RESEARCH PROGRESS IN MECHANICAL AND MANUFACTURING ENGINEERING VOL. 2 NO. 2 (2021) 11-20

RPMME

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773 - 4765

Development of Drainage Cleaning Machine with Virtual Simulation

Chai Hao Wei[1], Noormaziah Jafferi[1]*

[1]Facaulty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Johor, MALAYSIA

*Corresponding Author Designation.

DOI: https://doi.org/10.30880/rpmme.2021.02.02.002
Received 02 Aug. 2021; Accepted 27 Nov. 2021; Available online 25 December 2021

Abstract: Drainage is one of the things that need to be taken into account when planning a town. It is important in ensuring the flow of wastewater from the residential areas is carried out to a proper sewerage system. The dumping of physical rubbish into drains has led to an increase in cases of blockage drains and has led to the issue of flash floods in major cities across the country. In addition, drain cleaning tasks in Malaysia still rely on inefficient manual labor and there is no element of sustainability in these operations for the long term in the future. Therefore, the aim of the project is to develop an automated drainage cleaning machine that can remove the solid waste that flows with the drain water with virtual simulation. This machine is designed based on the specific dimension of the drain and can easily install at the drain. This machine has two mechanisms to achieve the cleaning purpose which is the rotation and the push and pull mechanism. After the design phase, the full assembly of the drainage cleaning machine has completed the simulation which was conducted by SolidWorks. With the result obtained from the simulation and analysis, The time taken for a complete cycle of the cleaning operation is 25 seconds where it is capable of lifting 15kg of solid waste. It is operating for 1 hour, and as much as 144kg of solid waste can be cleaned from the drainage. The appropriate recommendation is that this machine is set to lift the solid waste out to side of the machine every 30 minutes regularly to ensure the optimal operation of cleaning and energy saving.

Keywords: Drainage Cleaning Machine, SolidWorks, Simulation, Motion Analysis, Drain Blockage, Solid Waste.

1. Introduction

Drainage is one of the things that need to be taken into account when planning a town. It is important in ensuring the flow of wastewater from the residential areas is carried out to a proper sewerage system. Therefore, the function of the drainage cleaning system is to maintain the environment of the drainage.

Corresponding author: normazia@uthm.edu.my

The aims of the drainage cleaning system are to ensure its route is free from waste and obstruction. It should be well-functioning as long as the surface water can flow into the drains and quickly disappear from the road[1].

According to the Act 617, the frequency to clean the drains is only once a month and this is set by the Waste and Public Cleansing Department (PPSPPA) [2]. The amount of dirt and waste after a month can easily cause clogging of drains[3]. Besides, the dumping of physical rubbish into drains has led to an increase in cases of blockage drains and has led to the issue of flash floods in major cities across the country[4]. In addition, drain cleaning tasks in Malaysia still rely on inefficient manual labor and there is no element of sustainability in these operations for the long term in the future. Wastewater from residential use and small businesses is usually discharged into drainage systems built in compliance with municipal planning. This drainage system is used 24 hours a day every week without going through a treatment process. These drains are usually easily clogged and water overflows. The system gets worse when there is heavy rain and floods. Existing technology and engineering advances can be combined with cleaning control methods outlined by the municipality. Maintenance using manpower and automated machine systems can help with clogging issues, restore the capacity of catch basins sediment and ensure the system works properly hydraulically to avoid flooding.

If it can produce a low-cost deep drain cleaning machine, it can provide to every drainage system in the city. It will reduce the solid waste contained in the drain using the auto mechanism technique[5]. A detailed description for the drainage cleaning mechanism which is to remove the floating or sub-floating solid waste where the machine can be immersed in the drainage system[6]. Apart from this, the conveyor portion of the machine should be against the flow of water. In recent years, there has been a growing number of publications focusing on the design and fabrication of drainage cleaning machines. Research in this area has shown a prototype fabricated with the metal bar and connected by arc welding. The working principle and its mechanism rotate the shaft when the motor is given the power[7]. This prototype can be placed across drainage with limitations of water flow through a low grid[8].

