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Research Paper

Design Study of Milking Machine Based on Topology Approach and Fluid Dynamic Analysis

Novi Sukma Drastiawati[1], Ahmad Ajib Ridlwan[1], Sri Handajani[1], Iskandar[1], Muamar Zainul Arif[1], Wahyu Dwi Kurniawan[1], Agung Prijo Budijono[1], Bidya Nur Habib[2]
[1]Universitas Negeri Surabaya
[2]CV. Cahaya Berkah Gusti, Indonesia

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Abstract

The large market for cow's milk makes the order capacity for cow's milk high and increases the milking process. In the production process, especially the milking process, people still manually use their hands, so fatigue often occurs, especially in people with more than 2 livestock. This causes the production process to be ineffective and the limited production results. Creating an automatic milking machine equipped with a milk can, a vacuum tube, and a hose. The aim of this research is a topology study carried out based on the model of the machine. The three-unit component affected the performance of the Milking Machine, especially the milk collector and milk can. Their size was analyzed to get the optimum one using fluid dynamic analysis. Optimization results for the topology of the milk collector bore diameter showed that the milk flow rate in the milk collector at a bore diameter of 9mm was 6,154 liter/min, at a bore diameter of 14 mm was 26,566 liter/min, and at a bore diameter of 19mm was 66,128 liter/min (conditions without being connected to hose). The shape of a milk can with a reduction of 30% from the initial weight, which is 3,358 kg to 2,350 kg, is owned by a milk can with the most optimal cone-dome tube shape. The difference in weight with the tube is generally 1,008 kg. The quantity flow when installed with a 2m long hose is 6,729 liter/min.

Keywords *milking machine, topology, study, model, fluid dynamic analysis*

INTRODUCTION

The large market for cow's milk makes the order capacity for cow's milk high and will increase the milking process. In the production process, especially the milking process, people still manually use their hands, so fatigue often occurs, especially in people with more than 2 livestock (Purnomo et al., 2021). This causes the production process to be ineffective and the production results are also limited. Creating an automatic milking machine equipped with a milk can, a vacuum tube, and a hose. Besides, a topology study will also be carried out based on the model of the machine. The three-unit component will affect the performance of the Milking Machine, especially the milk collector and milk can. Their size needs to be analyzed to get the optimum one (Hlongwane et al., 2018). Additive manufacturing development allows the redesign of products and the technological transformation processes. Additive manufacturing support is the most used method. Topology design can be optimized design through integration and allowing for the creation of complex shapes. The main method of product and process parameters, is design interpretation, selection, and re-design. The appropriate identification process and setup is selecting the best choice of variant on a morphological and functional level. The technological and drawbacks of a systematic re-design approach based on additive manufacturing technology and topology optimization.

Corresponding author's email: novidrastiawati@unesa.ac.id

Selecting design tools for variant products and process aspects using the method conducted to aim selection for the best re-design arrangement (Dalpadulo et al., 2020).

The contribution of the dairy industry to the increasing world population for nutrition security inside the daily proceeds on dairy farms milk growth is a fundamental factor in optimizing both product quality and performance. The paper examines optimizing the milking routine prospect and achieving high milking performance in machine settings with minimum impact on health. Small and big animals (cows) be modified for milk removal in the current ten years. The enhancement of wealth industrialized and the world population can affect dairy food products. Animal (cow) with large and small shape and herd size has been continuously enhanced to cover the requirement of the consumers and to confirm an equal income for the producers. Contemporary dairy farms are usually completed with new and modern machine milking (Odorčić et al., 2019).

The mechanical foundation and physiological from milking little ruminants are much the same as those of milking cows. Some differences and regulating design of milking machines and employment for the subsequent differences will be discussed. Milk growth needs cooperative work between the organizer and the sheep. The good result of sheep milking is more exceptionally dependent on the proficient connection between appropriate, operators, and effective pre-milking daily because the sheep emerge to have larger stimulation needs than cows. Sheep make specific units of milking machines that should emphasize the anatomy. Milking machine types have subsequent functions and sections. The components are a pulsation system structure, a system with control and vacuum production, milking units to pull milk from the udder, a composition for containing milk from the milking unit to the storehouse, additional instrumentation for sanitizing and cleaning this machine (milking machine), storage equipment, and milk cooler (Reinemann, 2015).

The first stage in this research is needs analysis, carried out by a research team at several breeders and smallholder livestock centers (SPR) in the district Subang. Some breeders in the hilly areas of Subang Regency are still milking conventionally. The use of cow milking equipment is difficult because road access is hard and steep. The solution offered by the research team is a milking machine portable bodypack type. The second stage is that the research team looks for sources of books and journals about machines' portable milkers. This is done to find the basic material regarding the Design of a portable cow milking machine. The third stage is making a design embodiment, namely sketching a portable milking machine model bodypack. It was clarified that the design in the form of a sketch must go through the initial design analysis stage. It is meant to ensure the suitability of the design before it is drawn using a 3D application. The fourth stage is a detailed design designed using an application. The Autodesk Inventor application is software that has a concept parametric design. Parametric design is a modeling method of 3D dimensions on CAD systems using parameters as design references such as shape, dimensions, constraints, and others. Parameters here are used to control the 3-dimensional geometric shape of the designed model. The advantage of design-based parametrics is the ability to produce various forms of models easily and fast. Every change in the shape of the model will update the part, assembly, and even working drawings automatically, so the possibility of working drawing errors can be minimized and this process is generated quickly and in real-time (Suhartono et al., 2019).

