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CFD ANALYSIS AND OPTIMIZATION OF PULSATOR USING TAGUCHI METHOD

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ABSTRACT

Pulsator(impeller) in the top loaded washing machine gives poor performance while cleaning the dirt as compared with agitator. Optimization of it, considering all the parameters regarding its contribution towards increasing the turbulent flow inside the drum will impact on its performance. Minitab 16 statistical software is used in the optimization process by preparing tabulation which shows valuable parameters column along with results column. After filling all the values, we can easily present the results in the form of pie chart, bar chart, etc., from that, the best effective parameters and its values were taken and declared.

The design of the pulsator is made as per accurate dimensions using the CATIA V5 software. Indeed a design of the washing machine drum with the impression of the impeller was also made. A step file copy of washing machine drum is saved as export file to ANSYS. CFD in ANSYS workbench which is being used widely for solving many fluid flow problems, is used here 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 which is being made in CATIA V5. A separate step file is made for every set of values as generated in Minitab.

Keywords: design and analysis of pulsator (Catia &Ansys), Orthogonal Array; Taguchi Technique;Analysis of Variance, etc.

INTRODUCTION

Washing machine: A washing machine (laundry machine, washing machine, clothes washer, or washer) is a machine to wash laundry, such as clothing and sheets. The term is mostly applied only to machines that use water as opposed to dry cleaning (which uses alternative cleaning fluids, and is performed by specialist businesses) or ultrasonic cleaners. Washing entails immersing, dipping, rubbing, or scrubbing in water usually accompanied by detergent, or bleach. The simplest machines may simply agitate clothes in water while switching on; automatic machines may fill, empty, wash, spin, and heat in a cycle.

Impellers in washing machine

Pulsator: 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.

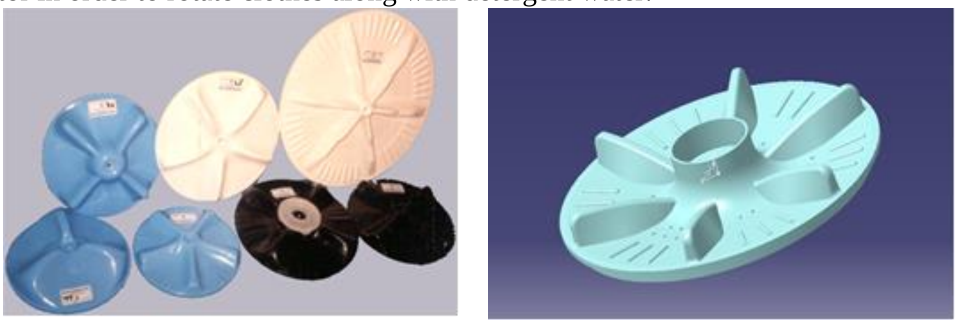

Fig.1. Pulsator

Need for optimization: The optimization of Pulsator is needed for the following reasons.

1. To bring high efficient washing in all aspects
2. To produce higher economy washing machines
3. To satisfy customer in their washing

Selection of pulsator to be optimized: The Pulsator of SAMSUNG WT8600 is taken and optimized.

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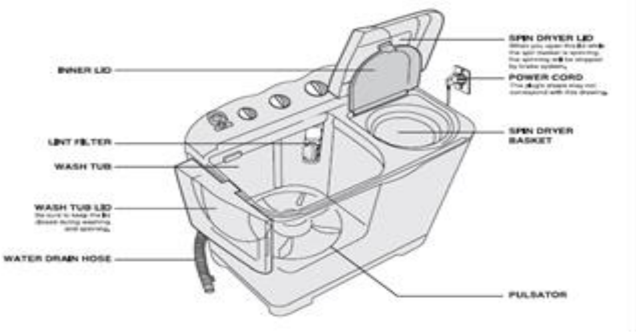

Fig 2.SAMSUNG WT8600

Table 1. Specifications

Dimensions (W X D X H)Mm	820 x 490 x 980
Water Pressure	0.05-0.78MPa 0.5-8.0 kg-f/cm^2
Weight (Net)	33kG
Extraction Efficiency	50 %
Standard Quantity Of Water	65 L
Rating Time	Washing 1Hour / Spinning 15minutes

What is fluid flow? Fluid flows encountered in everyday life include
- Meteorological phenomena (rain, wind, hurricanes, floods, fires)
- Heating, ventilation and air conditioning of buildings, cars etc.
- Combustion in automobile engines and other propulsion systems
- Interaction of various objects in the surrounding air/water

What is cfd? Computational Fluid Dynamics (CFD) 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) Software tools (solvers, pre- and post-processing utilities). CFD enables scientists and engineers to perform 'numerical experiments' (I.e. computer simulations) in a 'virtual flow laboratory Real experiment CFD simulation.

