

# Conceptual Design of a Customer Friendly Variable Volume and Variable Spinning Speed Washing Machine

C. A. Akaash Emmanuel Raj, V. R. Sanal Kumar

**Abstract**—In this paper using smart materials we have proposed a specially manufactured variable volume spin tub for loading clothes for negating the vibration to a certain extent for getting better operating performance. Additionally, we have recommended a variable spinning speed rotor for handling varieties of garments for an efficient washing, aiming for increasing the life span of both the garments and the machine. As a part of the conflicting dynamic constraints and demands of the customer friendly design optimization of a lucrative and cosmetic washing machine we have proposed a drier and a desalination system capable to supply desirable heat and a pleasing fragrance to the garments. We thus concluded that while incorporating variable volume and variable spinning speed tub integrated with a drier and desalination system, the washing machine could meet the varieties of domestic requirements of the customers cost-effectively.

**Keywords**—Customer friendly washing machine, drier design, quick cloth cleaning, variable tub volume washing machine, variable spinning speed washing machine.

## I. INTRODUCTION

THE washing machine is an essential home appliance to every family. The manufacturing of lucrative washing machines has been an important issue for the appliance industry. Current environmental awareness demands the improvement of washer efficiency with less product and maintenance cost. The reduction of washer mass is of crucial importance not only for environmental, but also for low price. Although many design modifications have been made on the existing washing machines over the decades, it remains big and heavy, weighing usually over fifty kilograms. Most of the washing machines experience an unbalanced rotation during spinning the masses as the clothes are not evenly dispersed in the drum. This issue was traditionally solved by adding a large concrete mass to the system. The vibration problem in washing machines originates from a rotating imbalance. Imbalance is caused by unevenly distributed load inside the washing machine's inner tub or drum. Several research has been performed on washing machines to analyze the suspension system to gain understanding on how to prevent "the oscillatory walk of washing machines" i.e., position shifting [1]-[3].

Evangalos and Iakovos [3] proposed an innovative method of minimizing vibrations and thus reliably stabilizing the washer was also presented. This technique produces excellent results, although it may increase the machines production cost.

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Mukherje and Bhardwa [4] carried out studies on vibration control methods of front-loaded washing machine. The authors reported that the vibrations can be controlled with vibration isolation/dampening pads, which can prohibit shaking the whole house during the spin cycle.

Tandale et al. [5] carried out studies on modeling, design and control of small component cleaning wash machine, with emphasis on lightweight, portable appliances. The machine was developed from the scrap materials to enhance reuse and recycle policy. This resulted in very much less production cost.

To create turbulence in the washing area of the immersed part of the component Tandale et al. [5] used air nozzles for blowing air of enough pressure to create the required turbulence enough to clean notches and critical areas. To enhance the washing water, they use the heating coils which are placed at the bottom of the tank. These coils are also being used from the oil heaters which had been there in the scrap. The chemical is also to be added in the water [5]. Thomas and Viktor [1] studied on several aspects of vibration dynamics in washing machines, viz., the capacity maximization through the study of tub movement, the vibration output from the machine to the surroundings, and the "walking" tendency of the system

Another researcher Gianmarco Bressanelli et al. [6] have analyzed and published methods to reshape the washing machine industry by making the machine economical. The research project discussed in their paper focuses on the washing machine (WM) industry for several reasons [7]. The product-service systems are the sustainable strategy suggested when the usage phase of a product is predominant [8]: for WMs, the utilization phase affects more than the 60 % of the total cost of ownership [9] and its environmental impact is much higher than the production and transportation stages [10]. The WMs have large chances of environmental improvement: even though customers' choice is mainly driven by price (instead of energy or water consumption) [11], the life cycle cost brings customers to opt for products with less energy and water consumption [12]. However, this seems not to increase the sales volume, making this disclosure potentially unattractive from a business perspective.

Literature review reveals that before the invention of the washing machine, clothes were washed and cleaned by agitating them with a typical pounder [13]. Most of these

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machines needed to be hand-cranked and clothes tended to get tangled around the rotating dolly elements. The tangling of the clothes was a problem that inventors overcame using an oscillating movement. Fiell [1] reported that S.S. Shipley used gas burners to heat the water, which was also another problem at the time. Fig. 1 shows a wooden domestic washing machine with a dolly-style agitator [1].



