Jurnal Engine: Energi, Manufaktur, dan Material e-ISSN: 2579-7433
Anugrah, Nurisna, Widiyanto, & Latif, Vol. 4, No. 1, 2020: 14-19

Performance Analysis of Plastic Bottle Crushing Machine with Electric Motor Drive

(1)*Rinasa Agistya Anugrah, (1)Zuhri Nurisna, (1)Fandi Widiyanto, (1)Aziz Abdul Latif

(1) Department of Mechanical Technology, Universitas Muhammadiyah Yogyakarta, Jl. Brawijaya, Tamantirto, Kasihan, Bantul, Special Region of Yogyakarta, Indonesia (55183)

**Email: rinasaanugrah@umy.ac.id*

Received: 01.05.2020 Accepted: 09.05.2020 Published: 30.05.2020

ABSTRACT

Garbage is now very possible to be recycled. One way to help the recycling process is to make a plastic bottle crushing machine. In this study, the test material is a plastic bottle with a thickness of 0.1 mm. Then we calculated the engine capacity, electrical energy, the profit of production costs, the comparison of the efficiency of the electric motor drive compared to the gasoline engine drive, the rotation of the blade, and linear velocity v-belt. This study's results were that the smaller modified machines could crush plastic bottles into crushed plastic with a length smaller than 20 mm as much as 27.93 kg/hour. The comparison efficiency of using a plastic bottle crushing machine with an electric motor drive with a gasoline motor drive is 2.6:1. It can be concluded that the plastic bottle crushing machine with an electric motor drive is superior to those with a gasoline engine drive.

Keywords: *crushing machine, plastic bottle, efficiency, working capacity, electrical energy, performance*

I. Introduction

Solid waste management is a major environmental problem in the world. Researchers predicted that approximately 6.3 Bt of plastic waste had been generated. Around 9% of which had been recycled, 12% was incinerated, and 79% was accumulated in landfills or the natural environment (Geyer, Jambeck, & Law, 2017). Scientists predict roughly that in 2050 the garbage and waste scattered around the world up to 12 Bt. Subsequently, Indonesia set a record of the second rank of the most plastic waste producing in the world. There are researchers (Orhorhoro, Ikpe, & Tamuno, 2016) found a similar problem in Nigeria, where people dumped solid waste and became a significant concern to government and society.

The problem of this global phenomenon can be minimized by reducing the volume and then processing it by incinerating or recycling. The plastic bottle crushing machine can reduce the volume of plastic bottle dumps indiscriminately across Yogyakarta cities. It has been researched and made a crushing machine to solve the problem in Nigeria (Orhorhoro, Ikpe, & Tamuno, 2016).

Plastic has many usabilities in daily life. It has several advantages that do not exist in other materials. It is lightweight, durable, anti-rust, anti-break, easily formed, and relatively inexpensive. Even when it becomes garbage, plastic can still be recycled to become raw material again. As researched by researchers (Ahmadinia, Zargar, Karim, Abdelaziz, & Shafigh, 2011) that they conducted to determine the effect of incorporating waste plastic bottles on stone mastic asphalt (SMA) mixture. They used a specific type of plastic, Polyethylene Terephthalate (PET) in their experiments. In this research, the size of plastic needs to be reduced in size to make it easy to melt.

On the other hand, in order to be easily stored, plastic needs to be reduced in size, the smaller the size of the plastic, the easier to compact its volume. Thus, a tool is needed to reduce the size of the plastic first. A plastic crushing machine can be one solution to this problem.

There are researchers (Syamsiro, Hadiyanto, & Mufrodi, 2016) who made a plastic crushing machine by pyrolysis. It was used for crushed plastic bottles to become smaller size. It was driven by a gasoline motor (gasoline engine drive) with 5.5 HP with a working capacity of 14 kg/h. Another research had also been conducted by other researchers (Azhari & Maulana, 2018), where they designed a slightly different crushing machine using a crusher system. Also, researchers (Junaidi, Nur, Nofriadi, & Rusmardi, 2015) produced a crushing machine but with a crusher type equipped with cylinder type reel. The construction was more sophisticated, while a more robust 10 HP driver was needed.

There was even a more complicated design (Yahya, 2017) in which his machine was solar-powered. The deficiency was that it could only crush a plastic bottle of 600 ml in 4.39 minutes with one panel and 4.19 minutes with two panels, which was very slow. Therefore this research used an electric motor with 2 HP since it was sufficient to empower the crushing machine.