Previous studies have shown that there is no standard dimension for the drainage cleaning machine as the width and depth of the machine depends upon the size of drains. Lined open drains generally are the concrete channels and the kerb and gutter. The material needs to be compacted and shaped to construct a firm base for the development of lining drains. The dimensions of lined open drain depend on the interests of public safety and difficulty of maintenance[9]. The maximum depth for lined open drains can be classified according to the cover condition. Maximum depth of 0.5m is for the drain without protective covering but the drain with solid or grated cover can be 1m maximum depth. Besides, the range of width for lined open drains is 0.5m to 1m. In order to prevent the sedimentation and vegetative growth, the range of the average flow velocity between 0.6m/s to 4.0m/s. Once the average flow velocity is over 2.0m/s, drains were first necessary to cover with solid or grated covers for the whole length or with a 1.2m high handrail fence. Two of the methods have been utilized to ensure public safety.

Many recent studies related to the drainage cleaning machine have shown that most machines designed have the similar working principle. The power supply for the motor is electrical energy. When the motor is switched on, the top shaft will rotate. Simultaneously, the sprocket wheel attached on the shaft will also rotate. The roller chain was inserted into the teeth of the top sprocket wheel and drives the sprocket wheel at the bottom[10]. The lift teeth start to lift up the solid waste. The solid waste was lifted and thrown into the collecting bin[11]. The solid waste was removed manually from the collecting bin when it was full[12]. In a study conducted, it has been shown that their prototype drainage cleaning machine used mild steel as their material[13].

Most of the analysis generally focuses on the experiment test. However, a virtual simulation is essential during the development of the drainage cleaning machine. In this project, the result obtained from the simulation was able to determine the torque requirement for the cleaning action of the machine

by using computer-aided design (CAD) software. Furthermore, this can reduce the manufacturing cost and time taken which can clearly show the shape and geometry of the machine without fabricating it. After the geometry of the machine has been decided, it can identify the weight of the machine and the torque requirement to analysis whether it is suitable to fabricate the prototype or make improvements with the current design.

2. Methodology

In this research, it has three stages involved. In Stage 1, literature review was conducted to obtain the related data. In Stage 2, there are the geometry developments for the prototype. In Stage 3, it will be the data analysis of the prototype and come out with the discussion.