The configuration arrangement and design of the milking machine based on common data in the emphasis stroke with the squeezing impact are indicated. Milking machine intensity for engineering accomplishment as a part of raising the fulness of milking is to drop and upgrade the total of residual milk in the cow's udder. The occasion that the part of the activity the box is made lower in thickness to the adsorption of the cup. The tail part with cylindrical shape and the cone part with a smaller diameter. It is formed by the continuation of the tail and the suction cup part is taken as the tube. The compression will enable to transformation of tact into a compression with a specific ratio of emphasis denomination in squeezing effect in the teat and interstitial spaces and temper the periodic impact of tubes on the udder of the animal (Yashin et al., 2022). The scheming of generative design tools based on the stage assembly system for the increasing process does not involve a fully set design of the chamber. The method more possibilities to the algorithm for difference variation. The design would involve engineers applying a different method of approaching and design thinking because the setup study shape for transformation design would necessitate. Generative design tools are immediately modern and their algorithms still necessitate further arrangement to be able to gain the outcome of the advanced level. There are some issues provided with the method that we found in this time that we found. The number one is design has substance non-functional fields with little material thickness. The number two is the infrequent addition of inclusion holes in the structured outcome in the excessive distribution of material. The number three, the available for examining is only a few manufacturing. Related concern to generative design equipment is that they are highly computationally required. The discussion for this study generally led to various hours to produce the outcomes. The decrease in specialized equipment is a necessity for these tools to fit on. Materials costs and manufacturing process neither of the tools considers, which is one of the major interests of design engineers, therefore its execution should be considered for new versions of the equipment. General studies are required to investigate how the implementation of this equipment in the early phases would have a current effect on the designer's progress (Vlah et al., 2020).

Based on observation the research aims to make a milking machine through the process of design, manufacturing, and experiment.

LITERATURE REVIEW

Cow's milk consumption in Indonesia is generally used for nutrition, diet, and for health. This production has increased year by year. The process of milking for developing countries is done manually and using human resources. Milk production of dairy cows is influenced by milking management. Massage duration and milk flow rate are part of milking management which can affect the rate of emission of milk production in dairy cows (Surjowardojo et al., 2016). A milking machine is a tool designed for the efficient result and hygienic of milk from a cow. This machine is transporting milk to the storage tube (milk tube). This process should be effective because this setting is aimed at achieving high milking production so that in a short operating time, maximum results are obtained (Odorčić et al., 2019). Cow milking machine has various types and price with advantages and disadvantages. A standard milking machine consists of a pulsator, milk claw, vacuum pump (the operating parameters of the milking machine should be chosen to confirm the lowest vacuum drops), milk bucket, and teat cup. This part shows that the milking machine was designed helpful to farmers in the milking process (R. Suhartono & Efendi, 2020; Ströbel et al., 2013). One of the most significant in the dairy industry is an AMS (Automatic Milking System). It has increased rapidly in the last few years and the number of commercial farms milking with Automatic Milking System (Cogato et al., 2021; Lessire et al., 2020).

Milk production has come a long way since milking cows was done manually. Because the capacity to milk cows manually has limitations in terms of quantity, milking cows for large-capacity farms uses cow milking machines. Currently, the machine is used to help farmers milk several cows at once. Cow milking machines speed up the milking process by producing an average of 15,837 liters (9,000 liters/2,377 gallons) per cow per year. However, even though using a cow's milking machine farmers do not do it easily. Farmers also maintain long daily routines that require feeding and cage care. This article will focus on discussing how the milking machine works from the component side to how it works. New Zealand and Southern Australia are known as countries that produce the highest quality milk. In New Zealand, this cow milking machine is known as a pulsator vacuum system. The principle of the cow milking machine is to extract milk from the cow through a vacuum system. The cow's milking machine works using a constant vacuum air technique to the end of the teat to suck the milk out and bring it to the container. In addition to the vacuum system, there is air pressure in such a way as to maintain blood circulation. So that the cows do not feel pain during the milking process using the machine. Although milking machines have evolved with various technologies, they share the same basic components. Air is removed by a vacuum pump at a constant speed. Then the machine is connected to a piping installation system that empties into the reservoir. The concept is like a traditional milkmaid that collects milk into a container (Cara Kerja Mesin Pemerah Susu Sapi, 2021).

Dairy cows are the main producers of milk for human consumption needs. The demand for cow's milk is now increasing, and so is milk production. However, the milk produced must be hygienic, not polluted, and guaranteed quality, then handling, equipment, and milking must be done properly. Equipment that can be used by breeders are cow's milk squeezer machine. A milking machine is a semi-automatic machine for milking cows. This machine is not made for just one tail cow, but mostly one set of tool components is made to milk 200 cows per hour. The system of the series of tools consists of a vacuum pump, regulator (tool gauges), and pulsators. All components are integrated to convey milk to a container which will then be processed into a product. In the market, various types of milking machines are circulating, but the price of the milking machine varies Cattle are quite expensive, around IDR 17 million-IDR 25 million. Team observation results researchers in Subang Regency in June July 2018 found several problems: (1) breeders have not been able to buy a cow milking machine that is sold in the market now because the price is very expensive, (2) farmers find it difficult to operate the cow squeezer machine so they need a machine which is easy to operate, (3) the cow milking machine is now felt by farmers to be lacking suitable for small scale breeders as the machine takes up a lot of space and less space effective if used breeders in mountainous areas. A milking machine is a semi-automatic machine for milking cows. According to the Big Indonesian Dictionary, portable means easy to bring. Based on the explanation above, it can be concluded that a milking machine portable cow is a machine that is used to assist the process of milking cows and is easy to carry around. All milking machines consist of a) a Vacuum Pump b) a Pulsator c) a Milk claw d) a Teat cup and e). Milk container (Bucket). Based- on the observations of the research team at several smallholder livestock centers (SPR) it was concluded that the milking equipment currently circulating in the farmer's environment is a type of Star Farm BTM milking machine with a price of IDR 16,000,000 generally used for large-scale breeders, while for small-scale breeders still using the conventional milking system. So based on the background above, a bodypack type milking machine is needed that can be used for farmers small scale or individually (Suhartono et al., 2019).

