Design and Development of a Commercial Hair Trimmer Cleaner Unit

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Abstract

A product design and development process has been adopted to study and improve the performance of unit cleaner system. A hair trimmer with liquid detergent in cartridge is fixed as a cleaner system to design and analyse. The 3D model of the system is designed with NX CAD software. The modification is cartridge unit is made on counter face to increase the turbulence of the fluid in the wash zone. The file has been extracted and imported in LS Dyna for meshing the model for detergent liquid flow analysis. The velocity vector and pressure magnitude of the fluid flow is analysed through a StarCCM+ higher fluid analysis software. The input process condition of the pump in cartridge assemble unit has a speed 2000 rpm and velocity of the liquid as 1 m/s. From the analysis, the suction pressure noticed at the pump zone is 950 Pa and the discharge of fluid in the pump is 850 – 900 Pa at wash zone. Difference in fluid velocity found decreased and it is in the range of 0.8 to 0.95 m/s. The predominant factor in the design is alternate openings in case baffle has increased the turbulence in pressure and the velocity of the fluid found same.

Introduction

In an assembling, every single result of the business is significant. To expand the market interest, it is required to recognize the advancement of the item from one phase to another. Insignificant headway in comparable challenging item may prompt drop the competing confidence on the lookout. The elements like quality, lead time, cost, straightforwardness and progression will contend the item in the market [1]. In current scenario, it is not only to perform the task and it is also important to focus on right task. In general, it is said as lean enterprising system to reduced time, control waste and simplify the process without compensating product quality. The product life cycle management does not perceive anything about the product or its process and the main object is to find betterment in the existing system. one of the predominant products competing in the market against the gender and age is hair trimmer. There are different methods to handle human hair trimming process [2, 3]. It is very important to ensure that the unit cleaner process used to trim the hair is clean and safe for the next cycle or next turn of day. At the same, the there are skin transmitting disease which will lead health (life) losing issues [4]. In addition, residues in the hair trimmer will different skin issues such as; anxiety, pain, skin irritation and skin patches [5]. In order to address the safety and health issues, the trimmer layers are cleaned with detergent medium / soap water. To discuss in detail, the research has been performed to develop the shaving unit with cartridge cleaner system. To handle this issue, product development processes is one of the best tools used to identify the best and feasible solution. Beckera et al (2013) made an item to report on Philips shaving instrument using product development processes [6]. From the analysis it has been acknowledged to paper work on shaver machine with details on advancement stage. Design and modelling of product with virtual tool is one of the best techniques, used to predict the optimal solution [7]. Therefore, an attempt is made to develop a unit cleaner system comparing the existing products in the market and identifying a suitable design for the product development of shaving instrument.

In this research, an attempt is made to study a real time industrial product to analyse and improve the performance of the system. Product chosen for the analysis is a hair trimmer, which is important against to the gender and age factor. Repeated use of uncleaned system / product will cause skin problems and may lead to severity in health issues. To overcome the shortfalls in hair trimmer, the cartridge unit with a detergent medium is proposed to design. In addition, a design is planned with a small pump to circulate the fluid on wash zone. A 3D model and computational fluid dynamics for the flow of detergent fluid from the cartridge to wash zone and back to cartridge are simulated. In order to improve the flow of fluid, a modification in cartridge baffles are made. From the simulation, the velocity vector and pressure flow of the fluid is studied to infer and recommend the system.

Product Design And Development

In this cycle, the quantity of item accessible in the market are recognized for examination and issue ID. For every item, the particulars and highlights are concentrated exhaustively to investigate execution of the product. Some of the basic variables fixed for correlation are; outer force, size, cost and convenience. From the recorded factor, the material examination is likewise one among the significant factor that