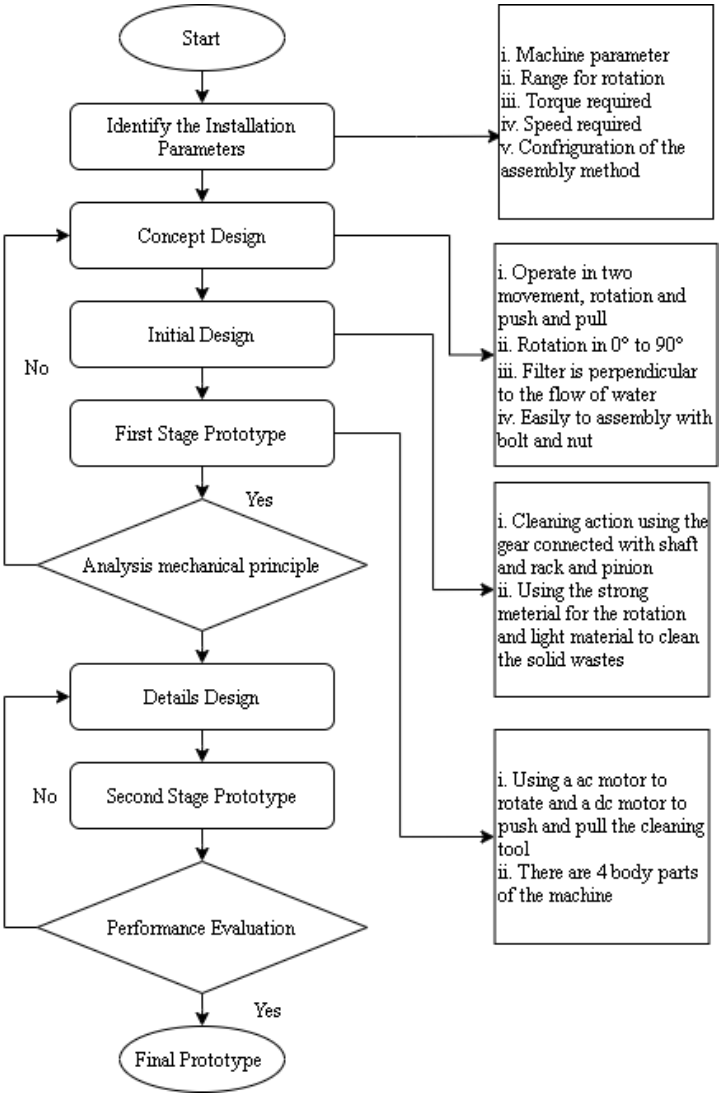


Figure 1: Research Flow Chart

2.1 Conceptual Design

The conceptual design is used to define the problem and gather the information to generate the concept which consists of a different phase to identify from an overall view to each of the parts based

on the requirement. First will be the product design specification. It is a phase to identify the problem in the early design process. Then, the objectives were clarified based on its level of importance.

The development of the machine needs to meet the requirement of several criteria. The machine must be capable of lifting up the waste by rotating the shaft and had the motion of push and pull for the cleaning tool. Then, it will have several alternatives to meet the requirement of the criteria. Concept evaluation will help to make the comparison among these alternatives and come out with selection of the components for the actual prototype concept.

Table 1: Physical and operational characteristics of drainage cleaning machine

Specification	Description
Motion	Rotation, push and pull motion
Motor	AC motor for rotation and DC motor for push the solid waste into the collecting bin
Stability	Symmetrical design and install with bolt and nut
Uses	Filter with hole in rectangular shape.
Operation method	Automatic operation
Number of motors	One motor for gear rotates One motor for rack and pinion
Material	The material used must be corrosion resistant to the water.
Size	Maximum height around 0.5m Different width depends on drain (0.5m ≤ w ≤ 1.0m)
Weight	1. The estimated weight for the machine not over 50kg
Durability	2. Durability against water, Capable to create different obstacles for the waste
Economic	3. Easy to control and install
Service	Regular maintenance: once per 1-2 month 4. Changing the body parts depend on the condition

Table 2: Conceptual Selection

Function	Selection
Sources of Power supply	AC and DC
Types of motor for rack and pinion	DC motor
Types of motor for shaft rotation	AC motor
Material Selection for the frame	Mild Steel
Installation method	Bolt and nut

2.3 Full Assembly of Drainage Cleaning Machine

After the concept was decided, the model geometry was created by SolidWorks. The structure of the machine is designed with four main parts. Part A will be the shaft that is connected with the motor that lift up waste. Part B will be the frame of the machine and the solid waste filter. Part C will be the rack and pinion to push and pull the cleaning tool. Last, part D will be the collecting bin and a

rectangular drain model. All the mechanism parts were connected with the motor to allow the system to function well.

