Six Sigma Methodology for Design of Membrane Filtration System

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ABSTRACT

Water contamination is produced by discharging the pollutants in a water bodies. Filtration of water should be done to remove harmful contaminants. This research based on designing a portable water filter that implies a system of membrane filtration using six sigma. This research involved the design for six sigma including "define, measure, analyze, design and verify" Melt, Dry and Wet spinning processes is majorly used to manufacture a membrane. Prototyping is developed using a software Solid Works and implementing a 3-D CAD modelling to attain the "design" stage. Here, we use the size of membrane varies from 0.01 microns to 0.1 microns. The water filtration system is proficient in rejecting the viruses, bacteria and other contaminants to produce a safe and healthy drinking water that is free of contaminants. It is concluded that the size of pores mainly changes from 0.01 to 0.1 microns. The rate of flux based upon the module volume and size length. The module could be used as a both out-in mode and in-out mode. The effects of fouling is just because of solutes storage on the surface of membrane and this could be minimized by back washing after some time.

Keywords: DFSS, Prototyping, Solid Works, Rate of flux, Fouling

1. INTRODUCTION:

The water contamination is major problem in daily life. Water contamination is produced by discharging the pollutants either directly or indirectly in a water bodies without sufficient treatment to eliminate hazardous compounds. Water contamination causes most of the problems by the pollutants that are emitting either directly or indirectly in a water bodies lacking sufficient treatment. The purpose of membrane is just like a water filter to remove the heavy metals like mercury, lead and also to remove bad taste, and chlorine and this membrane is used for aesthetic basis. Using a membrane just like a water purification system is still at its initial phase just because it needs a specific system of filtration to purify. For that reason, a broad study is required to plan a systems of water filtration utilizing this membrane technique.

The purpose of this study is designing a water filter (portable) that utilizes a system of membrane filtration manipulating a methodology of six sigma design. To design a process, product or service the method of this six sigma methodology (DFSS) could be used [1]. The main area of focus using this method is such that to design process, product or

service perfectly in first attempt rather than wasting time to refine the process, product or service. The attention of organization should be on process, product or service using six sigma technique and there is a demand for them to evade the occurrence of mistakes. Deming cycle profitability as well as quality, to increase the quality of design could take over the customers of higher value, which could contribute to enhance the share of market, profitability, earnings as well as margins. A sigma level of 4.5 could be achieved by most of the organizations by implementing the projects of six sigma to refine the process, product or service by way of redesigning process, product or service. This technology of DFSS includes complex and powerful mechanism that imparts maximum to success a new technology or product. Various critical parameters is also analyzed by using this six sigma method [2].

2. METHODOLOGY

The methodology of this research is such that, using a method of DFSS (Design for six sigma) a water filter (portable) intending to design by utilizing a membrane system. The DFSS relays on "DMADV" will be used. Most simplified design is DMADV. This is abbreviated as "Design, Measure, Analyze, Design, and Verify" presented below.

2.1 Define

The first step in the methods of DFSS is "define" the goals of project along with the internal as well as external needs of customer. Therefore, the demand of user is first preference just because it highlights that problems which customers faced when product is utilizing in a market. For review purpose, the information would recorded.

2.2 Measure

DFSS involves second step "measure" which means to measure as well as to find out the specifications and needs of customer. These specifications presents the service or a product in such a way that it could be measured. This permits the data to compared and collected with the essential sets.

2.3 Analyze

Now at stage three, there is a step called as "analyze". In this method, the product or process completely analyzed and furthermore it reviewed to find out the best way to attain to attain suitable results. The factors that needs refinement and improvement either in the manufacturing process or in products are recognized. At this level, prototypes analyzed. The motivation behind this step is such that it appears with incorporating alternatives, analyze alternatives as well as alternatives to finish the product or a process.

2.4 Design

This step relays on the information grasp in the analysis, it has an ability to plan/design the new processes and new products. The work done is being reviewed by repeating the step analysis and compared the specified design with this new design. Products could be tested by the customers and new design products could be tested by that products which are tested by the customers to examine the way to which they fulfills customer needs or expectations.