The dairy cow shed business is a business that has the potential to raise wheels. The economy, so that in villages producing livestock milk is a very big profit in the Indonesian market. The large market for cow's milk makes the order capacity for cow's milk become high and will result in the milking process of cows also increasing. Kampung Susu Lawu is a commodity for cattle breeders who have unique products pure dairy cow's milk. Lawu milk products are processed by the community around Lawu village which has cattle livestock. The price of this Lawu milk product starts at IDR 20,000. While enjoying milk, visitors can also carry out agro-tourism activities around the village. Order cow's milk exceeding capacity makes industrial partners unable to meet capacity production due to the long process of milking cows (Imananda, 2021; Kunradus, 2020).

Previous studies have mentioned the effect of milking machines on milk production. For example, (Aslam et al., 2014) machine and hand milking of cows mentioned the increase in milk production is 12% and a decrease in labor is 18%, as well as an increase in the welfare of dairy cows. Likewise, (Khan, 2008) conducted a study related to the performance of tub-type portable milking machines on buffalo milk production. From the results, vacuum levels of 46-48 kPa and 44-46 kPa gave maximum milk yields (0.807 and 1.086 liters per minute) for single and multiple clusters. Lower milking vacuum extends machine life (increases linear slip frequency, lower milk flow rate) and can degrade milk produced while larger milking vacuum levels can cause problems in the condition of the cow's teat skin and suboptimal milk release (Reinemann et al., 2005; Reinemann, 2015).

The main features of the milking machine are teat cups (shell and silicon rubber liners), a long milk tube, a long pulsation tube, a pulsator, a vacuum pump, a tank, a receiver, and an electric motor (Krawczel et al., 2017). A tub-type milking machine system consists of four basic components namely a) a vacuum system, b) a pulsator that changes the level of vacuum around the nipple, c) a milking unit or group made up of four teat cups with liners connected to the claws and d) milk collection tube. After installing the teat cup, the disconnect of milking machine to the milk from the dairy cow by applying a partial vacuum to the teat creates another pressure which results in the opening of the milking duct and the milk flowing out of the teat tank through a pipe into the receiving vessel (Gleeson et al., 2004; Gk & Rk, n.d.).

The parameters of the tool can be tested using simulations or mathematical modeling. Mathematical modeling is an important equipment for analyzing the impact of selected design components of tools. A simulation tying all tool sections makes it possible to analyze (Golisz et al., 2021).

METHODOLOGY

The method used in this research is a Topology Study to analyze the optimization of the offered model. Topology optimization is how materials should be placed within the available design space. Topology Optimization starts with a design space that represents the maximum allowed size for a component. Optimization of the topology study is useful for optimizing the geometry of the milk can and milk collector about the quantity flow of milk that can be sucked through the bore of the milk collector and later accommodated in the milk can. In designing products according to user/consumer needs, primary data is needed in the form of the Voice of Customer (VOC). From this system can be known how the form products that will suit the needs of the user. Quality Function Deployment (QFD) for mapping the Voice of Customer in detail. A review in terms of the geometry of the tools and mechanisms, ethics developing a QFD-based product requires input data from consumers, where the consumer's language is still general, not yet technical, and materials or tools from milking machine compartment there is a purchase that takes a long time. In developing a product, a design process is required first. Using CAD-based 3D design is a deep concrete form implementation. This 3D CAD design will later become a reference for engineers for the product manufacturing process.

Figure 1. Topology Workflow

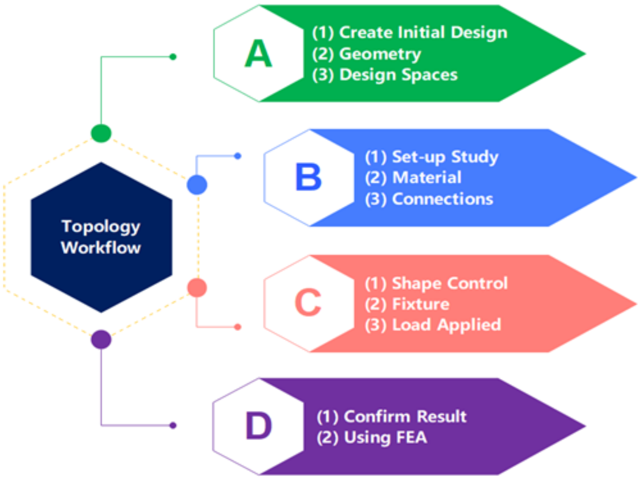


Figure 1. Topology Workflow

From Figure 1 above, the workflow topology starts with preparing a product design model that you want to optimize the components for. The next step is to set the study on the milk can and milk collector components. Shape control is carried out to find out the optimization of the weight of a good milk can and to find out the good bore diameter of the milk collector.

