Design and Build a Power System on a High-Density Polyethylene Plastic Crusher Machine

Ganjar Pramudi[1*], Ilham Azhar Raihan Rahmanul Hakim[2]
[1]*Manufacturing Engineering Technology, Sebelas Maret University, Surakarta, 57126, Indonesia*
[2] *Mechanical Engineering, Sebelas Maret University, Surakarta, 57126, Indonesia*
**Email Corresponding Author: ganjar.pramudi@staff.uns.ac.id*

ABSTRACT

Plastic High Density Polyethylene (HDPE) merupakan salah satu bahan material plastic yang biasa digunakan untuk pembuatan kemasan berbahan plastic. Sampah plastic berjenis HDPE yang jumlahnya meningkat setiap tahunnya dapat dimanfaatkan dengan mendaur ulang dengan cara yang baik. Salah satu cara untuk mengelola sampah plastic HDPE adalah dengan mendaur ulangnya menjadi serbuk untuk bahan komposit. Mesin crusher plastic HDPE digunakan untuk mencacah sampah plastic HDPE menjadi potongan-potongan kecil seperti serbuk, sehingga memudahkan proses daur ulang untuk bahan komposit. Maka dirancanglah mesin Crusher atau penghancur plastic HDPE ini dengan desain pisau baru agar hasil cacahan dapat maksimal dan menggunakan motor listrik dengan daya rendah sehingga dapat menghemat cost produksi. Penggerak yang digunakan berupa motor listrik dengan daya 3 HP kecepatan 1420 rpm. Dengan gaya pemotongan sebesar 99,3 N.mm2, sehingga mampu menghasilkan serbuk halus sebanyak 100 gram selama 60 menit. Pengujian dibagi menjadi 2 jenis, yaitu pengujian tanpa plastic HDPE dan dengan plastic HDPE.

Keywords: Crusher; Power; Design; HDPE Plastic

ABSTRACT

High-density polyethylene (HDPE) plastic is one of the plastic materials commonly used for making plastic packaging. HDPE plastic waste, which increases in number every year, can be used by recycling in a beneficial way. Recycling HDPE plastic waste into powder for composite materials is one way to manage it effectively. The HDPE plastic crusher machine is used to chop HDPE plastic waste into small pieces such as powder, thus facilitating the recycling process for composite materials. The HDPE plastic crusher, also known as the crusher machine, was designed with a new knife design to maximize shredding results and is equipped with a low-power electric motor to reduce production costs. The drive used is an electric motor with a power of 3 HP at a speed of 1420 rpm. With a cutting force of 99.3 N/mm², it is able to produce 100 grams of fine powder for 60 minutes. Testing is divided into 2 types, namely testing without HDPE plastic and with HDPE plastic.

Keywords: Crusher; Design; HDPE Plastic; Power;

INTRODUCTION

Plastic is a ubiquitous object that plays a crucial role in today's modern life. Plastic is used for various purposes in daily life, ranging from food packaging, household appliances, children's toys, electronics, and automotive components. The increase in the use of plastic materials has resulted in an increase in the production of plastic waste from year to year [1, 2].

The waste problem has become a concerning global issue, especially with the rapid developments of modern times. However, proper plastic waste management does not keep pace with the increasing use of plastic products. As a result, this condition worsens the amount of plastic waste in the world. One of the largest producing countries of plastic waste is Indonesia, which is ranked third in the world. Indonesia produces 67.8 million tons of plastic waste, or 185,753 tons of plastic waste produced daily by 270 million Indonesians. [3]

Based on the above problems, High Density Polyethylene (HDPE) plastic waste, which is increasing in number every year, can be used by recycling in a good way. Recycled plastic is widely used as a composite material. The use of composite materials with HDPE materials requires HDPE materials in powder form. Currently, the powder manufacturing process still uses a flour grinding machine. However, the machine is ineffective because it causes excessive heat in the machine because the knife used is not suitable for crushing HDPE plastic, and the result is not optimal [4].

