23rd ABCM International Congress of Mechanical Engineering
December 6-11, 2015, Rio de Janeiro, RJ, Brazil

CONCEPTUAL DESIGN OF A DISINFECTION MACHINE TO CONTAINERS OF HAZARDOUS WASTE

Anderson Gomes Ferreira
Federal University of the Minas Gerais, Department of Mechanical Engineering, 6627, Antônio Carlos Avenue, CEP 31 270-901, Belo Horizonte, MG, Brazil.
anderson.ferreira@iesab.com.br

José Silvério Borela
Federal University of the Minas Gerais, Department of Mechanical Engineering, 6627, Antônio Carlos Avenue, CEP 31 270-901, Belo Horizonte, MG, Brazil.
José.silverio@iesab.com.br

Bárbara Nilsiane da Silva Teixeira
Federal University of the Minas Gerais, Department of Mechanical Engineering, 6627, Antônio Carlos Avenue, CEP 31 270-901, Belo Horizonte, MG, Brazil.
barbara@iesab.com.br

Enoque Gertrudez
Federal University of the Minas Gerais, Department of Mechanical Engineering, 6627, Antônio Carlos Avenue, CEP 31 270-901, Belo Horizonte, MG, Brazil.
enoque.gertrudez@iesab.com.br

Antônio Eustáquio de Melo Pertence
Federal University of the Minas Gerais, Department of Mechanical Engineering, 6627, Antônio Carlos Avenue, CEP 31 270-901, Belo Horizonte, MG, Brazil.
pertence@ufmg.br

Abstract. *Industries and operating rooms are large generators of hazardous waste to human and the environment (biological and chemical risks). Companies responsible for the treatment of such waste, largely transported in drums (container built in polymeric material), are using processes for disinfection unsafe for the operator and not efficient, still other companies discard such containers with the waste to be treated. Addition of material from the container to the processing system with the residue increases the energy consumption and the amount of formation of ashes and gases of the process. To realize the reuse of containers, adding efficiency to the system and promote an environmentally friendly treatment process, was developed the machine conceptual design to conduct disinfection of containers securely. Obtained the automated machine design, comprises pipes, valves, pump, reservoir. This paper presents a conception design to a mechanical machine for disinfection of polymeric container 200 liters, that was intended to allow the reuse of containers for transport of waste ensuring economic, technical and operational viability.*

Keywords: *disinfection machine design, waste container cleaning, disinfection drums*

1. INTRODUCTION

Companies that perform treatment of hazardous waste receive it in special containers. In Brazilian reality are used containers of 200 liters to transport hazardous waste. Some companies discard these drums jointly with the residue and others use washing and disinfection by a manual process.

Due contain hazardous waste, the manual disinfection process of the containers is dangerous to the operator, who to this end must to use special equipment such as aprons, gloves and respirators with filters. Figure 1 shows the manual disinfection process.

Figure 1.Photo of the hand disinfection process of drums of 200 liters. a) Manual washing b) Manual disinfection.

According to Wampler, T.P (2006), pyrolysis promotes treatment of waste through the breaking of chemical bonds only with the use of thermal energy, adding more mass, more energy is required and the greater will be the amounts of gases and solids formed. As Niessen, W.R (2012) the incineration of hazardous waste promotes treatment by breaking molecules using oxidation at high temperatures, the amount of ash and gases to be filtered from the process is proportional to the mass incinerated. Therefore, the reuse of containers becomes important for energy efficiency and improve cost-effectiveness of treatment systems. Recent work (Tôrres Son, et al., 2014) showed conclusion of the technical and environmental viability of pyrolysis plant built in Belo Horizonte, it works by a process named "Pyrolix" and aims to treat hospital waste. However, the plant is disabled due not to present economic feasibility, the plant does not have any system to allow disinfection and reuse containers.

In this paper, we intended to discuss the hypothesis that a simple mechanical design carry out disinfection of such containers with a system that presents full feasibility. Operational feasibility to ensure the safety of operators. Technical feasibility to ensure that drums can be disinfected with quality. Economic viability to generate profit from the reuse of containers and eliminating the cost of incinerating them.