The following is a design model of the milking machine that has been designed

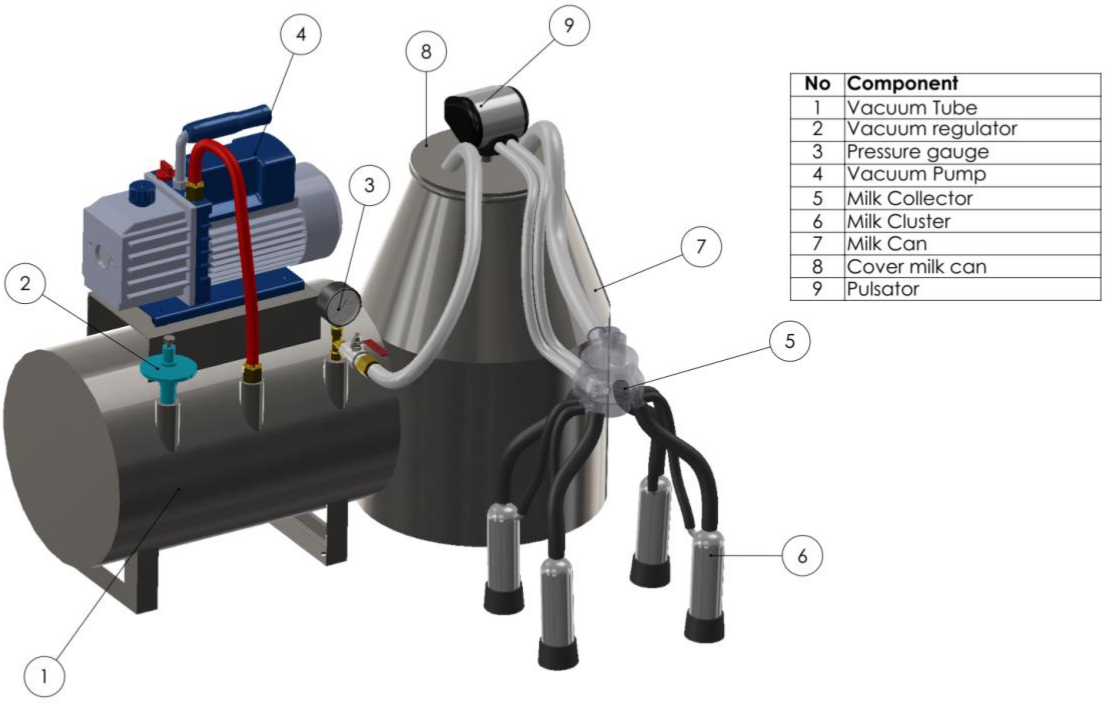


Figure 2. Milking machine design model

The material used is stainless steel 304 with a yield strength value of 206,807 MPa. The vacuum regulator functions to regulate the vacuum pressure in the vacuum tube with a pressure value (-). There is a pressure gauge to monitor the value of the vacuum pressure that occurs in the vacuum tube. The milk collector is connected to the Milk cluster nozzle for the milk suction process and is included in the suction system category. The milking phase and the resting phase can take place alternately, the milking machine is equipped with a pulsator which functions to adjust the air pressure between pressurized and vacuum conditions. At other times, the pulsator regulates the resting phase and the milking phase.

FINDINGS AND DISCUSSION

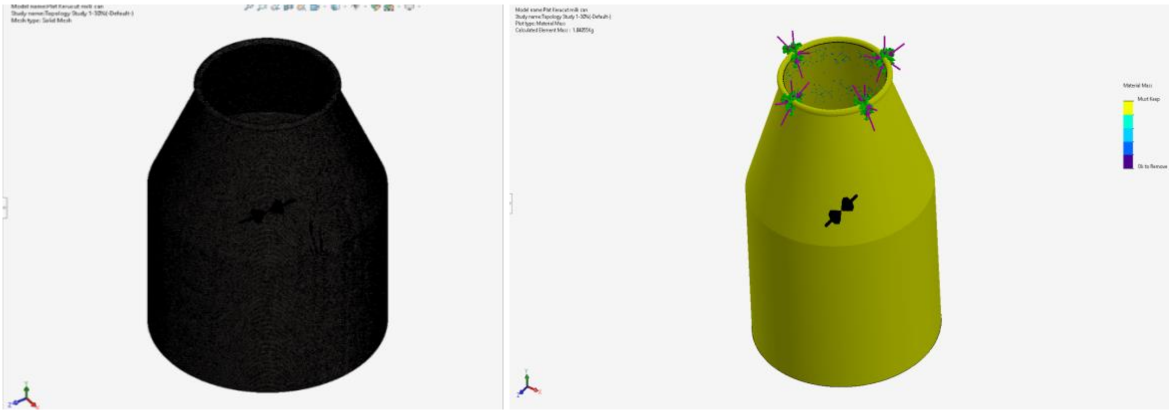
A computational design method, topology optimization purpose to increase material distribution in design space with loads and constraints affected. This concept maximizes the design's performance. The efforts of reduction are developed to topology optimization tools. This method is required for engineers. It can be iterative in designing analyzing in performing multiple design variations. It can support and offer solutions for engineers. Topology optimization, for shape and size, is one of the three main categories of structural optimization. (M. P. Bendsøe, 1989; Osvaldo et al., 2017; Vlah et al., 2020).

Point 1: Topology Study of Milk Can

In the topology study, milk cans are presented with two geometry models and milk cans are tubular as usual and are tubular with a cone dome on top.

Figure 3. Milk can design model (a) regular tube and (b) cone dome tube

In model (a) the dimensions are Diameter: 310mm, Height: 440mm, and Thickness: 1mm. In model (b) the dimensions are Diameter: 310mm, Height: 440mm, and Thickness: 0.8mm. The shape of the model (a) will be optimized into the shape of the model (b) to reduce the weight of the milk can itself.