Fig. 1 Wooden domestic washing machine with a dolly-style agitator, 1920 [13]

Nowadays, washing machines are much more energy-efficient than the earlier versions (see Fig. 2) by adjusting the power consumption to the size of the load. New generations of machines are currently being developed that will be even more energy-efficient and will also eliminate the need for ecologically harmful detergents [13].

Energy-efficient and more ecological machines are actually important design concerns. New materials and new manufacturing technologies mean that development is ongoing and other characteristics will be exploited and incorporated. A radical change of the washing concept will probably be the next development step, which will depend on inventor imagination and the degree of research investment. Machine-user characteristics will be explored in the near future, since human-centred design philosophy is now a reality. Many companies are designing and manufacturing customised products for restricted groups of clients to satisfy individual needs. Technologies such as rapid prototyping and rapid tooling can be used for rapid product development and will certainly push for the design of personal and individually customised products.

In this paper we have aimed at overcoming the various disadvantages of the usual customary designs such as high levels of wear due to the movement between the closely placed drum and the prime body and the unwanted wastage of water and energy during washing of clothes irrespective of the amount of clothes being loaded, i.e. even if small amount of clothes are being loaded, the customary machine tends to use the same amount of power and speed that a large or heavy amount of clothes require. These are some of the potential reasons that reduce the lifetime of the usual customary washing machines.

Though many analyses have been carried out and various literature exists, they are not feasible to the common man due to the complexity of the technique used or the amount of time required to implement the technique. This down the lane has led to the increase in surge for the development of a more economical design and the manufacturing of a single machine that overcomes the existing challenges. This design focuses on being more customer friendly when compared to the existing customary designs, this is achieved by the usage of the specially designed variable volume drum and the variable spinning speed rotor, thus overcoming the potential disadvantages and increasing the lifetime of the washing machine when compared to the existing customary design [1]-[15].



Fig. 2 Ribby twin-tub washing machine, 1932 [13]

It is well known that artificial muscle technologies have wide potential applications in biomimetic machines, including robots, industrial actuators and powered exoskeletons. A powered exoskeleton is a wearable mobile machine that is powered by a system of electric motors, pneumatics, levers, hydraulics, or a combination of technologies that allow for limb movement with increased strength and endurance. The electrically activated polymers (EAP's) based artificial muscles offer a combination of light weight, low power requirements, resilience and agility for locomotion and manipulation. Future EAP devices will have applications in aerospace, automotive industry, medicine, robotics, articulation mechanisms, entertainment, animation, toys, clothing, haptic and tactile interfaces, noise control, transducers, power generators, and smart structures. Pneumatic artificial muscles also offer greater flexibility, controllability and lightness compared to conventional pneumatic cylinders. Pneumatic artificial muscles are aiding performance according to thermodynamic principles. The authors are attempting to make use of the pneumatic artificial muscles for designing the variable volume and variable spinning speed washing machine tub herein.

## II. CONCEPTUAL DESIGN

In this preliminary study, we are presenting a conceptual design of a customer friendly variable volume and variable spinning speed washing machine. Note that for designing the variable volume tub we are proposing smart materials with artificial muscle with pre-designed viscoelastic properties for adjusting the volume corresponding to the washing clothes size and weight. The merits of the smart materials with artificial muscle are invoked herein for designing a customer friendly variable volume and variable spinning speed washing machine.

After being meticulously worked upon the various disadvantages and the issues lurking in the washing machine industry, a completely innovative and daring approach was made towards the vision of the washing machine design. Herein we are presenting a customer friendly variable volume and variable spinning speed washing machine. Figs. 3 and 4 show the 3D drawings of the proposed washing machine.



Fig. 3 The conceptual design of the main physical body of the variable volume and the variable spinning speed washing machine

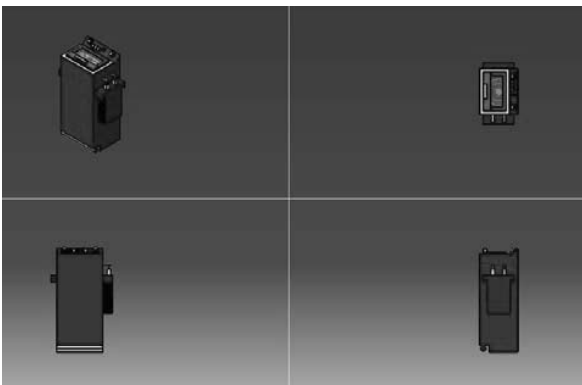


Fig. 4 Various 3D views of the proposed washing machine (corresponding to Fig. 3)

The main focuses of the design tend to be on the variable volume drum. The variable volume drum was designed using smart materials and pneumatic cylinders. Fig. 4. Shows the 3D diagram of the variable volume drum. The concept works based on the principle of contraction and expansion of the drum, therein saving unwanted volume of the drum like in the conventional design from creating unwanted friction leading to the various losses arriving in the conventional washing machine, that contribute heavily to the presence of the average efficiency machine existing today.