Is critical to understand the requirements of consumers for justify and specify a product opportunity. It is done by the market's research, which is based on necessity. Among other sources of information, is used qualitative survey of market, according to Baxter (1998). Qualitative assessment of the market provide the following premises for the disinfection system: must to be simple (easy operation), economic (low cost for investment, maintenance and operation), suitable for containers of 200 liters made with polymers having 950 mm high, diameter equal 600 mm and approximate mass 4 kg.

2. DEVELOPMENT

For the conception of the system, preliminarily, it was verified necessity and then was selected one conceptual design, for this was studied the fixation system, and finally evaluate all process of disinfection according the feasibility of it.

2.1 Conception design

Budynas e Nisbett (2006) complement the proposed list by Joseph E. Shigley e enumerated 26 considerations to be evaluate in the design of a product, ranging in priority according to the specific nature of each project. The priority considerations, according to the specific product and customer requirements, are cost, functionality and security.

A systematic approach to design has been developed and proposed by Pahl and Beitz (1996), who divide their model into four phases:

1. Product planning and clarifying the task;
2. Conceptual design (purpose of this article);
3. Embodiment design;
4. Detail design.

The conceptual design is represented in Fig. 2 and in Fig. 3.

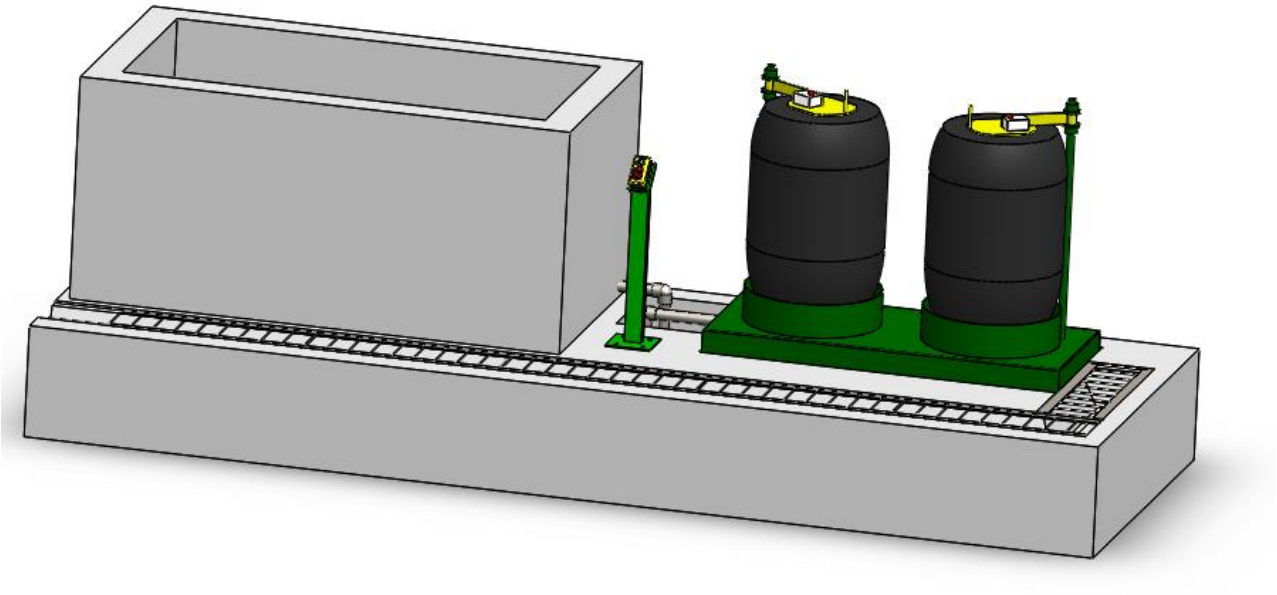

Figure 2. Representation of the conception design

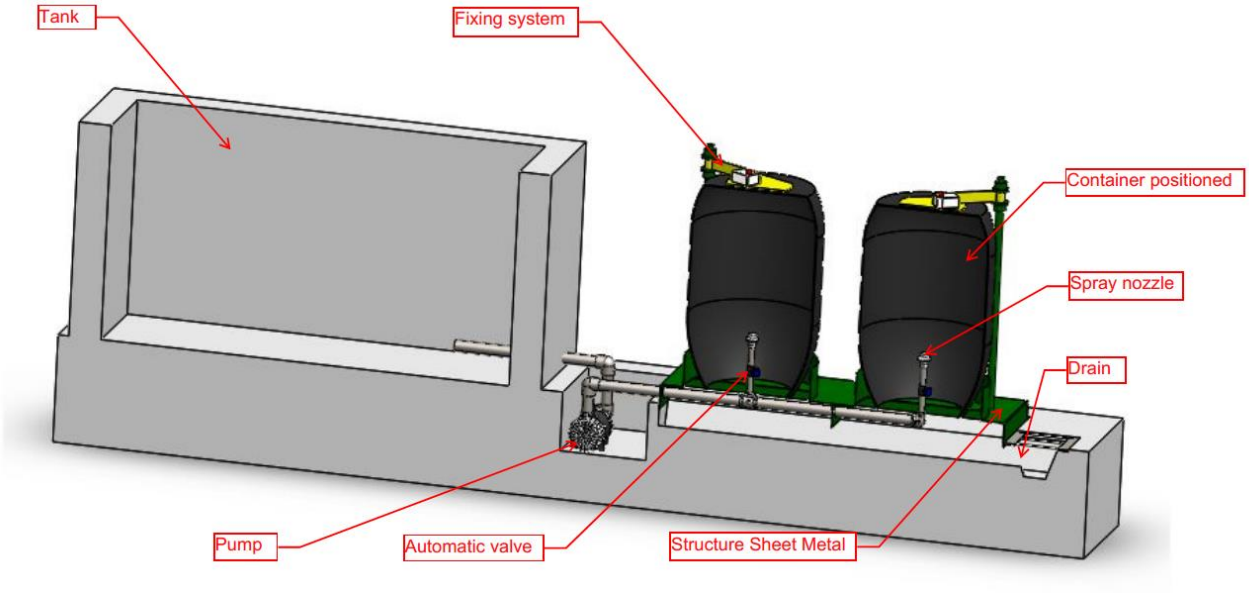

Figure 3. Representation of the conception design with internal details and identification of components

The conceptual design envisages a systematic operation according to the following operation flow:

1º. The operator drives in the machine control panel (composed of a green pushbutton, a red pushbutton and red lamp), the green pushbutton power up the machine, then the red lamp is actuated;