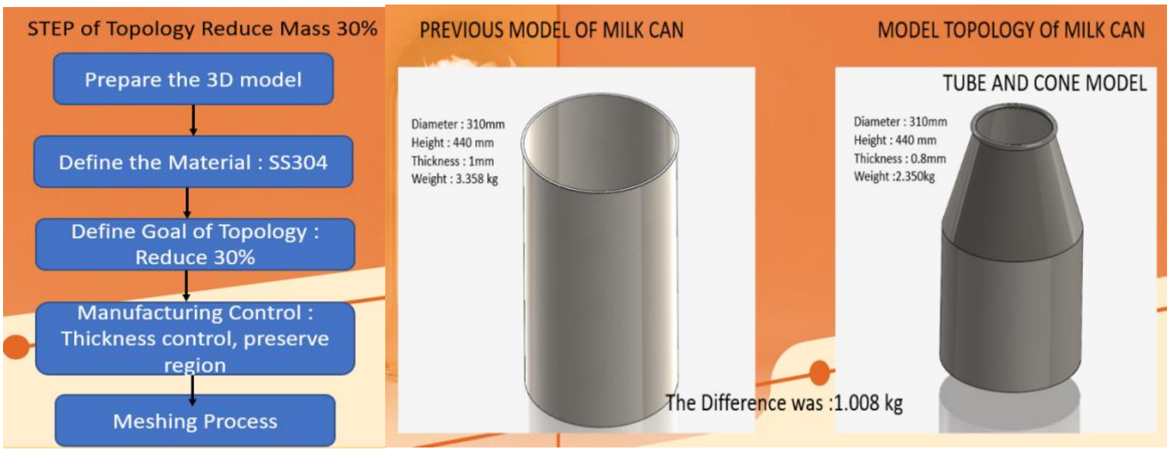


Figure 4. Reduction of milk can weight

Point 2: Topology Study of Milk Collectors

Preparing in the study of flow and the significance of the design studies differences that have an impact on final designs. The initial geometry preparation and design space definition are the main differences in this method. This part is additionally and possibility of selecting multiple design support tools, manufacturing, and materials to implement the study. It provides possibilities for the results comparative overview. In the topology study of the milk collector, it is presented about the flow of milk fluid in the milk collector when there is a vacuum at a pressure of 3.5 bar.

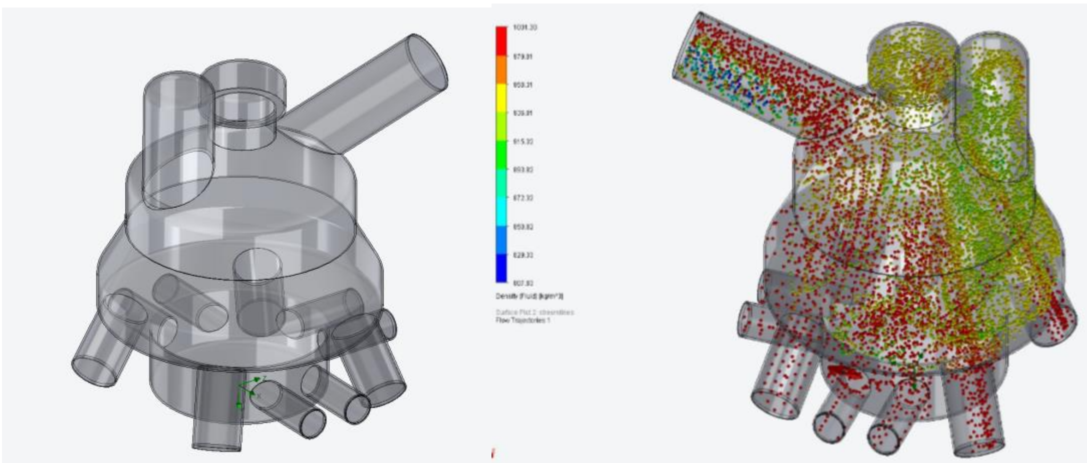


Figure 5. Geometry of milk collectors

The average milk flow rate is a good indicator of milking efficiency. The average milk flow rate is calculated as the total milk production divided by the total machining time. The average milking time and average milk flow rate for the entire milking group can easily be calculated. If automated data collection is not available, a random sample of about 10 cows from the herd will yield an estimated mean flow rate for the herd of up to +/- 0.5 kg/min.