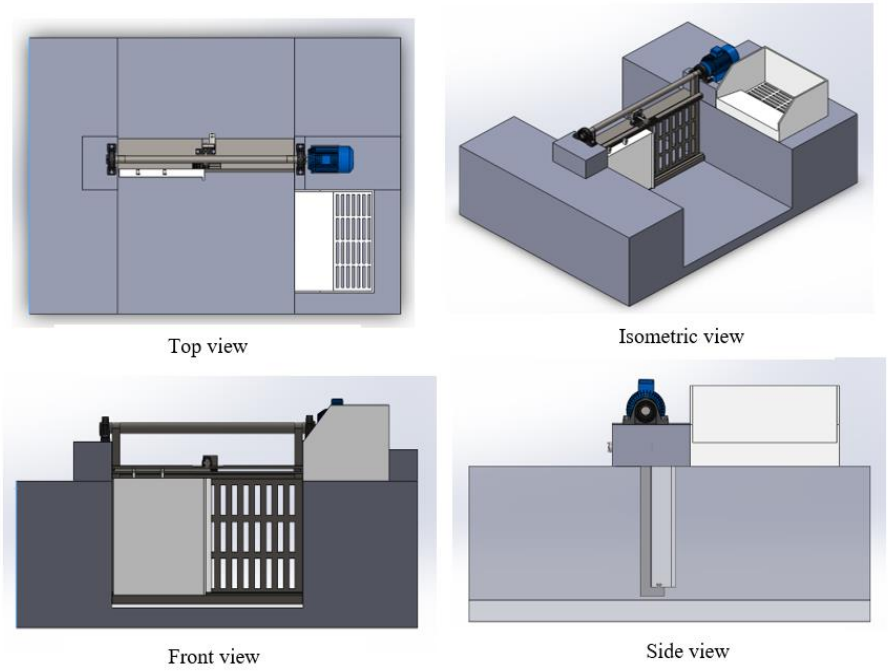


Figure 2: View of Drainage Cleaning Machine

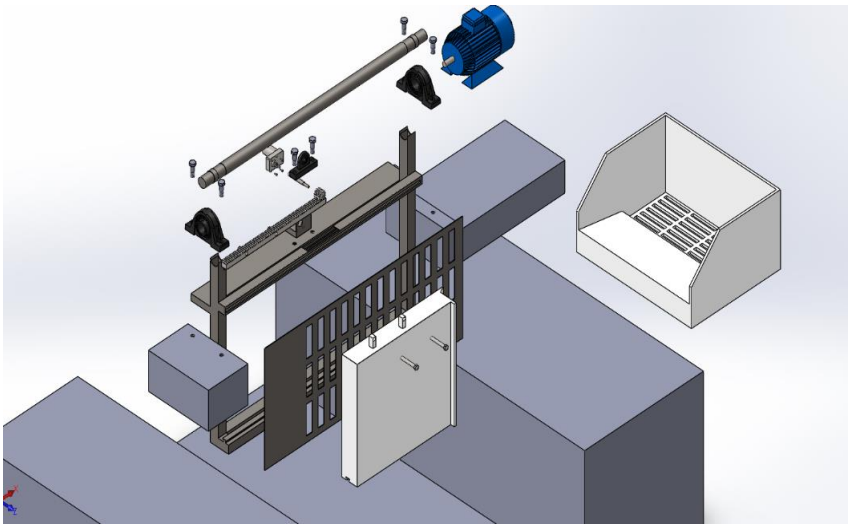


Figure 3: Exploded View of Drainage Cleaning Machine

3. Results and Discussion

The result obtained on the 3D model prototype such as the torque required based on different weight of solid waste and the angular velocity based on the duration of time will through the motion analysis of SolidWorks.

3.1 Maximum Torque Required for the Shaft Rotation

This simulation is applied the weight of the solid waste on the bottom of the frame which is directly convert the weight (kg) to force (N). Figure 4 shows the initial and final position for the rotation which

is 90°. In addition, the maximum torque generally will be obtained from the starting point which the shaft begins to rotate for the lift up purpose.

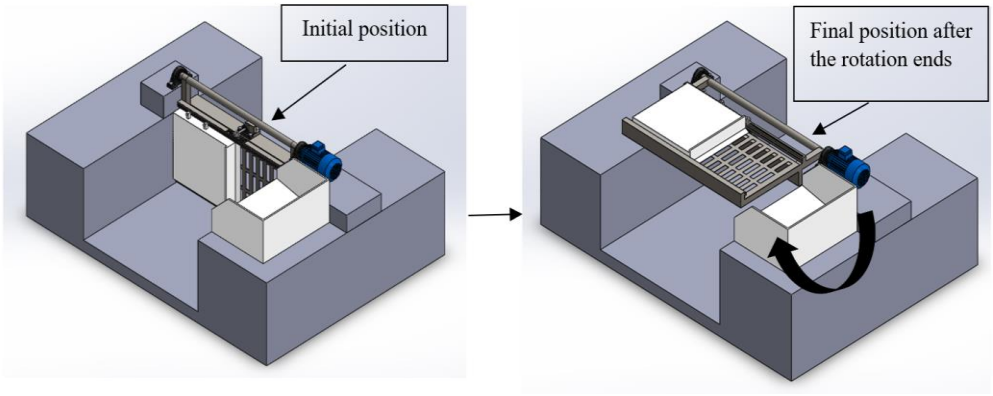


Figure 4: Initial and Final Position for Rotation

Table 3: Maximum Torque for the Rotation in 10s

Mass of solid waste (N)	Maximum torque required (N/m)
0	99.79
24.525	99.85
49.05	99.92
73.575	99.99
98.1	100.05
122.625	100.12
147.15	100.19

3.2 Maximum Torque Required with 147.15N of Solid Waste in Different Duration of Time

This simulation is to determine the torque required based on different duration of time with a constant 90°distance and a constant force applied on the bottom frame of the machine which is 147.15N. It shows that the time taken to lift up the machine in 10s has the minimum torque requirement.