Other types of machines whose function for a cutting object (Rachmawati, 2019) also use an electric motor as a driver of this machine. It has many advantages, such as not needing maintenance, is not noisy, and does not produce air pollution.

Based on the background above, this research has the main objectives to analyze the performance of plastic bottle crushing machines with electric motor drives.

II. Materials and Method

The design was place-compact and straightforward because it used microscale of micro industrial. The machine uses an electric motor drive, as seen in *Figure 1*. The height was 1.4 m, and the width was 0.8 m.

The design of the blade is presented in *Figure 2*. There are two types of blades, fixed blade and rotary blade, which the thickness of each blade is 10 mm, and its length and width are 238 mm and 70 mm, respectively. The angle of the blade is 31 degrees.

Figure. 1. Plastic Bottle Crushing Machine

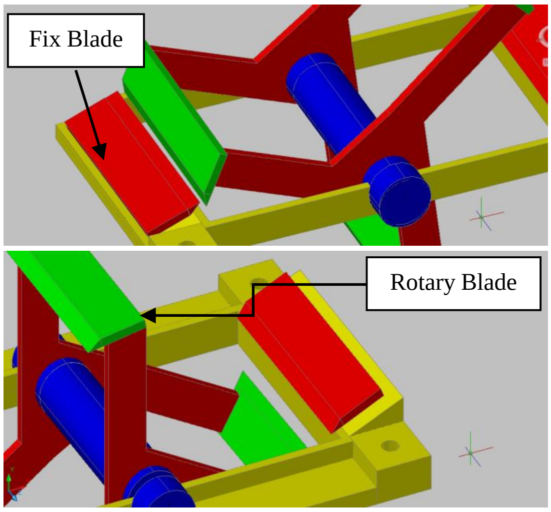

Figure 2. Blade of Plastic Bottle Crushing Machine

2.1. Rotating Velocity of Blade Shaft

Based on research (Sutowo, Diniardi, & Yanto, 2010), a formulation is used to calculate the rotating velocity of the blade shaft as follows:

$$\frac{n_1}{n_2} = \frac{D_p}{d_p} \quad (1)$$

where:
n_1 = rotating velocity of the electric motor shaft
n_2 = rotating velocity of the blade shaft
D_p = Diameter of the driven pulley
d_p = Diameter of the driving pulley

2.2. Linear Velocity of V-Belt

This calculation to get the value of the linear velocity of V-Belt by adopting equation from (Sutowo, Diniardi, & Yanto, 2010):

$$V = \frac{\pi \times d_p \times n_1}{60 \times 1000} \quad (2)$$

2.3. Time of Testing Crushing Machine

The experiment was done with five attempt testing for the obtained result of the time average needed to crush up 1 kg of plastic bottles. This data was used for substituted into variables of the formula to calculate an estimated working capacity.

2.4. Calculation of The Estimated Working Capacity

In this formulation to get estimated working capacity, because 1 hour is equal to 60 minutes, so the equation became like the following:

$$\frac{1\ \text{kg}}{x} = \frac{t_{av}}{60\ \text{minutes}} \quad (3)$$

where :
x = working capacity of crushing machine (kg/h)
t_{av} = time average

The ratio of crushed plastics weight in a minute divided by an hour equal to the ratio of time average in minutes divided by an hour (60 minutes).

2.5. Calculation of The Cost of Electrical Energy Use

After finding out the electric motor power, the unit energy was searched, then the cost per hour was obtained by multiplying the price per unit of electric energy used. Then cost per day could be determined by multiplying the hourly cost by operating time per day in hours. Also, cost per month could be obtained by multiplying the cost per day by multiplying the number of operating days per month. Then, we want to know the cost per year just by multiplying it in a year.