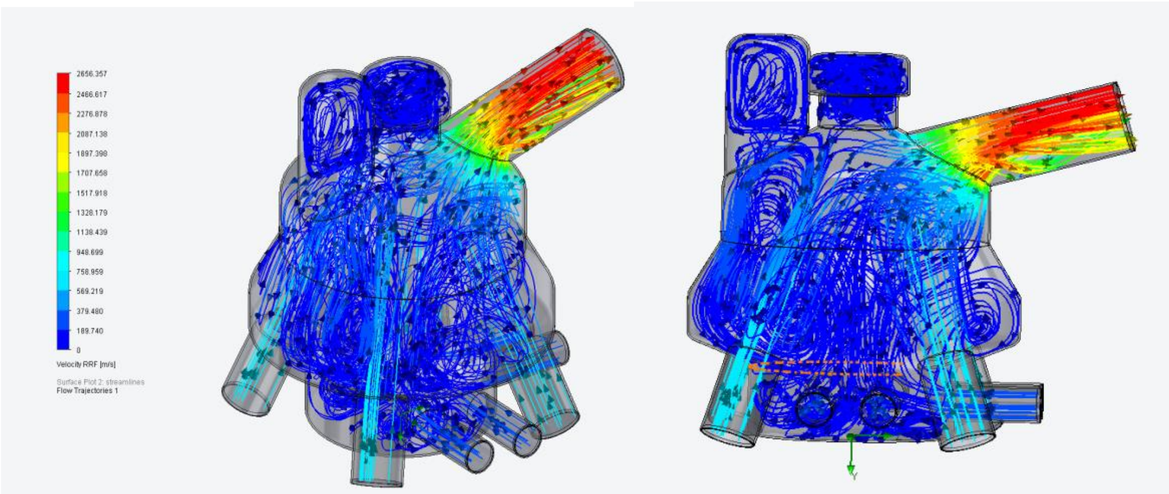


Figure 6. The milk flow rate in a vacuum milk collector at a pressure of 3.5 bar

In Figure 6, the results of the optimization of the topology of the milk collector bore diameter show that the flow rate of milk in the milk collector for a bore diameter of 9mm is 189.74 m/s, for a bore diameter of 14 mm is 466.321 m/s and for a bore diameter of 19mm it is 1328 – 2087 m/s s. Furthermore, the milk collector that is installed with a vacuum hose will have the following flow quantity. Design parameter values in size optimization related to the element to cross-sectional areas. The optimum solution regarding displacement, weight, and stress. Problem concerning truss structure, frame, and support bars is often applied. This method does not allow for new element addition or removal of voids in the structure (Osvaldo et al., 2017; Vlah et al., 2020).

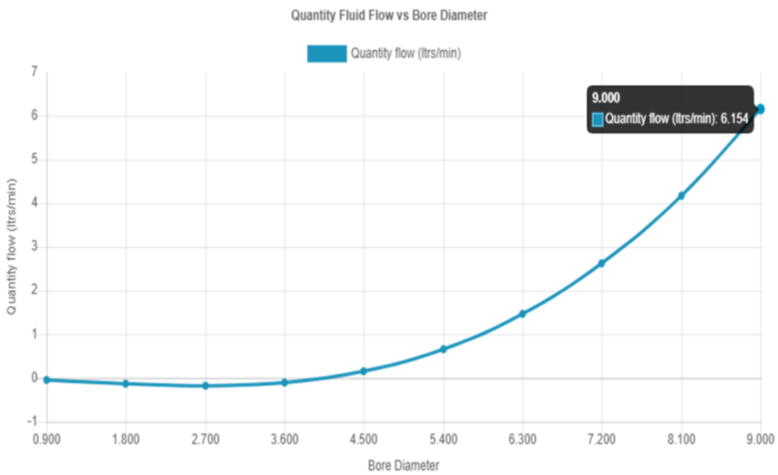


Figure 7. Quantity fluid flow of milk collector VS bore diameter 9mm

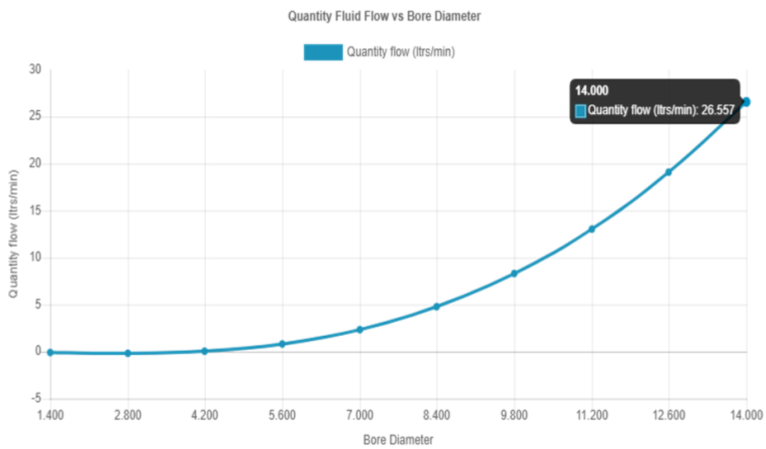


Figure 8. Quantity fluid flow of milk collector VS bore diameter 14mm

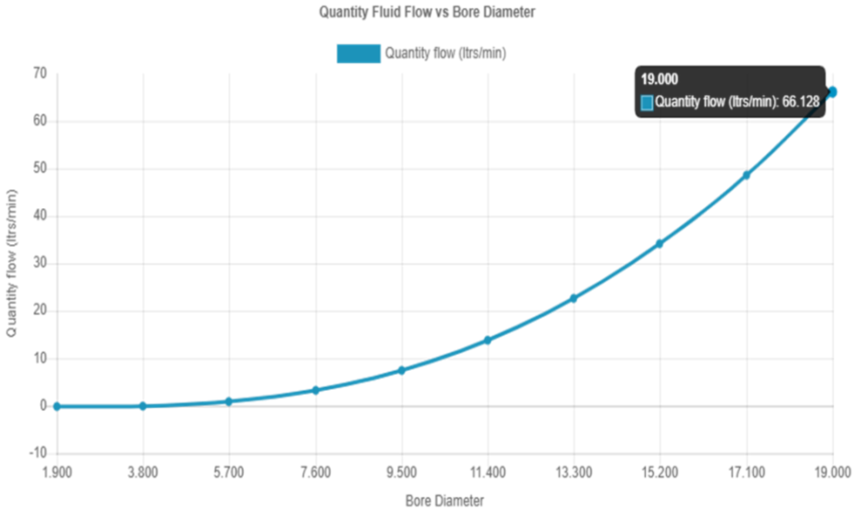


Figure 9. Quantity fluid flow of milk collectors VS bore diameter 19mm

In Figures 7, 8, and 9 from the results of the optimization of the topology of the milk collector bore diameter, the milk flow rate in the milk collector at a bore diameter of 9mm is 6,154 ltr/min, at a bore diameter of 14 mm is 26,566 liter/min and at a bore diameter of 19mm is 66,128 ltr/min (conditions without being connected to a hose).