2º. The operator, holding the empty container (the residue already destined to treatment unit) positions the same in the machine, in the upright position with the spout down, in the confined space. Then the fixing system is rotated above the container, a signal receiver communicates the presence of waste container for washing;

3º. The automation system verifies the security conditions and performs the process of washing and disinfecting the container. It is actuated the pump and opened the valve in according of the sensor which communicates the presence of the container. The pump promotes the pressurization of the disinfecting solution to convey the same from the reservoir to the spray nozzles, which promote the jet in proper pressure and flow. The red lamp signals the occurrence of the process;

4º. The spray nozzle promotes the spray jet across the internal area of the container, eliminating solid and liquid particles that may be aggregated in the wall. In addition, it promotes the detachment thereof and outflow into the outlet nozzle of the container, ending by reaching the drain;

5º. While the disinfection procedure is performed for a drum, the operator can place simultaneously another container at the second nozzle. The same cycle of action will be make for both positions, there is no need for synchronization;

6º. The post wash liquid is drained and collected in a separator of water and oil, consisting of baffles, decanting heavy components.;

7º. After the set time, the system stops pumping sanitizing solution, and signals to the operator by turning off the red lamp above each container. Then, the disinfection process for the container is complete, and the operator remove this and can restart the cycle.

The productivity attained by the machine is 120 containers per hour, needing just one operator to perform the work. Figure 4 shows how the dimensions were set to provide better ergonomics and anthropometric parameters to facilitate the operation.

