# Numerical and Computational Analysis of Pulsator Parameters of Washing Machine

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***Abstract - Pulsator (impeller) in the top loaded washing machine gives poor performance while cleaning the dirt as compared with agitator. Optimizing it leads to increase the turbulent flow inside the drum which has more impact on its performance. The design of the existing pulsator is made as per accurate dimensions. CFD is used to set out the results for optimized pulsator. The main important factor to improve is turbulence inside the washing machine drum which is directly proportional to fluid velocity at points. The most influencing parameters were changed in various levels as per analysis on the design. Finally ANOVA is to be used to identify the most contributing factor.***

***Keywords - Washing machine, turbulence flow, Reynolds number.***

## 1. INTRODUCTION

Better washing machine designs and operation could reduce energy and water usage and extend textile life. Washing machine studies have been conventionally pragmatic, since laundering typically involves complex motion of many cloth pieces in an inhomogeneous (liquid, textile, detergent, activist) setting. This paper presents a physics-based mold of fully-submerged clothes washing in two- and three-dimensions. The compound textile pieces are model as lean stretch plates with tensile, clip, twisting, and torsion rigidity, while the wash liquid is model with the incompressible Navier Stokes equations.

The fluid–cloth interaction is modeled via an immersed boundary method, and complex two- and three-dimensional advanced geometries are simulated with a Cartesian domain-mapping technique. The simulations have relatively coarse pledge that does not resolve all length scales for typical washing machine operating conditions). The simulation results include cloth stresses, torque on the wash bin, and the action and bend of fused cloth pieces. The simulations scrutinize how cloth motion differs with Reynolds number and cloth loading. The results let slip that for an agitator-driven3-D wash geometry higher Reynolds number, cloth pieces are near the agitator bottom of the wash basket are first pushed by centrifugal force towards the outer stationary walls of the wash bin, then augment towards the apex float up where they return to the axis of rotation and then sink towards the agitator. The variation of the axis of mass positions of the cloth pieces are to increase for higher Reynolds number operating conditions.

Usage pattern of clothes washing (and clothes washers) are strongly related to local cultural practices. In emerging markets such as China, numerous types of technology often co-exist. Some use less energy but more water (the impeller type), and some use more \energy but less water (the horizontal axis type). The opposition between different technologies is thought to lead to better customer choices. However, it could also lead to changes in clothes-washing habits from frosty to warm wash, and therefore to much elevated power use. This paper examine the standard development process in China to illustrate that adoption of foreign technologies and technical standards, if not carefully calibrated to the narrow civilizing practices, could have in advertent penalty for force use and environment.

Dress washing machines (washers) are ubiquitous in the up to date world. However the garments washing process has largely escaped a detailed computational analysis because a physically meaningful numerical description of the relevant phenomena has not been formulated. Detailed physical descriptions of wash processes should account for the coupled, unsteady, complex, and three-dimensional motions of the fluid and cloth mixture when driven by the complex and moving geometries of the agitator and wash basket. Numerical solution strategies\must simultaneously be appropriate for three-dimensional motion of a fluid and nearly arbitrary deformation of the cloth. This study describes a clothes washing simulation developed from first principles attains these goals.

### 1.1 Pulsator in Washing Machine

A device that stimulates rhythmic motion of a body; a vibrator. A pulsator (impeller) is a member that is mounted to a motor in order to rotate clothes along with detergent water. The fig 1 shows the pulsator of washing machine.

**Fig. 1** Pulsator

There are both merits and demerits are there in using pulsator and agitator. Top-loading washing machine in Asia use impeller instead of agitator. Impellers spin and pulse to turn the washing in excess of, rather than slanting it. Washing machines with impellers tend to be easier to load and unload, but their dust taking away isn't always as good as agitator models. Hence the optimization of low cost pulsator is essential.

### 1.2 Need for Optimization

The optimization of pulsator is needed for the following reasons.

- To bring high efficient washing in all aspect.
- To produce higher economy washing machines.
- To satisfy customer in their washing.
- To survive in the competitive market.