The phase of design perspective needs to acknowledge generative design equipment. It has major potential originally because this method can concurrently test a substantial number of materials and produce multiple alternative designs. This ideate can save time and support substantial creativity. However, generative design tools are still in deliberation and of a few comprehensive issues. A decision is required before it is widely used by engineers. In the conceptual design phase topology optimization is a preferable option for the optimization of components while generative design furnishes more promotion when shape and design layout are not yet established. Nevertheless, it has the potential to apply tools of topology optimization to take the original idea on how to navigate the design. Tools will only prepare the engineers with a single optimal recommendation for one case. Topology optimization and generative are important design outcomes that will substantially appropriate the design space definition. Constraints and loads are set up as well as on the set objectives. In these methods, the designers need proficiency in defining a model for optimization to be able to set up the design methods and assess the generated outcomes (Vlah et al., 2020).

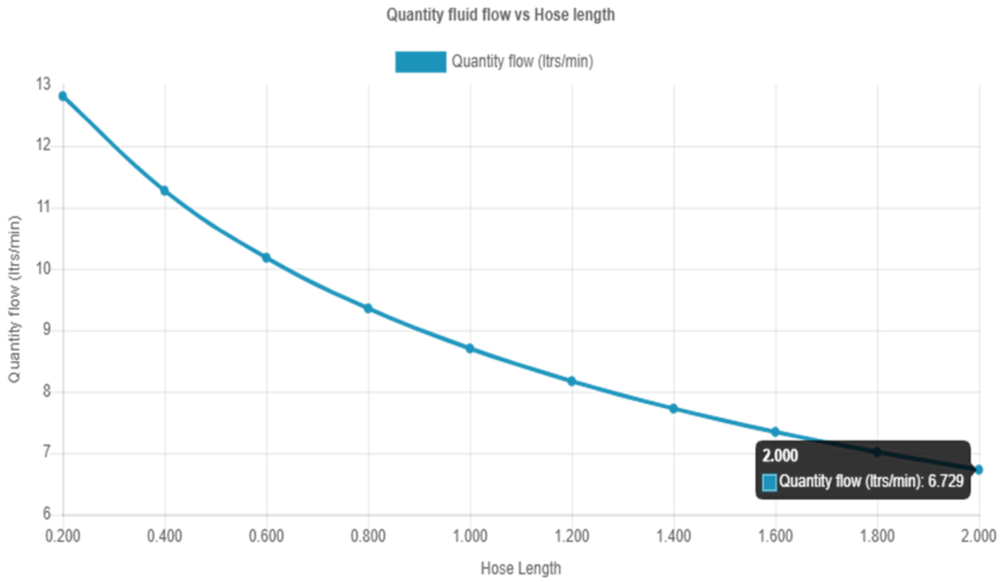


Figure 10. Quantity of fluid flow of milk collector VS Hose Length 2m

In Figure 10 it can be seen that the quantity flow when installed with a 2m long hose is 6,729 liter/min.

CONCLUSIONS

Based on the results of the topology study of the milk can and milk collector, it can be concluded as follows:

1. The shape of a milk can with a reduction of 30% from the initial weight, which is 3,358 kg to 2,350 kg, is owned by a milk can with the most optimal cone-dome tube shape. The difference in weight with the tube is generally 1,008 kg.
2. Optimization results for the topology of the milk collector bore diameter showed that the milk flow rate in the milk collector at a bore diameter of 9mm was 6,154 liter/min, at a bore diameter of 14 mm was 26,566 liter/min, and at a bore diameter of 19mm was 66,128 liter/min (conditions without being connected to hose).
3. The quantity flow when installed with a 2m long hose is 6,729 liter/min.

LIMITATIONS AND FUTURE RESEARCH

The limitations of the study are only using topology simulation and fluid dynamic analysis.

REFERENCES

Aslam, N., Abdullah, M., Fiaz, M., Bhatti, J., Iqbal, Z., Bangulzai, N., Choi, C., & Jo, I. (2014). Evaluation of different milking practices for optimum production performance in Sahiwal cows. Journal of Animal Science and Technology, 56(1), 13. https://doi.org/10.1186/2055-0391-56-13

Cara Kerja Mesin Pemerah Susu Sapi. (2021). Cara Kerja Teknologi. https://www.cara-kerja.com/2021/12/cara-kerja-mesin-pemerah-susu-sapi.html

Cogato, A., Brščić, M., Marinello, F., & Pezzuolo, A. (2021). A 20-Year Analysis of the Evolution of Automatic Milking Systems: Processes, Technologies and Livestock Environment. 3. https://doi.org/10.3390/ieca2020-08825

Dalpadulo, E., Gherardini, F., Pini, F., & Leali, F. (2020). Integration of topology optimisation and design variants selection for additive manufacturing-based systematic product redesign. Applied Sciences (Switzerland), 10(21), 1–13. https://doi.org/10.3390/app10217841

Gk, H., & Rk, S. (n.d.). "Design and Fabrication of Cyclic Operated Milking machine" (Vol. 3). www.ijariie.com