The 3D diagram clearly showcases the purifier connected to the machine, with its inlet and outlet connecting directly towards the pipes of the variable volume drum. The Conceptual design boasts it's absence of outlet port. This was made possible due to the presence of the purifying unit. Detailed discussions on the purifier/purifying unit will be made later in the paper.

Note that for designing the variable volume tub we are proposing smart materials with artificial muscle with pre-designed viscoelastic properties for adjusting the volume corresponding to the washing clothes size and weight. The designed smart materials are popularly called responsive materials that have one or more properties, which can be significantly changed in a controlled fashion by external stimuli.

The preloaded settings in the washing machine helps control the pneumatic cylinders, i.e. when a small amount of clothes is to be loaded, the settings is changed which leads to the expansion of the pneumatic cylinders which in turn pushes along the viscoelastic smart material and thus the drum contracts to the required size therein producing lot of space between the drum and the prime body and reducing unwanted

Friction. In this same machine when a larger volume of clothes are to be loaded for a wash, the settings are changed and the pneumatic cylinders contract and pull along the viscoelastic drum and expanding it. This could be easily understood after a clear cut view of the drum as shown in Fig. 6.

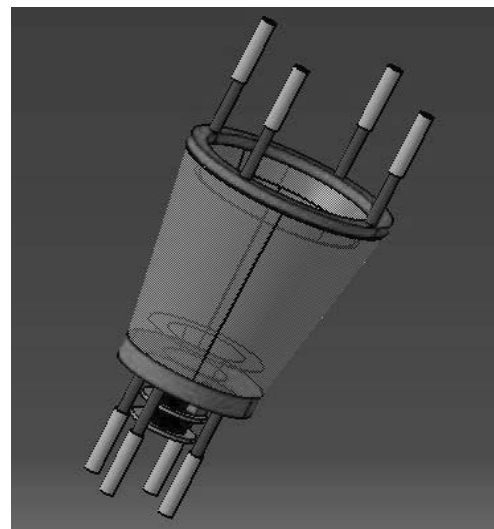


Fig. 5 The conceptual design of the variable volume drum

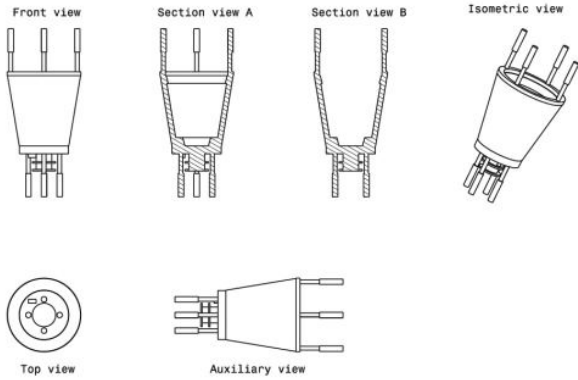


Fig. 6 Different 2D views of the variable volume drum

The conventional drum is usually a metallic tub attached with a flywheel over which the belt from the rotor rotates. The proposed conceptual design (see Fig. 5) shares this similarity with the usual conventional washing machine. The section views A and B in Fig. 6 show the contraction of the drum and give a visual idea of the variable volume drum. Similar to the conventional washing machine drum, the flywheel below the variable volume drum is connected to the rotor. If focused on Fig. 5, it is observed that a purple cuboid is observed which is a heating element #1. Another adaptation from the conventional washing machine is the heating element. Similar to usual customary washing machine drums, the heating element is placed on the variable volume drum.