**TABLE 1** Specifications of Washing Machine

| | |
|---|---|
| Dimensions( mm) | 820 x 490 x 980 (W x D x H) |
| Water pressure | 0.05-0.78mpa 0.5-8.0 kg-f/cm² |
| Weight (net) | 33kg |
| Extraction efficiency | 50 % |
| Standard quantity of water | 65 l |
| Rating time | Washing 1hour / spinning 15minutes |

## 2. MODELING

Designing of pulsator and its model is created in catiav5. Written in C++ programming language, CATIA is the cornerston of the Dassault Systemes product lifecycle management software suite.

**TABLE 2** Specificationof Existing Pulsator

| S.NO | Parameter | Dimension |
|---|---|---|
| 1 | Draft angle at centre of blade | 30˚ |
| 2 | Thickness of blade | 20mm |
| 3 | Height at leading edge of blade | 32mm |
| 4 | Height at lagging edge of blade | 6mm |

The specification of pulsator is shown in table 2.

The modeling is shown in fig 2.

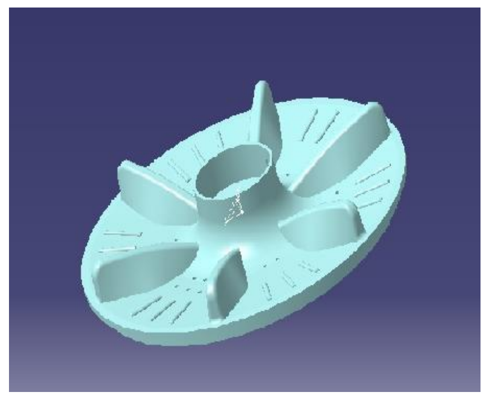

**Fig 2** modeling of pulsator

## 3. OPTIMIZATION OF PULSATOR

The Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varies.

### 3.1 Array Selector

This thesis is to maximize velocity of flow inside the washing machine drum by varying the pulsator geometry within optimal levels; The higher the better quality characteristic is selected. A standard Taguchi L25 Orthogonal Array (OA) is chosen for this investigation as it can operate four parameters, each at five levels. The four most influenced identified parameters (A) Draft angle at centre of blade; (B) Blade thickness; (C) Height at leading edge of blade and (D) Height at lagging edge of blade.

### 3.2 Remodel Pulsator

The remodel pulsator with drum shown in fig 3, the three dimensional meshed view of washing machine shown in fig 4

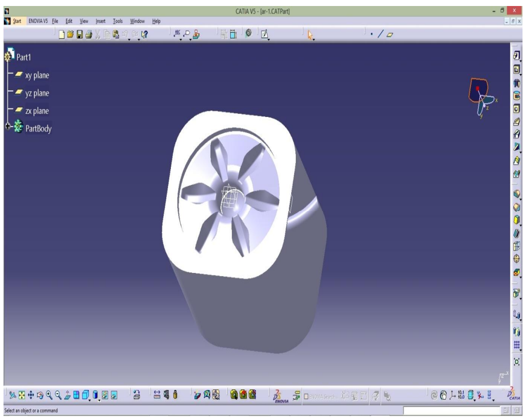


**Fig 3** 3D Remodel pulsator with drum

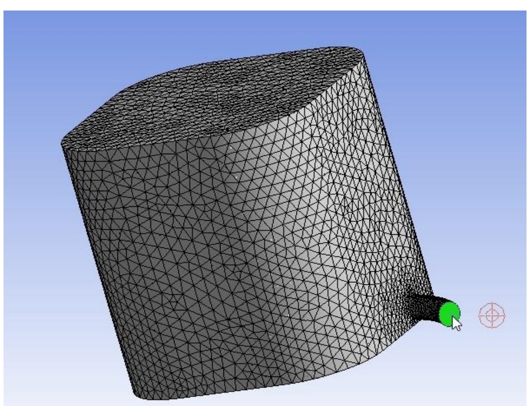

**Fig 4** Meshed model of drum

### 3.3 Computational Fluid Dynamics

It provides a qualitative (and sometimes even quantitative) prediction of fluid flows by means of mathematical modeling (partial differential equations) numerical methods (discretization and solution techniques) and software tools (solvers, pre-and post processing utilities). CFD enables scientists and engineers to perform numerical experiments (computer solutins).