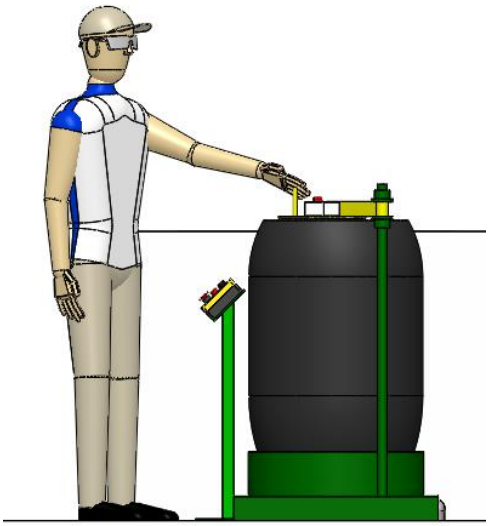

Figure 4. Representation of the dimension of machine according with the human body

2.2 Fixation system for container

It has developed a fixation system (Fig. 5) wherein a ring attached to an articulated arm is supported under the cap bottom of the container. The drum is with the opening facing down. The arm has a degree of freedom that allows the rotary motion, with the turning center in the column under which it is mounted. Which allows assembling and fixing container agilely and effortlessly by the machine operator.

The container is fixed by interference. The upward movement of the drum locks the fixation system. Just making a circular motion to the side allows the withdrawal of the container already disinfected. An existing under cover sensor identifies the presence of container. This sensor that enable to opening of the valve.

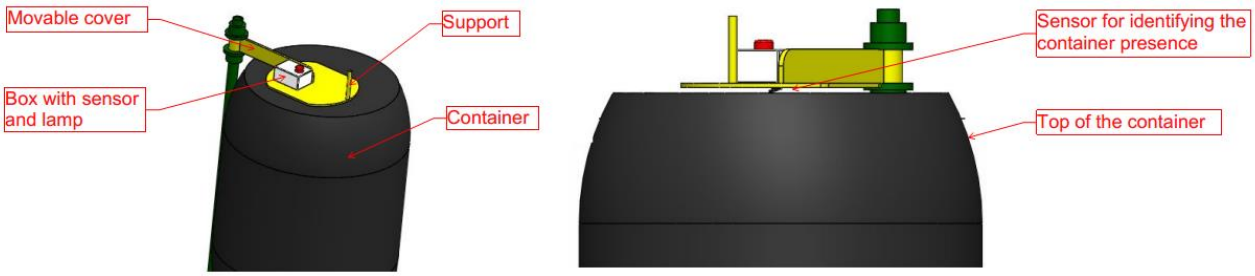

Figure 5. Fixation system for container in perspective and in side view

2.3 Disinfection process

As shown by Cubillos (1981), disinfection processes aim the destruction or inactivation of pathogenic organisms capable of producing disease, and these organisms can survive in water for several weeks at temperatures around 21ºC and in some cases, for several months at low temperatures. To promote cleaning and disinfecting of containers is

necessary to perform the removal of liquids and solids that may adhere to the inner walls thereof, which is done by means of a jet of liquid solution having water as a solvent. For disinfection aspect of this design, which aims to containers used for medical waste transport, chemical study was developed and showed the sodium hypochlorite solution (NaClO) as high efficiency for disinfection and with low price.

For the aspect of cleaning (removing debris that may cling to the container wall), NaSf et al. (2002) propose that the determination of the spray nozzle is specific for each condition, and the multi-channel solid jet nozzles is indicated in this case.

The conceptual design predicts angle and length of action, and by means of experimental tests on different working conditions, was determined the optimal point for pressure and flow to provide the disinfecting and cleaning of the containers. Is need to have a flow rate and pressure to promote efficient action considering that the lower flow, then less liquid required, less effluent for disposal and less energy consumed. In Tab. 1. are presented the nozzle sprinkler specification data.

Table 1. The nozzle sprinkler specification data.

Parameter	Value
Pressure	40 PSI
Flowrate	100 l/min
Distance action	1 m
Type	Multi-channel solid jet
Rotation	60 ± 30 rpm
Angle	270° up

The sequence of photos in Fig. 4 presents sprinkler nozzle that operate according presented parameters.

