(4), (2011) 12-18. <https://doi.org/10.5293/KFMA.2011.14.4.012>
- [15]. Pravin D. Bhawar, M. B. Patwardhan, Design and Analysis of Boiler Feed Pump Casing Working at High Temperature by using Ansys. International Journal of Science and Research (IJSR), 3(6) (2014) 2392-2395.
- [16]. Khurmi, R.S., Gupta, J.K., Machine, (2005), Eurasia Publishing House, India,
- [17]. Suneel Ahirwar, Manish Kumar Prajapati, Nitin Vishwakarma, Akash Tomar, Linear Structural Analysis on Centrifugal Pump. International Journal of Engineering, Management & Medical Research (IJEMMR), 1(10), (2015).
- [18]. Amit Rakshit, Bikash Banerjee, Analysis The Internal Pressure of The Thin Cylindrical Shell By Newton's Forward Interpolation. International Research Journal of Modernization in Engineering Technology and Science, 2(8), (2020) 754-757. https://www.irjmets.com/uploadedfiles/paper/volume_2/issue_8_august_2020/3009/final/fin_irjmets16_31109538.pdf
- [19]. Ahmed Ibrahim, Yeong Ryu, Mir Saidpour, Stress Analysis of Thin-Walled Pressure Vessels. Modern Mechanical Engineering, 5(1), (2015) 1-9. <http://dx.doi.org/10.4236/mme.2015.51001>

- [20]. Zainul Huda, Muhammad Hani Ajani, Evaluation of Longitudinal and Hoop Stresses and a Critical Study of Factor of Safety (FoS) in Design of a Glass-Fiber Pressure Vessel. *International Journal of Materials and Metallurgical Engineering*, 9(1), (2015) 39-42.
<https://doi.org/10.5281/zenodo.1338082>
- [21]. Rentsendorj Usukhbayar, Jongsoo Choi, Critical safety factors influencing on the safety performance of construction projects in Mongolia. *Journal of Asian Architecture and Building Engineering*, 19(6), (2020) 600-612
<https://doi.org/10.1080/13467581.2020.1770095>
- [22]. Structural Margin Statistical Analysis: Effects of Reduction Factors and Statistical Noise on Performance Parameters. *International Journal of Statistics and Applications*, 14(3), (2024) 41-46
[DOI:10.0.23.35/j.statistics.20241403.01](https://doi.org/10.2335/j.statistics.20241403.01)
<https://e-jurnal.pnl.ac.id/polimesin/article/view/5605>
- [23]. Susilo Handoko, Regan Rahadian P, Hafid Suharyadi, Totok Widiyanto, Finite element analysis of wear and deformation in casing rings for centrifugal pumps. *Jurnal POLIMESIN*, 23(1), (2025) 121-127.
<http://dx.doi.org/10.30811/jpl.v23i1.5605>
- [24]. Sourav Das, Saurabh Bhamania, Sandhya Parate, Evaluating Die Life in High-Pressure Die Casting: Correlating Temperature Dynamics and Durability through Altair Inspire Cast and SIMSOLID. *Journal of Materials & Engineering*, 3(4), (2025) 377-392.
<http://doi.org/10.61552/JME.2025.04.002>
- [25]. Sourav Das, Francesco Di Giuseppe, Antonio Flores, Sandhya Parate, Jaideep Bangal, A case study: Analyzing the structure and optimizing the design of the aero handlebar assembly for the bicycle used in Japan's Olympic games, *Engineering Reports*, 6(2), (2023) 1-14.
<https://doi.org/10.1002/eng2.12783>
- [26]. Bench Mark, *The International Magazine For Engineering Designers & Analysts From NAFEMS, The Electromagnetics Issue*. (2020) 32-44
- [27]. Rajeev Ranjan Kumar, Rajesh Khodre, Design and Analysis of Centrifugal Pump Impeller- A Survey. *International Journal of Research Publication and Reviews*, 6(9), (2025) 1035-1039.
<https://ijrpr.com/uploads/V6ISSUE9/IJRPR52596.pdf>
- [28]. IS:5120-1977 Technical Requirements For Rotodynamic Special Purpose Pumps (First Revision)
- [29]. Robert A. Witik, Jérôme Payet, Véronique Michaud, Christian Ludwig, Jan-Anders E. Månson, Assessing the life cycle costs and environmental performance of lightweight materials in automobile applications. *Composites Part A: Applied Science and Manufacturing*, 42(11), 2011 1-17
<https://doi.org/10.1016/j.compositesa.2011.07.024>
- [30]. Minghui Wu, Jhuma Sadhukhan, Richard Murphy, Ujjwal Bharadwaj, Xiaofei Cui, A novel life cycle assessment and life cycle costing framework for carbon fibre-reinforced composite materials in the aviation industry. *The International Journal of Life Cycle Assessment*, 28, (2023) 566-589.
<https://doi.org/10.1007/s11367-023-02164-y>