Why use cfd? Numerical simulations of fluid flow (will) enable
- Designers of vehicles to improve the aerodynamic characteristics
- Petroleum engineers to devise optimal oil recovery strategies
- Surgeons to cure arterial diseases (computational hemodynamics)
- Safety experts to reduce health risks from radiation and other hazards
- Military organizations to develop weapons and estimate the damage
- CFD practitioners to make big bucks by selling colorful pictures

Software used: ANSYS Workbench 12 is used here to compute solutions for CFD Analysis. The ANSYS Workbench platform is the framework upon which the industry's broadest and deepest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user through even complex multi-physics analyses with drag-and-drop simplicity.

Taguchi's method design of experiments: The general steps involved in the Taguchi Method are as follows:
1. Define the process objective, or more specifically, a target value for a performance measure of the process. The target of a process may also be a minimum or maximum. The deviation in the performance characteristic from the target value is used to define the loss function of the process.
2. Determine the design parameters affecting the process. Parameters are variables within the process that affect the performance measure that can be easily controlled. The number of levels that the parameters should be varied at must be specified
3. Create orthogonal arrays for the parameter design indicating the number of and conditions for each experiment. The selection of orthogonal arrays is based on the number of parameters and the levels of variation for each parameter, and will be expounded below.
4. Conduct the experiments indicated in the completed array to collect data on the effect of the performance measure.
5. Complete data analysis to determine the effect of the different parameters on the performance measure.

The pictorial depiction of Taguchi method and additional possible steps, depending on the complexity of the analysis is given in the form of a flow chart.

Analysis of variance: The purpose of product or process development is to improve the performance characteristics of the product or process relative to customer needs and expectation. The purpose of experimentation should be to reduce and control variation of a product or process and decide which parameter affects the performance of the product or process. Analysis of variance (ANOVA) is a statistical method used to interpret experimented data and make decisions about three parameters. ANOVA is a technique which breaks down the total variation down into accountable sources; total variation is decomposed into its appropriate components.

Minitab: Minitab is a general purpose statistical package designed for easy interactive use. Minitab was originally designed as a tool to be used in teaching statistics. Its interactive features make it well suited to instructional applications, and Minitab's greatest popularity remains as a teaching tool. However, Minitab is sufficiently powerful that it is also used by many people in analyzing research data.

Uses of minitab

- Data and File Management - spreadsheet for better data analysis.
- Power and Sample Size
- Tables and Graphs
- Multivariate Analysis - includes factor analysis, cluster analysis, correspondence analysis, etc.
- Measurement System Analysis
- Analysis of Variance - to determine the difference between data points.

Designing

Designing of the Pulsator and its model is created in catiav5. The various things about CATIA v5 are given below.

CATIA V5: CATIA (**Computer Aided Three-dimensional Interactive Application**) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company assault systems. Written in C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Creo Elements/Pro and NX (Unigraphics).

CATIA started as an in-house development in 1977 by French aircraft manufacturer Avions Marcel Dassault, at that time customer of the CAD/CAM, CAD software to develop Dassault's Mirage fighter jet, and then was adopted in the aerospace, automotive, shipbuilding, and other industries.

APPLICATIONS

CATIA can be applied to a wide variety of industries, from aerospace and defense, automotive, and industrial equipment, to high tech, shipbuilding, consumer goods, plant design, consumer packaged goods, life sciences, architecture and construction, process power and petroleum, and services.