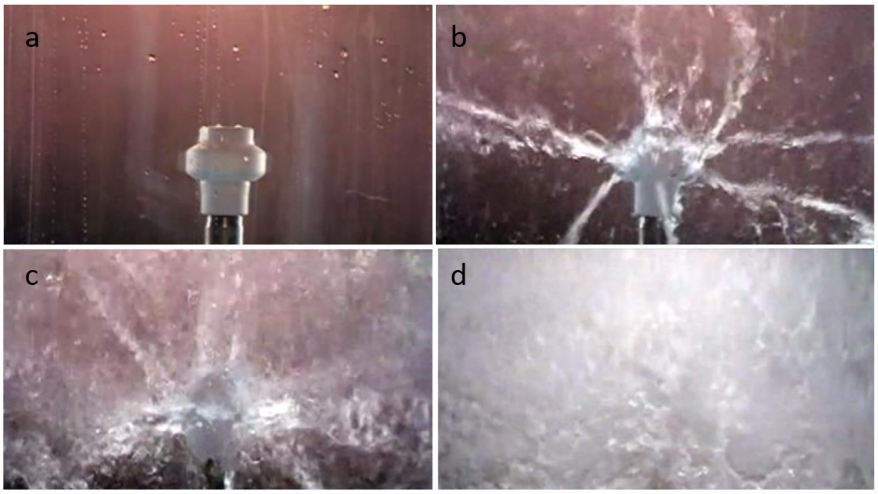

Figure 4. Spray nozzle that meets specification parameters in four conditions: a) not operating; b) start-ups; c) operating at 10 PSI; d) operating at 40 PSI. (27500D model built in Teflon, the Spraying Systems Co. © manufacturer)

2.4 Results

As result was obtained the conceptual design on virtual model performed in accordance with the aim to replace the current hand process of disinfection medical waste containers, and also to be deployed by companies that discard this drums. The design promotes the technical, operational, economic and ecological feasibility, and with the prioritized parameters for low cost, functionality and security.

The ensuring of operational viability is held by assures the preservation of the health of the operator. This only performs the work of positioning and removing the containers. There aren't any more exposure to splashes.

The technical feasibility is guaranteed by the automatic washing to promote higher quality than the hand process, using flow and pressure of ideas rates.

Economic viability is validated by the washing cost. Considering all costs (investment, operation, inputs) are less than the cost of the process carried out manually, and more economical than discard the container together the residue and purchase a new one.

3. CONCLUSIONS

The manual disinfection causes hazards to the operator by exposure to substances contaminants. Discard the containers is a harmful action to environmental preservation. The mechanical system is ecologically correct, demands less water and energy compared to hand washing process and allows the uses of containers.

The simplified mechanical systems can be applied with quality to conducting washing and disinfecting containers used as recipients of hazardous waste. These systems promotes safety and enables greater productivity. The presented conceptual design is more efficient than the current common processes in Brazilian reality.

In addition, the mechanical design developed provides economic viability. The main reason is that the reuse promotes energy saving, disposal of ash saving and gas of the treatment process saving.

4. ACKNOWLEDGEMENTS

Gratefulness to the IESAB Engenharia Mecânica for the financial support for development of the present study.

5. REFERENCES

Baxter, M.R., 1998. *Product Design: A practical guide to systematic methods of new product development*. Blucher.

Budynas, R., and Nisbett, K., 2006. *Shigley's Mechanical Engineering Design*. McGraw-Hill Series in Mechanical Engineering. Hardcover. 8th edition.

Cubillos, A., 1981. *Calidad y Control de La polucion del Agua. Mérida: CIDIAT/Centro Interamericano de Desarollo Integral de Aguas y Tierras*. Mimeo. Série Ambiente y Recursos Naturales Renovables.

NaSf G.G., Yule A.J. and L. Bendig, 2002. *Industrial Sprays and Atomization: Design, Analysis and Applications*. Springer-Verlag London Ltd.

Niessen, W.R., 2002. *Combustion And Incineration Processes*. Marcel Dekker. Andover, United States of America. 3rd ed.

Pahl, G., and Beitz, W., 1996. *Engineering design: A systematic approach*. Springer. 2nd edition

Tôrres Filho, A. et al., 2014. Tratamento de Resíduos de Serviços de Saúde pelo processo de pirólise". *In Proceedings of Congresso Brasileiro de Engenharia Sanitária e Ambiental*. Belo Horizonte, Brazil.

Wampler, T.P., 2007. *Pyrolysis-Handbooks, manuals*. CRC Press. United States of America. 2nd edition

6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.