Table 4: Maximum Torque for the Rotation in Different Duration of Time

Time taken to lift up the machine (s)	Angular velocity (deg/sec)	Speed (rpm)	Maximum torque required to lift up
5	27	4.50	101.64
6	22	3.67	101.05
7	19	3.17	100.70
8	17	2.83	100.46
9	15	2.50	100.30
10	13	0.83	100.19

3.3 Maximum Torque Required to Push Cleaning Tool

This simulation is to identify the maximum torque against the friction force to push the solid waste into the collecting bin where the frame was parallel to the ground. There is a constant velocity that can be directly obtained from SolidWorks after 488.35mm divided with 30mm diameter of pinion will have a rotation of 5860.2° at the pinion to push the solid waste into the collecting bin with 5s duration of

time. In addition, the friction force produced during the push motion will be identify through the calculation before to determine the maximum torque.

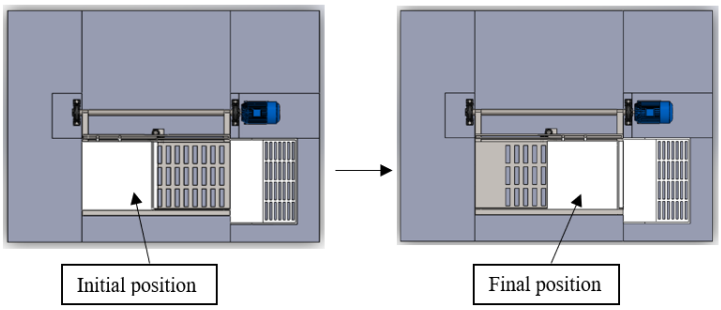


Figure 5: Initial and Final Position for Push Motion

Table 5: Maximum Torque Required with Different Friction Force

Weight of solid waste (kg)	Friction force (N)	Maximum torque (N/m)
0	0	0.024
2.5	9.81	0.147
5.0	19.62	0.294
7.5	29.43	0.441
10.0	39.24	0.589
12.5	49.05	0.732
15.0	58.86	0.883

3.4 Modification of Machine with A Gear Box

There is a problem that has been encountered after the simulation is done. The torque is the most important element in the shaft rotation because the machine will not operate due to the insufficient torque generated. However, the maximum torque of the rotation obtained for this drainage cleaning machine design is around 100 Nm in the simulation. This is a large value during the selection of the motor. Therefore, there is a method to reduce the torque input required. An AC motor with 15.20Nm has been selected and processes the gear analysis with it. Table 6 has shown the parameter of the gear box design. The specification of the gearbox has been calculated and the 3D models of gear box were created by Solidworks after calculation and validate the calculation through the simulation.

Table 6: Parameter of Gears

Gear set	1		2	
Gear	Pinion	Gear	Pinion	Gear
Number of teeth	15	45	15	45
Module (mm)	3	3	3	3
Pitch diameter (mm)	45	135	45	135
Torque (Nm) generated	11.35	34.05	34.05	102.15

