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DESIGN AND FABRICATION OF A LOW-COST CLEANING AND STERILIZING SYSTEM

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Abstract
In this work a system utilizing a dry steam (vapor) for cleaning and/or sterilizing and other processes of the same kind is developed. A custom made compact boiler with a heat source is utilized for the generation of steam. A reservoir is provided that contains a mixture of water, cleaning agents or other chemicals. A motor driven pump is used for pumping the liquid mixture into the boiler which is then immediately vaporized and subsequently discharged through a nozzle. The system is configured in a manner that it can be operated electrically under manual control. The interior of the boiler is shaped so that it helps in enhancing the flashing of the liquid. The speed of the pump, flow rate of water, size of boiler, and applied heating temperature are chosen such that a steady flow of steam can be maintained from the nozzle at a desired pressure and temperature.

Keywords: Cleaning and sterilizing, custom made boiler, steam, slider crank mechanism.

Introduction

Most of the conventional cleaning methods are ineffective for cleaning sticky substances like adhesives, grease, dirt, and highly viscous liquids etc. from surfaces. Although chemical assisted cleaning and sterilizing can be used for such purposes but most cleaning chemicals are toxic in nature and hence pose a threat to the health of the cleaner as well to other persons who may come in direct or indirect contact with the same. Besides this the cleaning of inaccessible locations is often a challenging task with the conventional cleaning methods. These issues often lead to the reduction in the effectiveness of the cleaning method and consequently may also compromise on the performance (efficiency) of the persons who are assigned for these particular jobs. Cleaning of surfaces which are laden with dirt, grease and other things of the same kind by conventional methods like smearing with a wet cloth, vacuum cleaning etc does not look aesthetic to the eyes as these methods always leave some amount of residual substances on the affected surfaces. Sterilizing of medical and surgical equipments, research apparatus, baby accessories etc by using chemicals is also not viable as it can have severe consequences upon their intended end use.

Steam or vapor based cleaning/sterilizing has proven to be an effective method not only for cleaning contaminated surfaces, as it is able to completely remove the laden greasy or grimy substances due to its high temperature and pressure, but also for sensitive sterilizing purposes. The commercial steam based cleaning/sterilizing systems are however meant for either industrial purposes or specialized purposes. These commercial systems are also quite heavy and non-portable and their costs are so high that common people can hardly afford to avail their services and benefits. Cleaning/sterilizing equipments for domestic, healthcare, educational institutions and local service like hotels, restaurants purposes have the common need of being portable, cheap, and easy to operate. Motivated by this fact we have designed and fabricated a low cost and portable cleaning and sterilizing steam based system. Designing and fabricating such a system has been a very challenging task as it is meant to handle and operate on high temperature steam. In the subsequent sections of this paper the detailed design and fabrication of the cleaning and sterilizing system will be detailed but prior to that several studies in the literature that are more or less related to our work will be discussed.

In [1] a multi-purpose machine was designed and fabricated for floor cleaning applications. The multi-purpose machine was designed using low cost passive components. A finite element analysis was carried prior to the actual fabrication of the machine. The machine was fabricated in a manner such that it can be operated with both automatic and manual control. In [2] the design and fabrication of a hybrid cleaning machine is presented. The machine employs a vacuum cleaner arrangement that is housed in a tri-cycle setup and can be operated by manual pedaling and solar power source. The machine is intended to be used for domestic purposes, hospitals, offices, bus stands, railway stations etc. The main advantage of the machine is that it does not need any electric power source for its functioning and hence it can be even operated in areas which are deprived of electricity. Singh Kumar Pravesh et al. [3] have provided the design and fabrication of a manually operated vacuum cleaning machine. The term manual here means that the machine does not need a source of external power (for example electricity) and it can be operated with just human muscular effort. The machine serves the same functions as can be achieved by conventional electrically operated vacuum cleaning machines (commonly known as vacuum cleaners). The machine is

envisaged to be used in Indian regions which are mostly deprived of electricity. The authors claim that the developed machine is economical as compared to the commercially available vacuum cleaners and its maintenance cost is also comparatively low in comparison to the electric based vacuum cleaners. The complete details of the parts used in the fabrication of their machine are provided in Table 1.