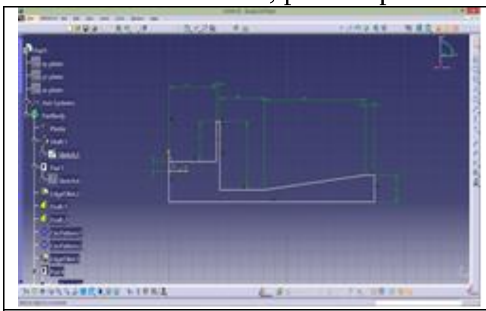

Fig 3.D Sketch

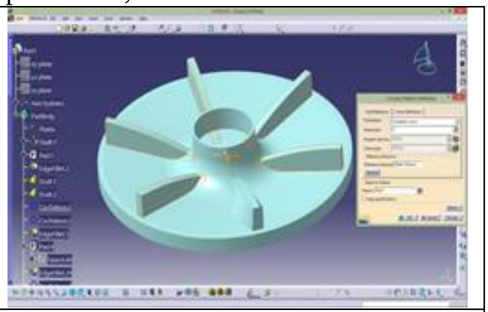

Fig 4.Circular Pattern of the blade

METHODOLOGY

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

Open ANSYS workbench 12 by start workbench, Double Click on fluid fluent to see set of procedures, Right click on Geometry and click import geometry and browse, Browse the step file path and click ok,Then right click on mesh and edit, Click mesh and go to sizing change the relavence center as medium(not course or fine),Right click on mesh and click generate mesh and Meshing will be created, Right click the section and click create named section, Type the name as inlet, Similarly type the section as Outlet and pulsator,Right click on mesh and click update, wait a while and close it.Go to workbench main menu right click on setup and edit, Fluent workspace will open and click check in general, Check whether the flow is defined laminar, Click Fluent database button,Select water-liquid (h2o<l>) and copy and check water-liquid appears.Go to cell zone condition, click edit and select water-liquid.Go to boundary conditions click inlet and edit, Give velocity as 4m/s,Similarly click outlet and edit,Let the pressure value be 0 at outlet,Every problem need to be initialysed. So go to solution initialization,Select inlet in computing from the box,Last is solving. Give no of iteration as 200,The itreation will run for a while and will complete,For getting the results, Go to graphs and animation - vectors – setup, Select scale as 15 and click inlet,outlet,mom(pulsator),walls part1.

The result will appear like this

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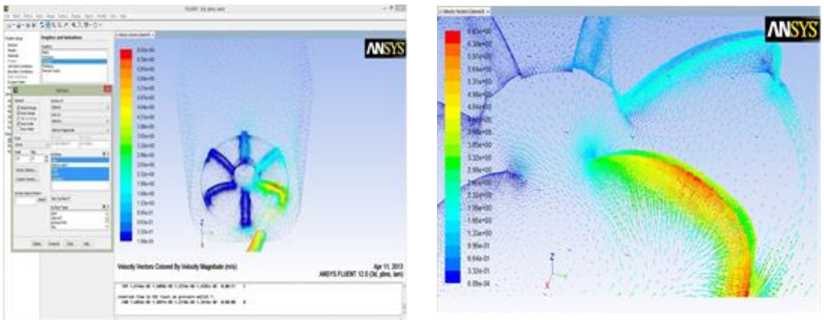


Fig 5. Results

VELOCITY VALUES WITH DIMENSIONS AND RESULTS THROUGH TAGUCHI"S METHOD

Table 2. Dimensions

		Levels				
		1	**2**	**3**	**4**	**5**
Factors	**Draft angle (A)**	30	26	28	32	34
	Thick (B)	20	16	18	22	24
	Leading edge ©	32	28	30	34	36
	Lagging edge (D)	6	4	5	7	8

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

RESPONSE TABLE FOR VELOCITY

Table 4.Response table for velocity

Factor	Level	Total	Mean
A	1	29.65	5.93
	2	31.36	6.272
	3	30.85	6.17
	4	31.66	6.332
	5	31.41	6.282
B	1	31.53	6.306
	2	31.5	6.3
	3	31.34	6.268
	4	30.77	6.154
	5	29.79	5.958
C	1	31.22	6.244
	2	31.57	6.314
	3	31.58	6.316
	4	31.49	6.298
	5	29.07	5.814
D	1	31.33	6.266
	2	31.25	6.25
	3	31.18	6.236
	4	31.63	6.326
	5	29.54	5.908
		154.93	30.986