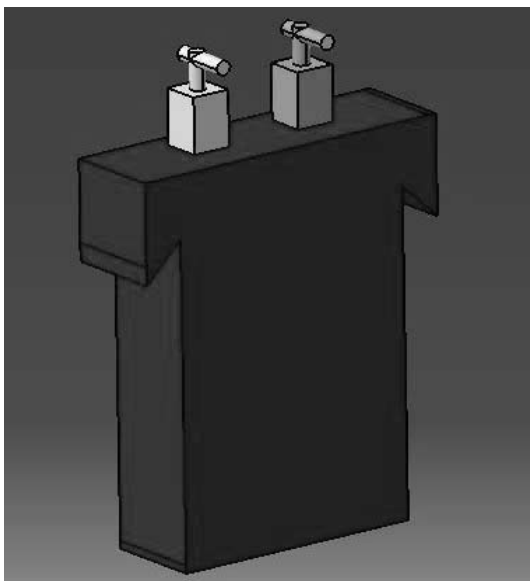


Fig. 7 The 3D view of the purifier

Another focus of this conceptual design is the desalination system or the purifier. The purifier model shown in Fig. 7 attached in the side of the machine has an inlet port and an outlet port on the outer surface. The inlet port of the purifier is connected to the outlet of the drum. Thus when water enters through the inlet of the machine, it flows through the inlet of

the drum and then is used for the respective washing operation, after being used the water is sent through the outlet which is connected to the inlet of the purifier. The water is then purified and sent through the outlet of the purifier, which is in-turn connected to the inlet of the drum, thus closing the cycle and enabling reuse of the recycled water. This could be understood by studying Fig. 8, which clearly illustrates the inner side of the purifier. As seen in Fig. 8 the piping showcases the path flow of water from the inlet of the purifier to the outlet of the purifier.

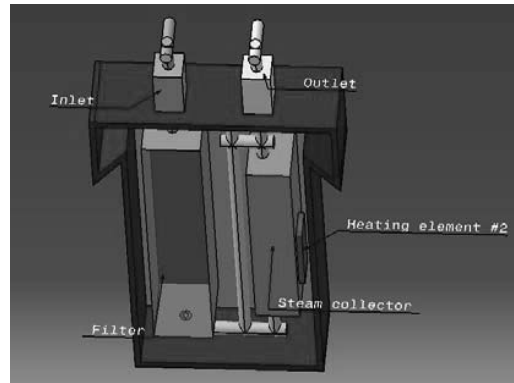


Fig. 8 Interior 3D view of the Purifier

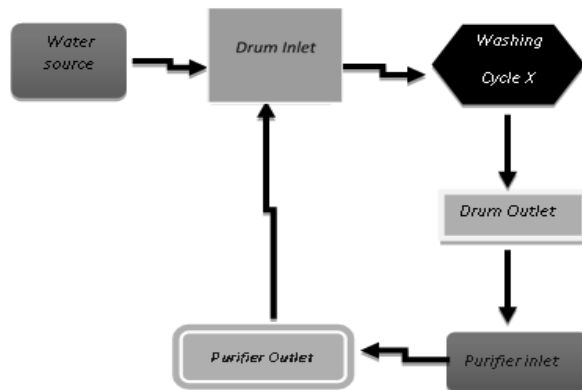


Fig. 9 Flowchart showing the water flow path for purification process

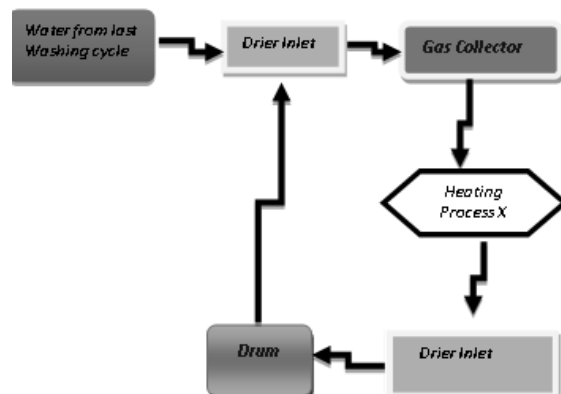


Fig. 10 Flowchart showing the steam flow for drying process

Herein we have proposed demineralization for the filtering process. Modern technology has paved way for single stage filtering demineralization process. Thus water from the outlet of the drum flows through the inlet of the purifier and therein passes through the filter. The demineralized water coming out of the filter passes through the outlet of the purifier which is sent into the drum for the consecutive operation. The water flow path could be more easily understood on studying the flowchart shown in Fig. 9. In this design we have also proposed a drier system. Unlike other standalone clothe driers usually found beside washing machines. In this design we have proposed an inbuilt clothe drier system.