Table 1

S.No	Component	Size	Quantity
01	Spur Gears	108 mm Diameter and 52 Teeth	04
02	Spur Gears	30 mm Diameter and 15 Teeth	04
03	Mild Steel Shaft	Length 190 mm and Diameter 12 mm	05
04	Ball Bearing	6200zz	10
05	Centrifugal Impeller	Not Available	01
06	Screw Rod	Length 210 mm and Diameter 10 mm	04
07	Aluminum Alloy Sheet	330x145x12 mm	02
08	Bicycle Sprocket	190 mm Diameter, 6 mm Thickness and 44 Teeth	01
09	Bicycle Sprocket	77 mm Diameter, 6 mm Thickness and 15 Teeth	01
10	Bicycle Chain	Length 1244 mm and Pitch 12.7 mm	01
11	Plastic Body Frame	545x300x205 mm	01
12	Suction Hose	1 m Length and 40 mm Diameter	01

In [4] the design and analysis of a manually operated floor cleaner is presented. Prathmesh Joshi et al. [5] have developed a manual driven platform cleaner.

The works reported in the literature on cleaning machines have mostly relied on either water based smearing or vacuum cleaning. Although, several portable and low cost systems have been designed but they still suffer from the limitations that were detailed in the introduction of this paper. Steam based cleaning and sterilizing systems have not been conceived yet, particularly, for low level applications like domestic, transportation, healthcare etc. Motivated by this fact and the belief that steam based cleaning and sterilizing can overcome the limitations of the conventional cleaning and custom designed cleaners, we have presented here the design and fabrication of the steam based cleaning and sterilizing system.

Proposed System

The schematic of the proposed system is shown in Figure 1. The proposed system consists of a compact custom-developed boiler in which the steam is generated. The boiler is made of 10 mm thick Iron sheets and has been fabricated at a local workshop facility. The boiler is made in cylindrical shape and the seam of the cylinder is arc welded, thus providing a leak proof design. A bottom plate is also arc welded to the cylindrical body. The upper plate is however hinged to the body so that the inspection of the whole assembly can be made without any difficulty. The circumference of the upper plate is beveled so that a leak-proof design can be obtained. For steam generation an electric heating element of suitable wattage is fitted inside the boiler. The interior of the boiler has serrated surfaces that help in enhancing the generation of the steam as they effectively increase the surface area of the boiler and consequently enhance the heat transfer rate to the water. . The water is fed to the boiler unit with the help of a 2 hp centrifugal pump and the necessary piping arrangement. Valves are provided at the inlet and the outlet of the pump, so that the water supply can be shut and regulated as per the steam generation demand. The boiler is provided with terminals for AC power input.