## 4. METHODOLOGY

The step by step procedures of making CFD analysis are given below.

The fig 5 shows the methodology of computational fluid dynamics. The boundary condition of process is using coarse mesh. The inlet velocity of pulsator is 4 m/s and outlet pressure is 0. The last step is solving, number of iterations are 200.

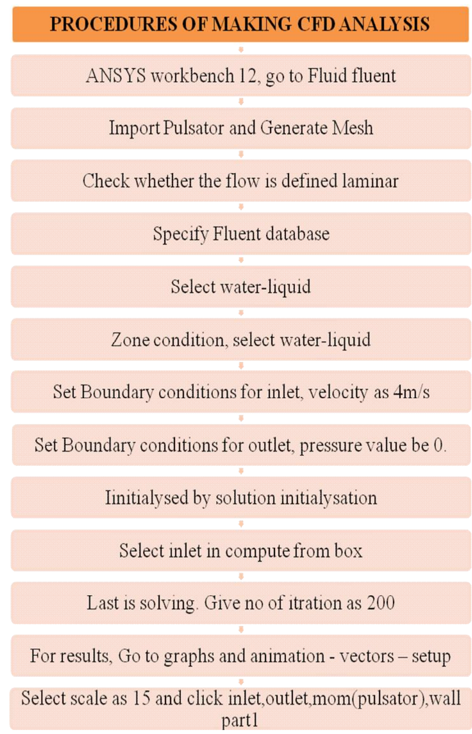


**Fig 5** CFD process

## 5. RESULT AND DISCUSSION

### Existing Model-1

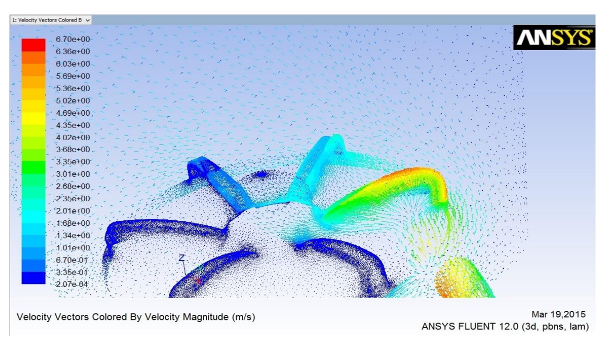


Fig 6 Velocity vector of pulsator

Existing pulsator is analyzed with the boundary conditions of velocity 4 m/s and water is the working fluid. From the computational analysis maximum velocity magnitude of pulsator is 6.63 m/s observed. This velocity distribution of pulsator is shown in Fig 6.

**Optimized Model - 1**

Fig 7 Velocity vector of pulsator with drum

From the computational analysis maximum velocity magnitude of pulsator is 6.76 m/s observed. . This velocity distribution of pulsator is shown in Fig 7

**Optimized Model - 2**

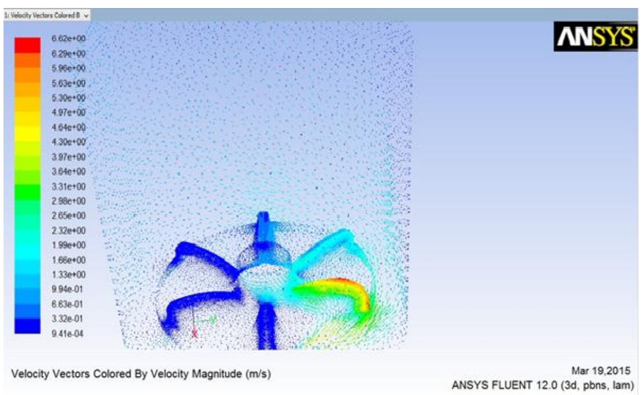


Fig 8 Velocity vector of pulsator with drum

From the computational analysis maximum velocity magnitude of pulsator is 6.60m/s observed. . This velocity distribution of pulsator is shown in Fig 8