Total number of observations, N=25 Total, T=154.93

RESPONSE TABLE FOR MEAN

Table 5. Response table for mean

Level	Draft angle	Blade thickness	Height at leading edge	Height at lagging edge
1	6.272	6.3	6.314	6.25
2	6.17	6.268	6.316	6.236
3	5.93	6.306	6.244	6.266
4	6.332	6.154	6.298	6.326
5	6.282	5.958	5.814	5.908
Delta	0.402	0.348	0.502	0.418
Rank	3	4	1	2

ANOVA TABLE

Table 6. ANOVA table

Sum of variance	**Sum of Square**	**Degree of freedom**	**Mean sum of square**	**F_{cal}**	**F_{table} at $\alpha = 0.05$**	**Remarks**
A	0.515464	4	0.128866	0.68367	0.623	**Significant**
B	0.432504	4	0.108126	0.57364	0.623	Insignificant
C	0.934744	4	0.233686	1.23977	0.623	**Significant**
D	0.546264	4	0.136566	0.72452	0.623	**Significant**
Error	1.507928	8	0.188491			
Total	3.936904	24				

In factor **'B' F_{cal}<F_{table}** i.e. It is clear that the factor B has insignificant effect on the velocity, since F_{cal} for the factor B is lesser than F_{table}. Hence factor A, C, D are the best factors among the four factors available to us.