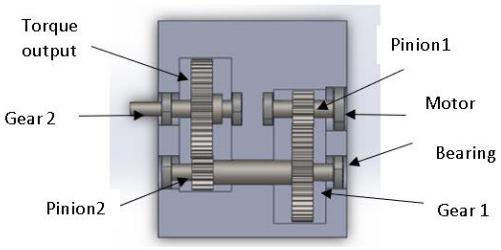


Figure 6: Position of the gears in gear box

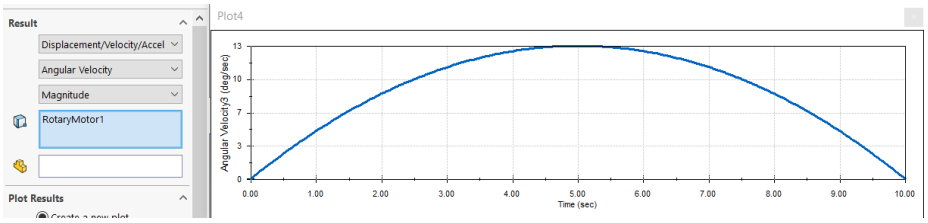


Figure 7: Output Angular Velocity Through Simulation

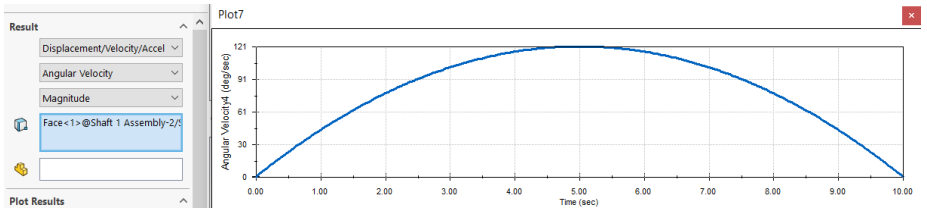


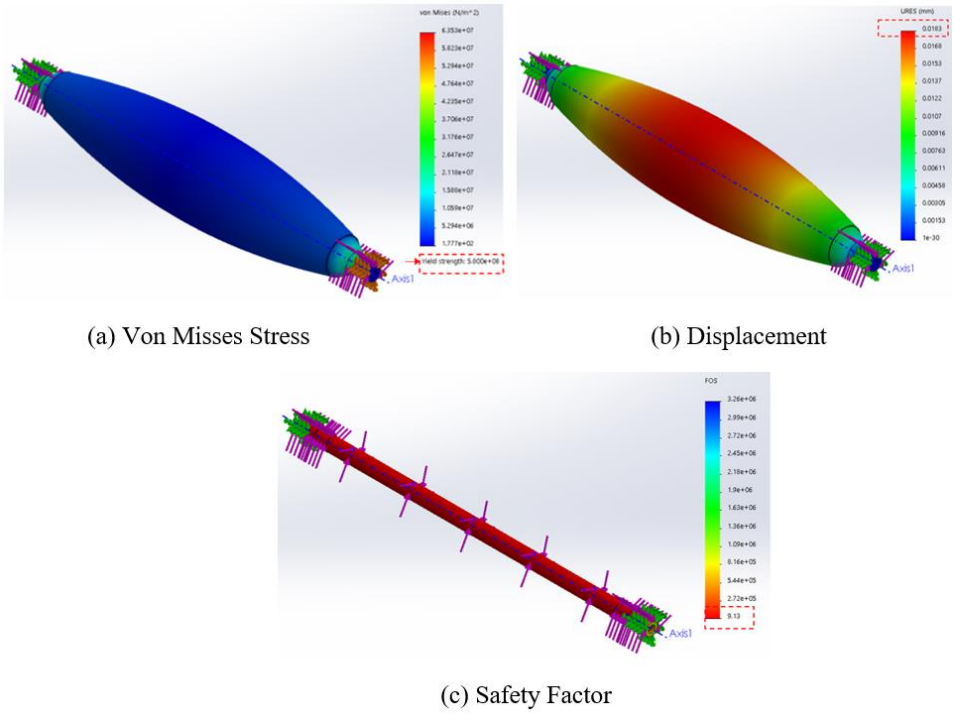
Figure 8: Input Angular Velocity Through Simulation

Table 7: Ratio of Speed Reduction Through Simulation

Type	Angular Velocity (deg/sec)	Speed (rpm)	Ratio of the speed reduction
Input	121	20.17	$\frac{20.17}{2.17} = 9.29$
Output	13	2.17	

3.5 Static Analysis for Rotating Shaft

Rotating shaft is a significant part in the design of the drainage cleaning machine. It is attached to the motor and transmits the power to rotate the body of the machine before the solid waste has been pushed by the cleaning tool. Therefore, the rotating shaft will be the component tested through the static analysis simulation. Result of the analysis will show in the figure 8 below:



(a) Von Misses Stress (b) Displacement

(c) Safety Factor

Figure 9: Static Analysis for Rotating Shaft

4. Conclusion

As a conclusion, all the scope and objectives of this project are achieved. The aim to design this machine with the basic mechanism of the rotation and push and pull motion is to reduce the level of solid waste floating. With a virtual simulation, it will become easier to select the appropriate component and equipment.