is considered as disadvantages present in items accessible in the current market. For the unit cleaner, the prerequisites of an item and it audit are gathered from the market. Figure 1 shows the stages engaged with item advancement of a unit cleaner. The task is launched with information assortment and the course of events is planned for the new item configuration is created according to the norm. In idea determination stage, the item plans are drafted/displayed utilizing various instruments; accordingly scarcely any virtual testing is additionally proposed to complete. For this situation the business item accessible in the market are recognized to make a correlation study. The significant item in the market is Philips, Panasonic, Braun and other district made neighbourhood items. From every one of the plans, best ones are chosen and further defences will be conveyed. Followed by check and approval, the plan archives, details and so on are inspected for the following advancement. The end clients' requirements are met by practical testing and check of item. In tooling stage, the apparatuses for the creation are noted and customized for assembling the item. The tooled tests are delivered and tried. After which the item is brought to showcase for its application.

Problem Identification And Concept Valuation

At this stage comparison a between the existing product and future product to be developed in design are evaluated. To perform the product concept valuation, the PUGH matrix has been made to compare and contrast the details available on existing product. As an initial point, fixing a product datum line for validation is an important task. In this research, the validation score is fixed in the range of -2 to + 2 with tie line. Each and every product are verified and scored to identify the novelty in the product with respect to the different concept questions. The questionnaires to identify the product are assemble level, product quality, usability, product cost, aesthetics (finishing, colour and appearance), number of spare / parts and product compactness. Response to the questionnaires with the score card arrived through PUGH matrix is

given in Table 1. It has been analysed to study the feasibility and challenges in modification of the product is identified. From the analysis it has been proposed to develop a separate cartridge unit with a detergent medium

Computation Fluid Dynamic And Design Flow Analysis

In this paper, the flow of detergent water (1% volume fraction) from the cartridge to unit cleaner is simulated through computation fluid dynamic (CFD) analysis. The 3D models of the cleaner unit are used to design with Unigraphics – NX CAD modelling software. Figure 2a shows the 3D model of hexagonal cartridge designed to clean the trimmer wash zone. The design models are stored in the form of 'ug.prt' format for easy transfer. Further the designed models are transferred to LSDyna software for meshing (discretization) of 3D model. In continuation to the demonstrating and meshing, the files are StarCCM+ software for computation fluid dynamic analysis. The data storage for meshing and analysis are in the form of parasolid to access easy in the simulation platform. From the analysis, the vector analysis and pressure ranges represent the flow direction of research proposed in product design analysis.

The simulation is performed as a direct engineering analyser which is used to perform turbulence model for incompressible fluids. The continuity equation for the pump flow control is composed as:

$$\nabla \vec{W} = 0 \quad \text{- Eq. 1}$$

and $\vec{W}$ is the relative velocity of the fluid which is commonly followed equation for pump flow analysis in CFD.

In some cases, the three – dimensional flow analysis are made Naviers – Stoke equation as given below [8]:

$$\rho [\vec{W} \cdot \nabla] \vec{W} = - \nabla P + \nabla \tau + S_m \quad \text{- Eq. 2}$$

which denotes density of the fluid (ρ); pressure under static condition (P); shear stress (τ) related to fluid viscosity and other additional force components (S_m). However, in this research, there are no mathematical or numerical equations to consider. The StarCCM+ is a reasonable package to produce better results on fluid dynamics. Table 2 illustrates the boundary conditions used for CFD analysis of unit clear. Similar results have been used for different cleaning system [9]. Most of the CFD analyses are made for types of pumps with different fluid using conventional fluent software [10, 11]. There are many bottleneck studies on development of product for commercial applications [12 – 14].

Explicitly the pump fluid is maintained with a constant density with steady state flow energy. In actual condition, the unit cleaner is used to pump the water from cartridge to cleaner wash out region and back

to cartridge region is about 3.0s of time. On continuous pumping the amount water flow varies and the level of water in the cartridge will be in flotation. To compare the fluid dynamics throughout the system, the CFD analysis has been performed for a time band of 5s using the StarCCM+ software.

With the above interaction condition, the water stream from the cartridge unit to clean out district is reproduced and the equivalent got back to cartridge locale is recognized. The investigation is developed regarding velocity vector and pressure component part for both two dimensional and three – dimensional examination.