**Optimized Model - 3**

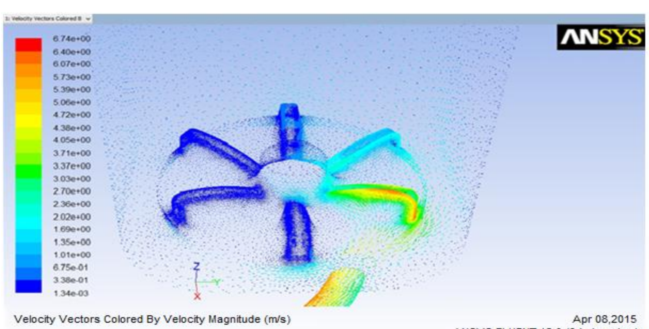


Fig 9 Velocity vector of pulsator with drum

Optimized pulsator is analyzed with the boundary conditions of velocity 4 m/s and water is the working fluid. From the computational analysis maximum velocity magnitude of pulsator is 6.74 m/s observed. . This velocity distribution of pulsator is shown in Fig 9.

**5.1 Velocity Values with Dimensions**

**TABLE 3** Velocity Values

| S. NO | Draft Angle (degree) | Thickness (mm) | Leading edge (mm) | Trailing edge (mm) | Velocity (m/s) |
|---|---|---|---|---|---|
| 1. | 30 | 20 | 32 | 6 | 6.36 |
| 2. | 30 | 16 | 28 | 4 | 6.30 |
| 3. | 30 | 18 | 30 | 5 | 6.40 |
| 4. | 30 | 22 | 34 | 7 | 6.24 |
| 5. | 30 | 24 | 36 | 8 | 4.35 |
| 6. | 26 | 20 | 28 | 5 | 6.26 |
| 7. | 26 | 16 | 30 | 7 | 6.29 |
| 8. | 26 | 18 | 34 | 8 | 6.36 |
| 9. | 26 | 22 | 36 | 6 | 6.07 |
| 10. | 26 | 24 | 32 | 4 | 6.38 |
| 11. | 28 | 20 | 30 | 8 | 6.27 |
| 12. | 28 | 16 | 34 | 6 | 6.29 |
| 13. | 28 | 18 | 36 | 4 | 5.97 |
| 14. | 28 | 22 | 32 | 5 | 5.88 |
| 15. | 28 | 24 | 28 | 7 | 6.44 |
| 16. | 32 | 20 | 34 | 4 | 6.32 |
| 17. | 32 | 16 | 36 | 5 | 6.36 |
| 18. | 32 | 18 | 32 | 7 | 6.34 |
| 19. | 32 | 22 | 28 | 8 | 6.30 |
| 20. | 32 | 24 | 30 | 6 | 6.34 |
| 21. | 34 | 20 | 36 | 7 | 6.32 |
| 22. | 34 | 16 | 32 | 8 | 6.26 |
| 23. | 34 | 18 | 28 | 6 | 6.27 |
| 24. | 34 | 22 | 30 | 4 | 6.28 |
| 25. | 34 | 24 | 34 | 5 | 6.28 |

## 6. RESULTS THROUGH TAGUCHI'S METHOD

**6.1 Taguchi Method**

Quality control methodology that combines, control charts and process control charts with product and process design to achieve a robust total design. It aims to reduce product variability with a system for developing specifications and designing them into a product or process. It was named after its inventor, the Japanese engineer-statistician Dr. Genichi Taguchi who also developed the quality loss function.

### 6.2 Taguchi Design

Taguchi Orthogonal Array Design = L25 (5**4)

Factors: 4, Runs: 25

Columns of L25 (5**6) Array

General Linear Model: Velocity Versus Draft Angle, Blade Thickness

**TABLE 4** GENERAL LINEAR MODEL

| Factor | Type | Levels | Values |
|---|---|---|---|
| Draft angle | fixed | 5 | 26, 28, 30, 32, 34 |
| Blade thickness | fixed | 5 | 16, 18, 20, 22, 24 |
| Height at leading edge | fixed | 5 | 28, 30, 32, 34, 36 |
| Height at lagging edge | fixed | 5 | 4, 5, 6, 7, 8 |

The table 4 shows the values of linear model of velocity versus blade angle and thickness.