2.6. Calculation of Profit of Operation Cost

For calculating the profit of operation, the cost was conducted by doing the following steps:

a. Determined gross profit per kilogram
b. Determined Gross profit per 1 hour operation
c. Determined Gross profit per day
d. Determined Net profit

2.7. Comparison Between The Efficiency of The Electric Motor and Gasoline Engine of The Driver

Comparing both electric motor and gasoline engine driver of this research, below was the formula:

$$\frac{P_{EM} \cdot x}{P_G \cdot y} = \frac{C_{EM}}{C_G} \quad (4)$$

where :
P_{EM} = Power of Electric Motor Drive
P_G = Power of Gasoline Engine Drive
x = Ratio number for Electric Motor Drive
y = Ratio number for Gasoline Engine Drive
C_{EM} = Capacity The Crushing Machine with Electric Motor Drive
C_G = Capacity The Crushing Machine with Gasoline Engine Drive

III. Result and Discussion

3.1. Rotating Velocity of Blade Shaft

By using equation (2), the results were obtained:

$$\frac{1400}{n_2} = \frac{53{,}7}{79}$$

$$53.7 \text{ x } n_2 = 1400 \text{ x } 79$$

$$n_2 = \frac{1400\, x\, 79}{53.7}$$

$$n_2 = 2059 \text{ rpm}$$

The results of functional testing on Crushing Machine were the electric motor rotated at 1,400 rpm, and the blade shaft rotated at 2,059 rpm.

Measuring the rotating velocity of a pulley of blade shaft by using measurement instrument (Digital Laser Tachometer), as shown in *Figure 3* below, was obtained of 2,044 rpm, almost similar results to calculation method, but just a little different than 14 rpm only. This could be ignored so that it could be considered the same value.

Figure 3. Measuring Rotating Velocity of Pulley of Blade Shaft by Digital Laser Tachometer

3.2. Linear Velocity of V-Belt

By using equation (2), the result was obtained:

$$V = \frac{3.14 \times 53.7 \times 1400}{60 \text{ x } 1000} = 3.9 \text{ m/s}$$

With the rotating velocity of the electric motor of 1,400 rpm, the V-Belt's linear velocity that linked both pulleys was 3.9 m/s.

3.3. Time of Testing Crushing Machine

The plastic bottle can machine make the bottles show in *Figure 4* below to become crushed plastic with a small size.

Figure. 4. Plastic Bottles

The crushed plastic size was smaller than 20 mm of length, and it was 100% pulverized. The working capacity of this machine was 27.93 kg/hour. *Figure 5* showed the crushed plastics.

Figure. 5. Small Crushed Plastics

Table 1 below presented the time of Testing Crushing Machine during crushing 1 kg plastic as a method to find the average time per 1 kg crushed plastic. The result was 2.04 minutes.

Table 1. Time of Testing Crushing Machine

No.	The thickness of Plastic (mm)	Weight of Crushed Plastics (kg)	Times of Testing (minutes)
1	0,1	1	2.13
2	0,1	1	1.56
3	0,1	1	1.59
4	0,1	1	2.03
5	0,1	1	2.09
Total			10.20
Time Average			10.20/5 = 2.04

3.4. Calculation of The Estimated Working Capacity

By using equation (3), the result were obtained:

$$x = \frac{60 \text{ minutes x } 1 \text{ kg}}{2{,}04 \text{ minutes}}$$

$$x = \frac{60}{2{,}04}$$

$$x = 29.4 \text{ kg/h}$$

The estimated working capacity was 29.4 kg/h with continuous operation after reduced by the depreciation of the operation process, which was 5%, so capacity becomes 27.93 kg/h.

3.5. Calculation of The Cost of Electrical Energy Use

Steps to obtain the following cost of electrical energy use:

a. Obtained electrical energy used per hour
 1 kWh = Rp 1,467.28 (type 2200 VA)
 The power of the electric motor was 1.5 kW, so electrical energy used per hour was 1.5 kWh
b. Cost electrical energy used per hour
 Cost electrical energy used per hour = 1.5 x 1,467.28 = Rp 2,200.95 per hour
c. For example, times of operation machine was 7 hours, so :
 7 x 2,200.95 = Rp 15,406.65

If the operation time was 7 hours per day, the total cost was Rp 15,406.65 per day.

3.6. Calculation of Profit of Operation Cost

For calculating the profit of operation, the cost was conducted by doing the following steps:

a. Selling price – purchase price = gross profit per kilogram:
 Rp 7,000 – Rp 4,500 = Rp 2,500
b. Gross profit per kilogram x working capacity machine per hour = Gross profit per 1 hour operation:
 Rp 2,500 x 27.93 kg/h = Rp 69,825 per hour
c. Gross profit of an hour operation x 7 = Gross profit per day:
 Rp 69,825 x 7 hours per day = Rp 488,775 per day
d. Gross profit per day – electrical energy use = Net profit
 Rp 488,775 – Rp 15,406.65 = Rp 473,368.35

So, the net profit per day were 473,368 rupiahs.