Product Analysis Using Cfd Analysis

The arrangement of unit cleaner system was immersed in a liquid detergent (water + detergent) case at initial condition and pump actuating situation designed with Unigraphics NX modelling is shown in Fig. 3. The direction the liquid flow from the cartridge to unit system will be varied in a different direction with respect to the case design. The level of liquid available in the cartridge is 27 mm. The level of liquid in the cartridge found pumped within 0.3 s and the same liquid starts to reach same cartridge with a second. For better understanding the fluid flow direction from the cartridge (water side) to unit cleaner (air side) is simulated with real time basic working condition as a boundary condition of unit cleaner. During the cleaning process, the pump is actuated to rotate at a speed of 2000 rpm to pump liquid from pump volute to washout region and back to cartridge. At a maximum velocity of detergent fluid is 1 m/s and maximum pump pressure of 1000 Pa. The amount of liquid from the cartridge will be pumped at a flow rate of 1.8g/s (that is 18 ml/s). The rotating pump has high efficiency to acquire entire liquid from the cartridge to pump and splash over wash out region. The maximum time required to complete one cyclic flow of the liquid is 3.8 s. Figure 4 represents the fluid flow from pump volute to a unit cleaner washout region and back to cartridge with respect time gap. At initial condition, the liquid from the cartridge starts to reach the washout region 0.3s of time. With the same pump pressure, the water starts to spill out from the wash region to cartridge within a second. It has been accomplished only because of cartridge design and paying path to increase the pressure on alternate walls.

For detailed discussion, the velocity magnitude and pressure of the fluid at different regimes such as cartridge – pump – wash zone have been identified in the form of contour vector as shown in Fig. 5. At the pump zone the maximum fluid velocity has been noticed and the turbulence increased at cartridge during pump suction at a maximum velocity of 1 m/s. At this regime, the maximum pressure is noticed at the pump rather than the other regimes. Fluid from the suction point found moving towards (air) wash zone at a uniform velocity. Maximum pressure generated at the suction of the fluid is 950 Pa and it is uniform throughout the pump. At pump discharge point, the pressure found decreased and it is in the range of 850 to 900 Pa, as the wash out zone is open to air. Flow of fluid from the pump to wash zone is in lamellar (parallel) flow and the level of fluid velocity found in the range of 0.8 m/s to 0.95 m/s. The distraction happens at the end of pump orifice and lift velocity found reduced. Subsequently, the turbulence has originated at air zone due to high velocity of the fluid striking over the ridge. After a

maximum turbulence at the wash zone, the function of the fluids completed and the same drains with respect to the gravity direction.

To discuss in detail, the fluid flow direction on cartridge has been simulated for the alternate walls. The three – dimensional (3D) design of the cartridge having baffles with alternate openings in the case housing is given in Fig. 6a. The alternate design supports in increasing the fluid pressure and helps to squeeze the fluid in wash zone. For the same simulating pressure and fluid velocity; the fluid flow direction and its magnitude are identified through fluid flow analysis. Figure 6b represents the initial position of fluid to pump out from the wash zone and cartridge. Initially, the pump starts to drive the fluid from cartridge and moves towards first housing (Fig. 6c). At the same thriving pressure, the fluid squeezes to baffle housing with same pressure and flow of fluid makes ballets towards the openings. At the second stage, the fluid flow at first opening and produces severe turbulence and leads to move toward the alternate openings in the baffle. Figure 6d, represent the turbulence and the maximum fluid pressure generated over each baffle. The rate of pressure found decreased from initial point to end of cartridge zone. To discuss in detail the 3D view of the simulation is reported for better understanding. Figure 7 shows the flow of fluid in three dimensional with velocity magnitude. The fluid flow spills out of the cross wall and side ribs at varying velocity. The velocity magnitude found less while crossing the housing and it has weightage while crossing the baffle openings. It is also noticed that the magnitude turbulence of the fluid found less while crossing the baffles. The vortex / swirl of the fluid is due to multi corners at a close angle in the inner close wall. The velocity of the fluid vortex flow at the beginning (from the pump) is 1 m/s. At the same, the velocity found reduced due to atmospheric pressure and it found reduced with gravity flow.