2.5 Verify

This last fifth step involves verifying that the final output extracted results meets or superiors than the customer requirements. This step involves the verification of product as it

meets the required aspects or not. Basically this is a proceeding process. Even though the product launched in a market, the feedback of customer must be inspired and included in future designs. The final product involves all the aspects and it exactly meets the customer needs.

2.6 Manufacturing of Membrane

Various methods are proposed in a literature for hollow fibre membrane manufacturing. Currently there is an extensive applications of hollow fibre membrane. Membrane of hollow fibres has a major advantage than other aspects is greater area of surface to the volume ratio. Mainly three major approaches such as melt, dry and wet spinning are used. For membrane manufacturing basic material used is artificial polymer. Figure 1 presents different methods of membrane manufacturing [2].

Figure 1: Membrane manufacturing methods

2.6.1 Melt Spinning

In this process of melt spinning heating of polymer is performed on a temperature greater than the melting point in a stationary atmosphere and after this extrusion of liquid polymer takes place by using a spinneret. The phenomenon of phase change occurs along with a polymer solidifies by using immediate cooling. Hollow fibre or capillary is extracted using a uniform structure. A very thin fibres of N 5 pm wall thickness and a diameter smaller than the 50 pm could be obtained by just stretching a fibres.

2.6.2 Dry Spinning

In the technique of dry spinning, the polymer dipped in an extremely volatile solvent. The solution of the polymer heated after an extrusion process and polymer would solidify just because of solvent evaporation. An extremely thin fibres could be acquired by using this technique.

2.6.3 Wet Spinning

In the processes of technical membranes, mostly hollow fibres are twist by a technique of wet spinning. Using this technique any sort of membrane morphology could be acquired as most of the involved parameters could be changed. For HFM manufacturing, the methods proposed also relays upon the used polymer type along with its molecular weight. In a non-solvent bath the solution of polymer is extruded in which demixing takes place just because of solvent as well as non-solvent exchange. Among the non-solvent bath and spinneret there is a gap of air, where actually the formation of membrane begins. This intimates that first priority is a best control of current phase. This is mainly hollow fibres (integrally skinned) preparation case for separating gas and evaporate as the top most layer should be entirely free from all the defects. In the spinneret orifice the tube which usually utilized for the technique of wet spinning has a disadvantage in such a way that the air gaps conditions are very hard to control. That is why, a spinneret of triple orifice has been originated that permits a vastly superior conditions control and also that is suitable for all kinds of hollow fibres spinning [3].

2.6.4 Process involved in Manufacturing of Membrane

Polyvinyl alcohol, polyacrylonitrile, polyvinylidene fluoride, polyethersulphone, and as well as polysulphone the solution of a polymer is used in it. From all these, anybody could be used or they could be used in different ratios and different combinations as well. These solutions utilized in a liquid phase and also they are termed as “dope” and all these solutions retained in a tank called as solution tank. At various velocities, the water as well as polymer from the relevant tanks passed across the spinneret. For keeping the membrane bore diameter constant, the water is mainly used. The membrane formation actually starts at the gap of air among the water bath and spinneret. It depends upon requirements, the use of the spinneret would be of various types. It could be single-bored or multi-bored.
This could be possible involving single layered or two concentric bores or double layered or three concentric bores. Figure 2 highlights a membrane bundle [3].

Figure 2: Membrane Bundle

Next to potting process completion, a bundled fiber very small cross sectional area is cut at both ends in such a way that fiber bores which are blocked by the solution of potting or by POP are opened. After all this wind up in a housing. The best approach is such that fiber sealed firstly and then potting process carried out. Figure 3 displays a module making.