The drier system is placed inside the desalination system. The drier system shares piping with the desalination system. Fig. 10 shows the flowchart depicting the path of the steam flow. As seen in the flowchart given in Fig. 10, note that the water after its final washing operation flows into the drier system through the purification system. As shown in Fig. 8, the piping for the drier system and the desalination system is shared. Thus, the soap water from the final washing operation passes through the filter and the drying process begins. The demineralized water, now passes through the other piping arrangement and enters the gas container. The heating element #2 present near the gas container increases the temperature of the water and converts the water into steam. This steam is now sent into drum for the further drying process. This steam keeps circulating through several drying circles before the steam keeps evaporating and the clothes are dried.

### III. CONCLUDING REMARKS

In this paper we have proposed smart materials for making variable volume and variable spinning speed tub for loading clothes for reducing the vibration for a better dynamic performance. The smart materials with artificial muscles are recommended herein for designing a customer friendly variable volume and variable spinning speed washing machine. As a part of the varieties of dynamic limitations and demands of the customer friendly design optimization of a worthwhile and esthetic washing machine we have proposed a drier and a desalination system capable to supply desirable heat and a pleasing fragrance to the garments. We thus concluded that tub made with smart materials combined with a drier and desalination system will meet the varieties of home necessities of the consumers gainfully. This paper is a pointer towards for a commercial design of washing machines lucratively.

### REFERENCES

- [1] Thomas Nygård and Viktor Berbyuk, "Pareto optimization of a washing machine suspension system," 2nd International Conference on Engineering Optimization, September 6 - 9, 2010, Lisbon, Portugal.
- [2] Conrad, D.C., The Fundamentals of Automatic Washing Machine Design Based upon Dynamic Constraints, Ph.D. Thesis, Purdue University, 1994., 261 pages, ISBN 9780591345728.
- [3] E. Papadopoulos, I. Papadimitriou: Modeling, Design and Control of a Portable Washing Machine during the Spinning Cycle, Proceedings of the 2001 IEEE/ASME International Conference on Advanced Intelligent Mechatronics Systems (AIM 2001) pp. 899-904.
- [4] C.K Mukherje and Ajay Bhardwaj, A Study of Vibration Control Methods for Front Loaded Washing Machine, International Journal on Recent Technologies in Mechanical and Electrical Engineering (IJRMEE) ISSN: 2349-7947 Volume: 1 Issue: 2, 2014, pp. 47-48.
- [5] Tandale P, Shivpuje S, Ladkat S, Simran K, Design of Washing Machine for Cleaning of Small Components, International Journal of Emerging Engineering Research and Technology Volume 3, Issue 4, April 2015, pp. 30-36, ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online).
- [6] Gianmarco Bressanella, Marco Perona, Nicola Sacconi, Reshaping the washing machine industry through circular economy and product-service system business models. Procedia CIRP 64 (2017) 43 – 48.
- [7] Tukker A. Product services for a resource-efficient and circular economy – a review. J Clean Prod 2015; 97:76-91.
- [8] Tukker A, Choen MJ, Hubacek K, Mont O. The Impacts of household consumption and options for change. J Ind Ecology 2010; 14(1):13-30.
- [9] Sacconi N, Perona M, Bacchetti A. The total cost of ownership of durable consumer goods: A conceptual model and an empirical application. Int J Production Economics 2017; 183:1-13.
- [10] Devoldere T, Dewulf W, Willems B, Duflou JR. The Eco-Efficiency of Reuse Centres Critically Explored - The Washing Machine Case. Int J Sustainable Manufacturing 2009; 1(3):265-285.
- [11] Codini A, Sacconi N, Sicco A. The relationship between customer value and pricing strategies: An empirical test. Journal of Product and Brand Management 2012; 21(7):538-546.
- [12] Deutsch M. Life Cycle Cost Disclosure, Consumer Behavior, and Business Implications. J Ind Ecology 2010; 14(1):103-120.
- [13] Fiell C, Fiell P. Industrial design A–Z. Taschen, 2000.
- [14] T. Nygård, V. Berbyuk, A. Sahlén: Modeling and Optimization of Washing Machine Vibration Dynamics. Proceedings of the 9th International Conference on Motion and Vibration Control (MOVIC 2008), September 15-18, 2008, Technische Universität München, Munich, Germany.
- [15] Lemaire, C., Direct and Indirect Out-Of-Balance Detection for Future Generation Washing Machines, Appliance Manufacturer Conference & Expo, Opryland, Nashville, September 27-29 1999.