Summary Of The Work

Thinking about the skin security and medical problems because of the rehashed utilize the hair trimmer, an answer has been shown up. The presence of hair garbage and skin soil in the trimmer may be put away in the pocket zone. To eliminate such toxin, detergent water is utilized in the cartridge and siphoned to wash zone. Detergent pumped will take the cleanser liquid and washes the flotsam and jetsam and different impurities. Therefore, the substance gathered in the washed zone will be dropped to cartridge through gravity stream. The pressing factor created in the siphon zone has kept an adequate source to eliminate undesirable sources and clean the wash zone in 5 sec. The plans in the cartridge lodging and recreation of cleanser liquid has affirmed the disturbance stream and pressing factor variety in the cartridge unit. From the examination it has been affirmed that the proposed cleaning unit with cleanser liquid will support to keep up the hair trimmer sterile and protected to work for various employments.

Conclusions:

From the investigation, the hair trimmer cleaner is utilized to plan and re-enact to fix the attainability of the item to create and popularized. Following are the focuses to drawn from the recreation and investigation of the cartridge for disturbance stream:

1. On simulation, the pump working pressure induced in the pump is 950 Pa and which is close to the actual system of the pump maximum pressure of 1000 Pa. At the same the maximum fluid discharge at the wash zone is 1.8 g/s of flow to clean the hair trimmer cutting zone.
2. With respect to velocity contour, the maximum velocity of the detergent liquid recorded at the pump is 0.95 m/s. It was found reduced due to turbulence in the wash zone and subsequently increased due to gravity flow. On continuous pumping, the intensity of pressure or velocity found significant throughout the cartridge unit.
3. The baffle in the cartridge is designed on counter face of the housing. It has induced the fluid to flow on alternate openings and turbulence found increased. Arrangement of baffles may also support in settlement of debris drawn from the wash zone.
4. It may support to collect the hard debris over the cartridge and supports to settle

Therefore, the proposed design is suitable to adopt in product design of hair trimmer to clean and / or wash the debris from the air zone to cartridge. This will help the trimmer to maintain hygienic and safe service on next usage.

Declarations

Availability of data and materials: Not applicable

Competing interests: Not applicable

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Tables

Table 1: PUGH Matrix for the product existing in the online market

Product & factors	Product 1	Product 2	Product 3	Product 4
Assembly	0	-1	-1	-1
Manufacturability	0	0	1	0
Usability	0	0	0	0
Cost	0	-1	0	0
Aesthetic	0	1	0	2
Number of parts	0	-1	1	0
Compact design	0	0	0	0
Net score	0	-2	1	1
Rank	0	4	2	2
Continue	No	NO	NO	NO

Table 2: Boundary conditions used for CFD analysis of unit cleaner

Boundary condition	Range	Units
Density of the medium	0.9	g/cc
Total pressure (inflow)	1000	Pa
Cartridge reservoir	100	ml
Mass flow rate (out flow)	1.8	g/s
Operating temperature	298	Kelvin
Fluid initial velocity	0	m/s
Maximum time step	5	s

Figures

Figure 1

Stages involved to develop a unit cleaner product

(a) 3D model of Trimmer cartridge

(b) Problem flow analysis

Figure 2

Virtual Design of the cartridge and stages in problem analysis

Figure 3

Design represents the arrangement of unit cleaner system at initial condition and pump actuating situation.

Figure 4

Direction of liquid from cartridge – pump – unit cleaner – back to cartridge with respect to the time duration

Figure 5

Contour image to represent the velocity magnitude and pressure contour of the fluid flow between the cartridge – pump – wash zone.

Figure 6

Fluid flow direction and pressure variation on cartridge at different time duration.

Figure 7

Fluid flow at baffle casing and openings indicating the flow velocity magnitude.