Gleeson, D. E., O'Callaghan, E. J., & Rath, M. V. (2004). Effect of liner design, pulsator setting, and vacuum level on bovine teat tissue changes and milking characteristics as measured by

ultrasonography. In Irish Veterinary Journal (Vol. 57, Issue 5, pp. 289–296). Irish Food Publishers. https://doi.org/10.1186/2046-0481-57-5-289
Golisz, E., Kupczyk, A., Majkowska, M., & Trajer, J. (2021). Simulation tests of a cow milking machine—analysis of design parameters. Processes, 9(8), 1–13.
Hlongwane, D. K., Office, P., Mp, B., & Pleasant, M. (2018). Design of an automated livestock milking machine : case for Zimbabwean small scale farmers Department of Mechanical Engineering, University of Johannesburg, Faculty of Engineering and the Built Environment, Post Office Box APB 524 Bunting Road Campus. 2538–2546.
Imananda Arifanny. (2021, June). Kampung Susu Lawu Singolangu, Wisata Gratis Kabupaten Magetan yang Bernuansa Pegunungan. Https://Beritakbb.Pikiran-Rakyat.Com/Pariwisata/Pr-962012273/Kampung-Susu-Lawu-Singolangu-Wisata-Gratis-Kabupaten-Magetan-Yang-Bernuansa-Pegunungan.
Khan, J. (2008). Testing and performance evaluation of an imported mobile bucket milking machine for water buffaloes. 3(5). www.arpnjournals.com
Krawczel, P., Ferneborg, S., Wiking, L., Dalsgaard, T. K., Gregersen, S., Black, R., Larsen, T., Agenäs, S., Svennersten-Sjaunja, K., & Ternman, E. (2017). Milking time and risk of over-milking can be decreased with early teat cup removal based on udder quarter milk flow without loss in milk yield. Journal of Dairy Science, 100(8), 6640–6647. https://doi.org/10.3168/jds.2016-12312
Kunradus Aliandu. (2020, November). Agrowisata Kampung Susu Lawu Resmi Jadi Lokasi Wisata Baru di Magetan. Https://Www.Beritasatu.Com/Nasional/702845/Agrowisata-Kampung-Susu-Lawu-Resmi-Jadi-Lokasi-Wisata-Baru-Di-Magetan.
Lessire, F., Moula, N., Hornick, J. L., & Dufrasne, I. (2020). Systematic review and meta-analysis: Identification of factors influencing milking frequency of cows in automatic milking systems combined with grazing. Animals, 10(5), 1–23. https://doi.org/10.3390/ani10050913
M. P. Bendsøe. (1989). Optimal shape design as a material distribution problem. Structural Optimization, 1(December 1989), 193–202. https://doi.org/10.1007/BF01650949
Odorčić, M., Rasmussen, M. D., Paulrud, C. O., & Bruckmaier, R. M. (2019). Review: Milking machine settings, teat condition and milking efficiency in dairy cows. Animal, 13(S1), S94–S99. https://doi.org/10.1017/S1751731119000417
Osvaldo Querin, Mariano Victoria, Cristina Gordoa, Rubén Ansola, P. M. (2017). Topology Design Methods for Structural Optimization.
Purnomo, S. H., Sari, A. I., & Haris, M. A. (2021). Analisis Pemasaran Susu Segar Sapi Perah Di Kecamatan Mojosongo Kabupaten Boyolali, Jawa Tengah. Mimbar Agribisnis: Jurnal Pemikiran Masyarakat Ilmiah Berwawasan Agribisnis, 7(1), 898. https://doi.org/10.25157/ma.v7i1.4848
Reinemann, D. J. (2015). Milking Machine Basics and Special Considerations for Small Ruminants Biomechanics of Milk Extraction and Lactation Physiology View project Farm Animal Responses to the Electrical Environment View project. https://www.researchgate.net/publication/304626356
Reinemann, D. J., Rasmussen, M. D., & Ruegg, P. (2005). Evaluating Milking Performance DOENÇAS METABÓLICAS EM VACAS LEITEIRAS View project BIOSENS View project. www.fil-idf.org
Ströbel, U., Rose-Meierhöfer, S., Öz, H., & Brunsch, R. (2013). Development of a control system for the teat-end vacuum in individual quarter milking systems. Sensors (Switzerland), 13(6), 7633–7651. https://doi.org/10.3390/s130607633
Suhartono, R., & Efendi, A. (2020). Design and Manufacturing of Bodypack Portable Milk Machine With Capacity 5 Liters. 14(1), 52–59.
Suhartono, R. N., Efendi, A., & Faturohman, F. (2019). Desain Mesin Pemerah Susu Sapi Portable Model Bodypack. Jurnal Pendidikan Teknik Mesin, 6(2), 123–128. https://doi.org/10.36706/jptm.v6i2.9641
Surjowardojo, P., Trisunuwati, P., & Khikma, S. (2016). Pengaruh Lama *Massage* dan Lama *Milk Flow Rate* terhadap Laju Pancaran Produksi Susu Sapi Friesian Holstein di PT Greenfields Indonesia. FH. 17(1), 49–56.
Vlah, D., Žavbi, R., & Vukašinović, N. (2020). EVALUATION of TOPOLOGY OPTIMIZATION and GENERATIVE DESIGN TOOLS AS SUPPORT for CONCEPTUAL DESIGN. Proceedings of the

Design Society: DESIGN Conference, 1, 451–460. https://doi.org/10.1017/dsd.2020.165
Yashin, A. V., Polyvyanyj, Y. V., Kalinina, O. S., & Khorev, P. N. (2022). Results of studies of a suction-type milking machine with squeezing effect. IOP Conference Series: Earth and Environmental Science, 953(1). https://doi.org/10.1088/1755-1315/953/1/012014