COMPARING RESULTS WITH MINITAB

GENERAL LINEAR MODEL: VELOCITY VERSUS DRAFT ANGLE, BLADETHICKNESS

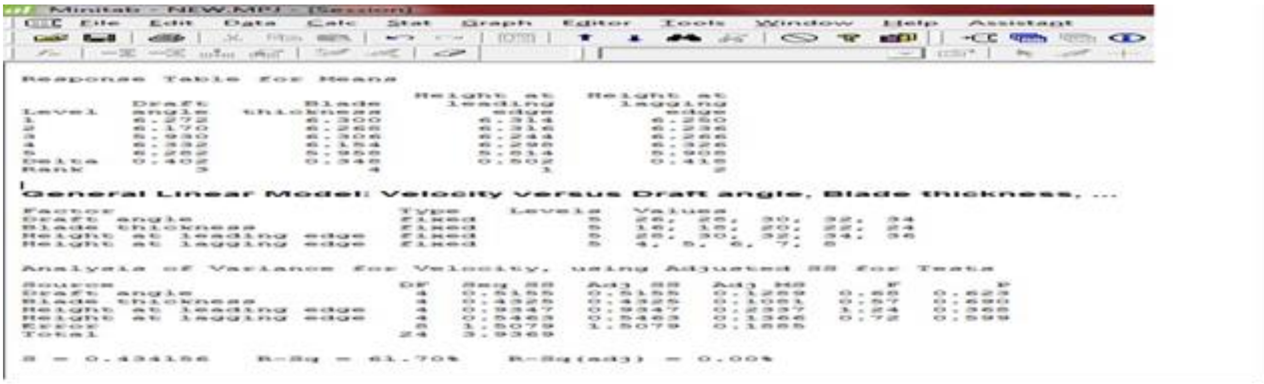


Fig 6. General linear model in MINITAB

MAIN EFFECTS PLOT FOR MEANS IN MINITAB AND RESIDUAL PLOTS FOR VELOCITY

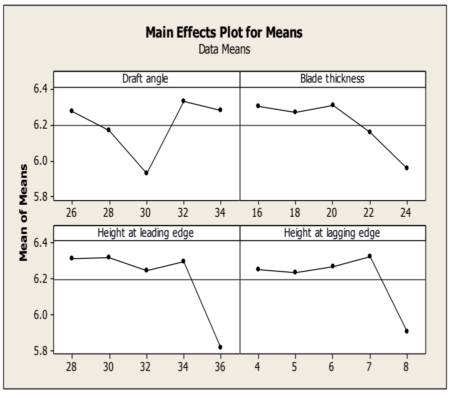


Fig 7. Main Effect Plot for Mean

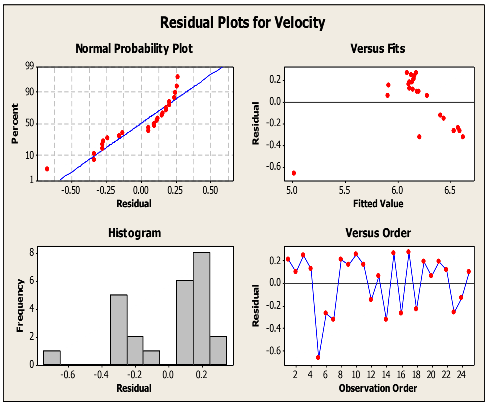
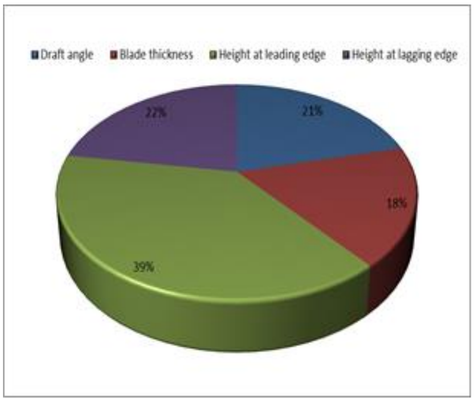


Fig 8. Residual Plots for Velocity

PIE CHART FOR INDIVIDUAL CONTRIBUTION



Parameters	F - VALUE	%
Draft angle	0.68	21.184
Blade thickness	0.57	17.757
Height at leading edge	1.24	38.629
Height at lagging edge	0.72	22.43
Total	3.21	100

Fig 9. Pie chart for individual contribution

COMPARISION OF ORIGINAL AND OPTIMIZED PULSATOR

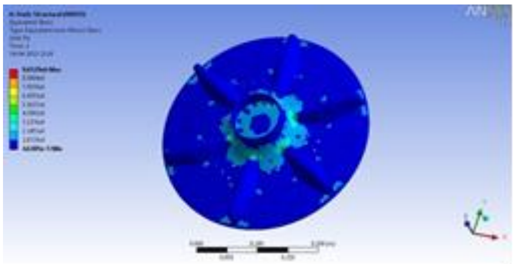


Fig 10. Original pulsator stress

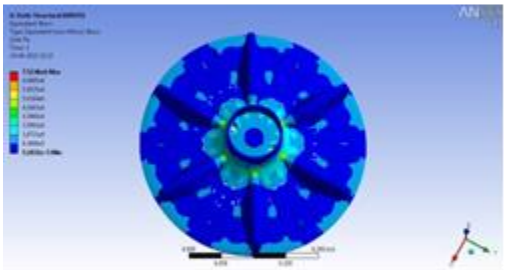


Fig 11. Optimized pulsator stress

OPTIMIZED PULSATOR VELOCITY

Analyzing the optimized pulsator, we get velocity = 6.45m/s, which is higher than the existing one.

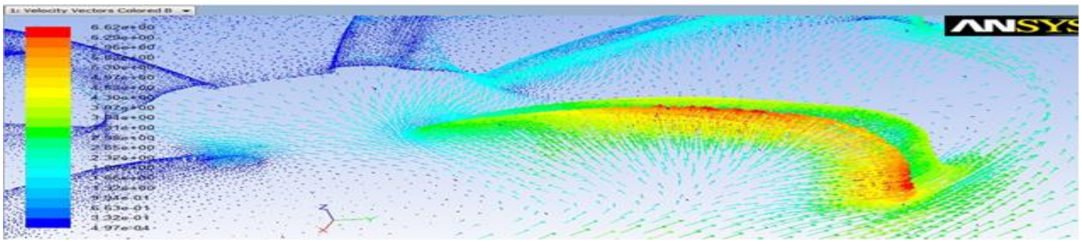


Fig 12. Velocity of optimized pulsator

COMPARING VALUES

Table 7. Comparing Values

FACTORS	Existing Value	Optimized Value
STRESS (N/m²)	9.65E+06	7.52E+06
VELOCITY (m/s)	6.36	6.45

These results show the reduction in stress and strain values as well as increase in velocity compared to existing pulsator.

CONCLUSION

Optimization is carried out in a sequential manner, starting from designing till the analysis in Taguchi's way as shown above. From the analyzed results, we can conclude that the best value with respect to each parameter are listed below

Table 8. 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 the washing drum in decreasing order are,

1. Height at leading edge – 39%
2. Height at lagging edge – 22%
3. Draft angle – 21%
4. Thickness – 18%

We also find stress and strain reduction in the optimized Pulsator when compared with the existing one. By applying these values in the design criteria best result than compared to the existing, can be attained.

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