3.7. Comparison Between The Efficiency of The Electric Motor and Gasoline Engine of The Driver

The research found that the capacity of their crushing machine with a gasoline engine drive was 30 kg/h with a power output of 5.5 HP (Upingo, Djamalu, & Botutihe, 2016). To get a comparison between the efficiency of the electric motor and gasoline engine for the driver of Plastic Bottle Crushing Machine by using equation (4), the result was obtained:

$$\frac{2\text{ HP . x}}{5.5\text{ HP . y}} = \frac{27.93\text{ kg}}{30\text{ kg}}$$

$$\frac{x}{y} = \frac{27.93 \times 5.5}{30 \times 2}$$

$$x : y = 2.56 : 1 = 2.6 : 1$$

The result showed a comparison between the efficiency of the electric motor and gasoline engine driver of 2.6:1. It proved that the electronic motor driver was more efficient than a gasoline engine driver.

IV. Conclusion

Plastic Bottle Crushing Machine can crush plastic bottles into crushed plastics with a length smaller than 20 mm and a thickness of 0.1 mm. With electric motor rotating at 1,400 rpm, the working capacity of this machine was 27.93 kg/h. The electric motor drive was more efficient than a gasoline engine drive, with a comparison efficiency of 2.6:1. The estimation of net profit per day was 473,368 rupiahs. Therefore, this machine is very recommended to use.

Acknowledgments

The author would like to thank Lembaga Penelitian, Publikasi, dan Pengabdian Masyarakat (LP3M) Universitas Muhammadiyah Yogyakarta for funding this research through the Internal Research Grant Scheme of Universitas Muhammadiyah Yogyakarta (Penelitian Kemitraan Dosen dan Mahasiswa) Fiscal Year 2019 with Letter of Decree: No. 196/SK-LP3M/I/2019.

References

Ahmadinia, E., Zargar, M., Karim, M. R., Abdelaziz, M., & Shafigh, P. (2011). Using waste plastic bottles as additive for stone mastic asphalt. *Materials & Design, 32*(10), 4844-4849. doi:https://doi.org/10.1016/j.matdes.2011.06.016

Azhari, C., & Maulana, D. (2018). Perancangan Mesin Pencacah Plastik Tipe Crusher Kapasitas 50 kg/jam. *Jurnal Isu Teknologi STT Mandala, 13*(2), 7-14.

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, *3*(7), e170078. doi:https://doi.org/10.1126/sciadv.1700782

Junaidi, J., Nur, I., Nofriadi, N., & Rusmardi, R. (2015). Pengembangan Mesin Pencacah Sampah/Limbah Plastik dengan Sistem Crusher dan Silinder Pemotong Tipe Reel. *Jurnal Ilmiah Poli Rekayasa, 10*(2), 66-73. doi:https://doi.org/10.30630/jipr.10.2.12

Orhorhoro, E. K., Ikpe, A. E., & Tamuno, R. I. (2016). Performance Analysis of Locally Design Plastic Crushing Machine for Domestic and Industrial Use in Nigeria. *European Journal of Engineering Research & Science, 1*(2), 26-30.

Rachmawati, P. (2019). Rancang Bangun Mesin Perajang Singkong yang Memenuhi Aspek Ergonomis untuk Meningkatkan Produktivitas Pekerja. *Jurnal Engine: Energi, Manufaktur, dan Material, 3*(2), 66-72. doi:https://doi.org/10.30588/jeemm.v3i2.581

Sutowo, C., Diniardi, E., & Yanto, M. (2010). Perencanaan Mesin Penghancur Plastik Kapasitas 30 kg/jam. *Sintek Jurnal, 4*(2), 39-49.

Syamsiro, M., Hadiyanto, A. N., & Mufrodi, Z. (2016). Rancang Bangun Mesin Pencacah Plastik Sebagai Bahan Baku Mesin Pirolisis Skala Komunal. *Jurnal Mekanika dan Sistem Termal, 1*(2), 43-48.

Upingo, H., Djamalu, Y., & Botutihe, S. (2016). Optimalisasi Mesin Pencacah Plastik Otomatis. *Jurnal Teknologi Pertanian Gorontalo, 1*(2), 112-139.

Yahya, M. (2017). *Desain Mesin Pencacah Botol Plastik Menggunakan Tenaga Surya.* Surakarta: Skripsi Jurusan Teknik Elektro, Universitas Muhammadiyah Surakarta.