The overall weight of the drainage cleaning machine required to lift up is 55.36kg with a 15.2Nm torque input. The time taken for a complete cycle of the cleaning operation is 25 seconds where it is capable of lifting 15kg of solid waste. Table 3 has shown the rotation to lift up the machine is 10s and Table 4 has shown the time taken for push motion required is 5s. Then, the rake board goes back to the original position from an angle of 90 degree to an angle of 0 degree in 10s. At the same time, the cleaning tool will also back to its original position in 5s during the rake board return to its position. It is operating for 1 hour, and as much as 144kg of solid waste can be cleaned from the drainage. However, it is impossible for every 25seconds, 15kg of solid waste is collected and lifted as it depends on the current of water flow in the drain and the amount of rubbish dumped by particular residential area. Therefore, the appropriate recommendation is that this machine is set to lift the solid waste outside of the machine every 30 minutes regularly to ensure the optimal operation of cleaning and energy saving.

There are various designs of drainage cleaning machines that can be found on the past research but all the designs have made the prototype only. The existence of drainage cleaning machines with virtual simulation has clearly shown the result of this study is able to reduce the cost and time spent to fabricate the prototype before analysis. Hence, virtual simulation can be a technology or a procedure before the real-life simulation and produce alternatives easily to achieve the basic mechanism of a drainage cleaning machine. This technology is suitable to develop the drainage cleaning machine which can determine the requirement and help to reduce the investment cost over time. In fact, it can also reduce the manpower and maintenance cost of the drain cleaning task. As a result, the blockage of drains can be reduced

Acknowledgement

The authors wish to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia that has supported the accomplishment of research activity.

References

[1] Bagul V S, Jadhav Y D, Bachhav S N, Bhadane B A and Shinde H S 2017 Automatic Drainage Cleaning System **2** 13–6

[2] Waste S and Management C 2017 Solid Waste and Public Cleansing Management Laws Of Malaysia Solid Waste And Public Cleansing Management Act 2007

[3] Flood N and Program I 2006 CRS Credit for Drainage System Maintenance

[4] Chandrasena D C N, Yusof K B W, Liyanapathirana V C, Ul Mustafa M R and Mustaffa Z 2017 Blocked drains syndrome: Physical degradation of the storm drainage system in a compact city *Adv. Sci. Lett.* **23** 1407–11

[5] Sharma M, Siddiqui S, Srivastava A P, Tiwari S K and Student B T 2017 Design & Fabrication of Automatic Drainage Cleaning System using Solar Panel *Int. J. Eng. Sci. Comput.* **7** 11317–8

[6] Ansari M. T., Kuruvilla R. G., Mathew S. B., Mathew S. C and Sreejith.R ER. 2018 Automatic Drainage Cleaning System with the Use of Solar Energy *Int. Res. J. Eng. Technol.* **5** 3957–60

[7] Ganeshu L. 2016. Semi-Automatic Drain for Sewage Water Treatment of Floating Materials *Int. J. Res. Eng. Technol.* **05** 278–81

[8] Babu Bhaskaran V G 2018 Design and Fabrication of Automated Drain / Gutter Cleaner Design and Fabrication of Automated Drain / Gutter Cleaner Machine *J. Emerg. Technol. Innov. Res.* **2** 16

[9] Leong T M, Kassim A H, Md.Noh M N, Ainan A, Dzulkifli A B and Shafie A 2012 *Urban Stormwater Management Manual for Malaysia, MSMA 2nd Edition*

[10] Varughese M D A 2018 Automatic Drainage Cleaning Robot *Int. J. Res. Appl. Sci. Eng. Technol.* **6** 1087–90

[11] Satpute S. S., Darole V. R., Khaderao P. M., Hiralkarl P. B. 2018. Automatic Sewage Cleaning System *Int. J. Adv. Eng. Res. Dev.* **5** 434–9

[12] Swapnil A. K., Sanket W.T., Sachin P.W., Akshay V. S. Automatic Garbage Collector Machine International Journal for Scientific Research & Development| Vol. 6, Issue 01, 2018 (online): 2321-0613 **6** 1382–4

[13] Rathod M, Pund V, Pungle R and Rathod J 2017 Automatic Floating Waste Collector 2114–7