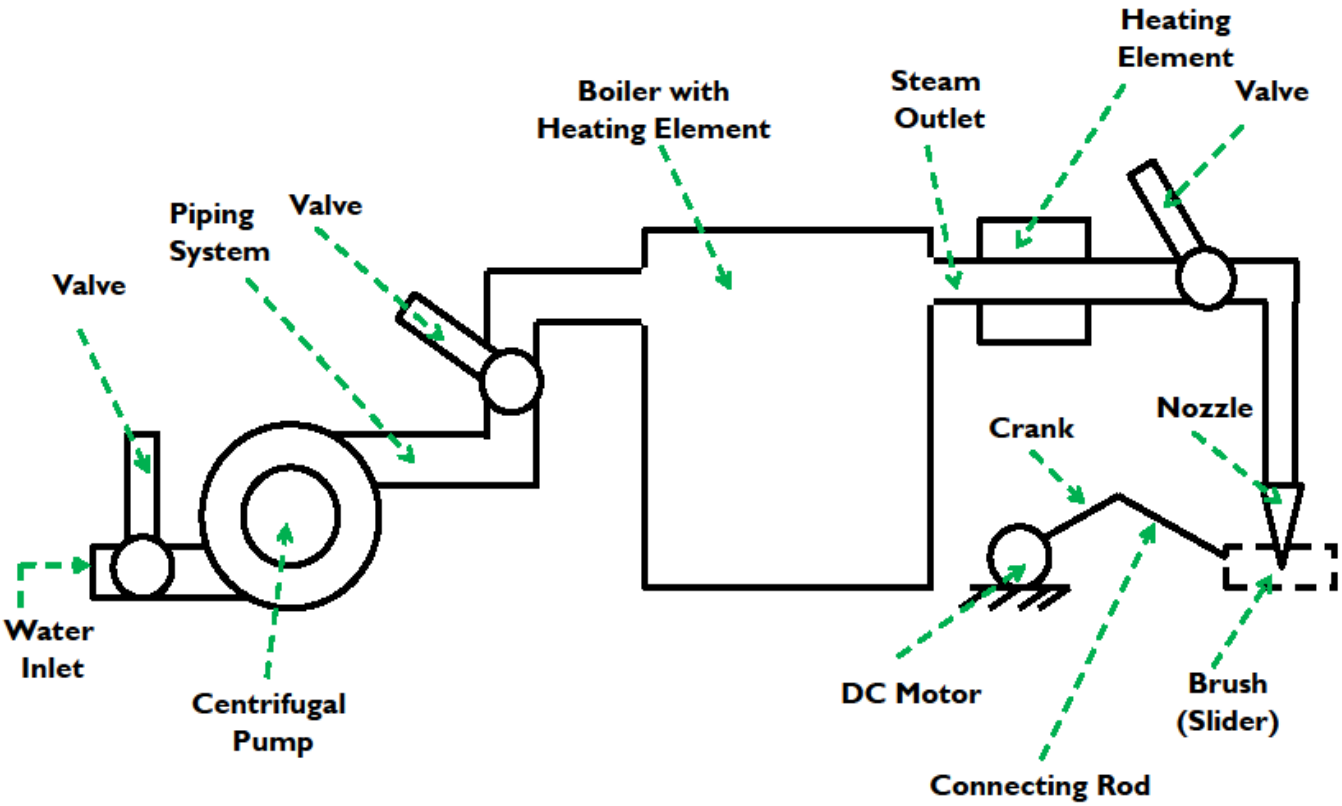

Fig 1: Schematic Diagram of the system

During the initial design and fabrication phase it was observed that the steam leaving the boiler is sometimes wet, that is, it has high moisture content (or equivalently low dryness fraction). The effectiveness of the cleaning of such a high moisture laden steam is somewhat lesser than the dry steam and as such an extra heating element was attached immediately to the exit of the boiler unit. This heating element ensured that the steam leaves the boiler with a high dryness fraction and has very high temperature. A valve is provided at the exit of the boiler unit to regulate the quantity of the exiting steam. The steam passes through the necessary piping arrangement before entering the nozzle. The nozzle used in the system increases the kinetic energy (and hence velocity) of the generated steam and hence enhances its utility for cleaning and sterilizing purposes. The high velocity of the steam also helps the unit to reach and clean inaccessible locations. The nozzle is made of Brass and is machined in a local workshop facility. The Brass billets used are of diameter 40 cm and height 120 cm.

The orientation of the nozzle can be adjusted and thus the unit can be used for cleaning or sterilizing any surface or part at any angle. For the purpose of cleaning, a brush or broom is provided which can be moved using a crank-slider mechanism. A DC motor is used in the slider-crank mechanism to impart rotary motion to the unit. The unit transforms this rotary motion of the motor (or crank) to sliding motion of the brush. The brush can be removed from the unit and any other suitable accessory can be attached depending on the application. Although, not shown in the schematic, the system is provided with a reservoir for feed-water. This reservoir ensures that there is sufficient quantity of water available even if there is no supply of external water. Besides this the reservoir can be used to mix certain cleaning agents like disinfectants to the water before it is converted to steam. The parameters like speed of the pump, valve positions (flow rates), electric energy supplied are chosen in such a way that a steady jet of steam is obtained at the exit of the unit. The thermal and structural analysis of the system reveals that the design of the proposed system is quite safe and has a good factor of safety with regard to strength and possible failure. The details of such an analysis cannot be provided here for space limitations. The pictures of the actual components used in the setup are shown below:

Figure 2: The custom developed boiler cylinder

Figure 3: The 2 hp water pump (Crompton make)

Figure 4: The ball valve for flow regulation

Figure 5: Heating elements used in the system

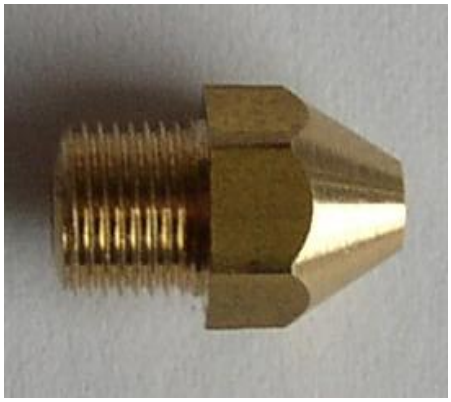

Figure 6: The steam nozzle

Conclusions and Future Work:

The design and fabrication of a steam based cleaning and sterilizing system is presented in this paper. The system is envisaged to replace the conventional cleaning systems like vacuum cleaners, especially in applications which need high quality cleaning. The developed system is compact and portable. It can be operated both manually and with the help of electric input. The components used in the system were custom fabricated using conventional machining processes at a local workshop facility. As a future work to this paper we would like to modify the design and make it more robust and efficient by incorporating several other low cost components. The design would be made more aesthetic by enclosing it in a well designed casing. The applications of the developed system would be exploited and several other design changes would be according incorporated.

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