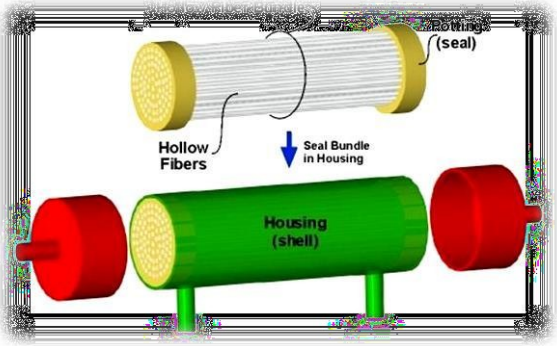


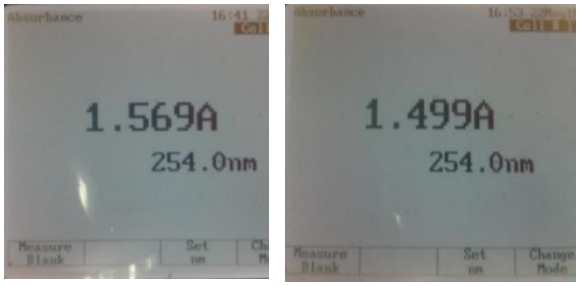
Figure 3: Module Making

In industrial waste water, industrial water, and in applications of beverage processing the membrane could easily installed in it all over the worldwide. With the flowing fluid, the cartridges of hollow fiber runs efficiently along the fibre wall to the membrane outside and along the center. This design is easy to handle the large circulation volumes, operations of single pass, dead end, and very flexible. The applications of membrane includes wine industry, beer industry, dairy industry, and purification of water, separation of citrus (upgradation) and for several other applications [3].

3. RESULTS AND DISCUSSION

Figure 4 presents a water condition before and after filtration process. The membrane based filtration system that utilizes the design approach of six sigma is presented successfully. The stability of this current approach is the ability to lead the development process entirely using a way of DMADV. DMADV presents the “define, measure, analyzed, design and verify”. For a particular objective, various tools are

implemented to follow these five (DMADV) stages. In a “define” stage a survey analysis of questionnaire form is used to gather information from a user. A “measure” stage is implemented to change the user collected information into an engineering characteristics that is why such a speculative information of user could easily be recognized in terms of engineering. For selection purpose as well as concept generation, decision matrix as well as morphological chart is being used in the “analysis”. Prototyping pre development is conducted using a software Solid Works and implementing a 3-D CAD modelling to attain the “design” stage. In the fifth stage proposed design “verification” is accomplished for the purpose of testing concept [2]. The majority of the processes in a technical membrane is governed by a technique of wet spinning. Using this technique any sort of membrane morphology could be acquired as most of the involved parameters could be changed. The effects of fouling just because of solutes storage on the surface of membrane could be minimized by backwashing after some time. This present study was proposed on a filtering system of membrane rather than the existing filter. For improving the quality of dirty water more work is required to refine the concept of selected design [3].



Original water Filtered water

Figure 4: Water reading before and after filtering process

4. CONCLUSION

The stated issue of water filter (portable) using a system of membrane filtration has been prospered. This current study was based on filtering system of membrane rather than the existing filter. Using a method of wet spinning mostly membranes are generated by using this way. The size of membrane changes from 0.01 microns to 0.1 microns. They are proficient in rejecting the viruses, bacteria and various other contaminants. The size of pores mainly changes from 0.01 to 0.1 microns. The rate of flux based upon the module volume and size length. The module could be used as a both out-in mode and in-out mode. The effects of fouling just because of solutes storage on the surface of membrane could be minimized by backwashing after some time.

3. REFERENCES

[1] **E. A. Cudney** and **S. L. Furterer,** "Design for six sigma in product and service development," *Applications and case studies CRC PRess USA*, 2012.

[2] **M. F. Mokhtar, B. Omar, N. H. M. Nor, N. F. M. Pauzi, S. Hassan,** and **W. W. Mohamed**, "Social and economic concern of supply chain sustainability (SCS)," in *IOP Conference Series: Materials Science and Engineering*, 2016, vol. 160, no. 1: IOP Publishing, p. 012073.

[3] **S. Z. Sapuan, M. Z. Mohd Jenu,** and **A. Kazemipour**, "Issue on calibration of direct feed biconical antenna in a semi-anechoic chamber using standard antenna method," 2014,vol.903: Trans Tech Publ, pp. 273-278.