### 6.3Analysis of Variance for Velocity, Using Adjusted SS For Tests

**TABLE 5** ANOVA FOR VELOCITY

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| **Draft angle** | 4 | 0.5155 | 0.5155 | 0.1289 | 0.68 | 0.623 |
| **Blade thickness** | 4 | 0.4325 | 0.4325 | 0.1081 | 0.57 | 0.69 |
| **Height at leading edge** | 4 | 0.9347 | 0.9347 | 0.2337 | 1.24 | 0.368 |
| **Height at lagging edge** | 4 | 0.5463 | 0.5463 | 0.1366 | 0.72 | 0.599 |
| **Error** | 8 | 1.5079 | 1.5079 | 0.1885 | | |
| **Total** | 24 | 3.9369 | | | | |

S = 0.434156 R-Sq = 61.70% R-Sq (adj) = 0.00%

The table 5 shows the analysis of variance of velocity. The parameter values are calculated to find out the error of analysis

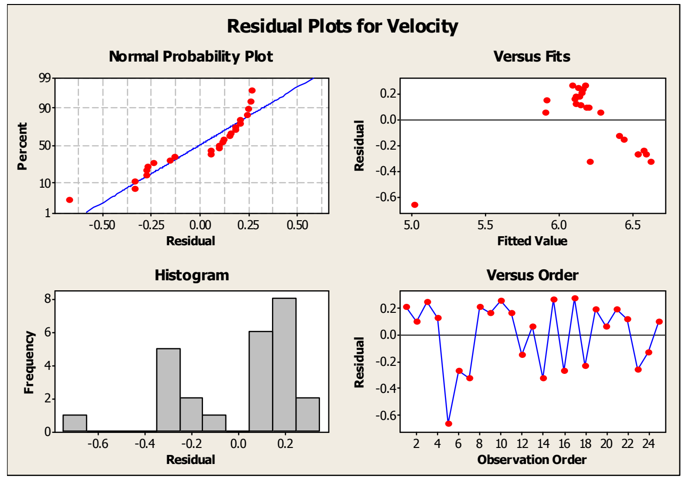


**Fig 10** Residual Plots for Velocity

### 6.4 Residual Plots for Velocity

The fig 10 shows the contour plot of main effect of residual plots for velocity. The main parameters (thickness, height at leading edge, height at lagging edge, draft angle) are used to drawn the graph and the values of parameters are varies from ANOVA method. The values of frequent and percent are drawn in varies graphs.

## 5. CONCLUSION

Pulsator model is created as per the dimensions of existing model and design would be modified to improve the performance of cleaning dirt. Existing pulsator is computationally analyzed through standard analysis software package. From the analyzed results, obtained velocity of the existing pulsator is 6.36m/s, stress 9.65 MPa and strain 4.83x10-5. This existing pulsator velocity is increased by changing parameters like Height a leading edge, Height at lagging edge, draft angle, Thickness.

Optimization is carried out in a in order manner, starting from designing till the analysis in Taguchi's way as shown above. From the analyzed results, conclude that the best value with respect to each parameter are like Height a leading edge, Height at lagging edge, draft angle, Thickness. The optimized velocities are obtained .The optimized stress 7.52Mpa and strain 3.76. The table 9 shows the best parameters values.

**TABLE 6** PARAMETERS WITH BEST RESULTS

| S.no | Parameters | Existing value | Value show best result |
|---|---|---|---|
| 1 | Draft angle (degree) | 30 | 32 |
| 2 | Thickness (mm) | 20 | 20 |
| 3 | Height at leading edge (mm) | 32 | 30 |
| 4 | Height at lagging edge (mm) | 6 | 7 |

Individually the parameters that contribute towards increasing the velocity proportionally the turbulence inside there washing drum in decreasing order are

1. Height at leading edge – Most contributing factor

2. Height at lagging edge – Second most

3. Draft angle – Third most

4. Thickness – Fourth most

Therefore results through Taguchi's method of optimization have been brought forth the important parameters to be optimized. By applying these values in the design criteria best result than compared to the existing, can be attained.

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