This is, of course, due to the improper use of machines for grinding HDPE plastics. When used, this grinding machine generates heat, causing the ground plastic to clump in the machine, resulting in the machine becoming jammed and needing to be cooled first [5]. The results of this plastic milling process are also very small, so the efficiency of the machine is very low [6]. From the above problems, this HDPE plastic crusher, or crusher machine, was designed. The crusher machine will crush HDPE plastic into fine powder for use in composite materials. Problems that arise in flour grinding machines can be handled by redesigning the blade design so that the shredding results can be maximised, in addition to the electric motor used having low power in order to save production costs [7].

The design of this crusher machine requires calculation and analysis, especially on power. Power in a machine is very important because it affects the performance and function of the machine [8]. One reason for optimal performance is that power is a measure of a machine's ability to do the job [9]. Sufficient power makes the engine performance optimal and improves the efficiency of the machine. With the redesign of this crusher machine, it is hoped that it can overcome the problems that existed in the previous crusher machine and benefit the community [10].

The greater the power of the machine, the more work is done in less time. However, too much power will require a lot of energy. Adequate machine power is essential to ensure sufficient cutting force during the cutting process. Sufficient cutting force ensures optimal machine performance and improves operational efficiency [11]. While large engine power can help increase cutting force, it can also increase energy consumption. From some of the existing problems, it is necessary to design the power system needed by the plastic crusher machine. Power systems require calculations in their design so that the machine can work optimally.

RESEARCH METHODS

The HDPE plastic crusher machine is a machine made with the aim of increasing productivity and effectiveness in the process of converting HDPE plastic waste into fine powder to make the HDPE plastic material into a composite material [12]. The HDPE crusher machine functions to chop HDPE plastic waste into fine powder. The design of an HDPE plastic crusher machine requires various things that must be considered [13]:

1. Determine the power of the machine and the capacity to be produced. 2. Determine the type and size of components used to design the HDPE plastic crusher machine. 3. Looking for literature on examples of HDPE plastic crusher machines on the market.

After understanding this, the next step is to make a crusher machine design. The design is made based on sketches and calculation designs to ensure the size of each component. The design of the crusher machine is shown in Figure 1.

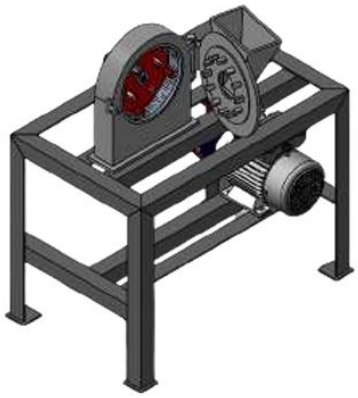

Figure 1. Crushser Machine Design

The HDPE plastic crusher machine is a machine that functions to chop or crush HDPE plastic waste into fine powders used for the manufacture of composite materials. The way the HDPE plastic crusher machine works starts from the main drive, which is an electric motor with a power of 3 HP and a drive rotation speed of 1420 RPM transmitted by pulleys and belts connected to the grinding knife shaft. The use of the chopper blade shaft and the shaft on the electric motor has a ratio of 2:1, with both having the same diameter of 28 mm.

Pulley and belt transmission are one of the main components of the HDPE plastic crusher machine. The pulley and belt transmission systems used in the crusher machine function to transmit power from the electric motor to the chopping blade shaft. The HDPE plastic crusher machine is shown in Figure 2.

Figure 2. Plastic Crusher Machine

The way the HDPE plastic crusher machine works is an electric motor with a power of 3 HP with a rotation speed of 1420 rpm, then power is transmitted by pulley and belt in a ratio of 2:1. The transmission system is connected to the shaft of the HDPE plastic crushing blade. The shaft used is 25 mm in diameter and is made of iron material that is able to transmit power from the motor [14]. The power transmitted in the shaft is connected to the crusher blade so that it can rotate to crush HDPE plastic. After the crushing blade rotates, pieces of HDPE plastic are inserted gradually so that the crushing process can run smoothly. Inside the machine there is a mesh or sieve that is used to filter the plastic that has become powder. HDPE plastic powder will come out of the bottom channel of the machine body.

RESULTS AND DISCUSSION

1. Crusher Machine Design

To find out the cutting force on the crusher machine, you must first know the shear stress of the material to be cut, namely the shear stress of HDPE plastic of 33.1 MPa. The cutting force is determined by looking for the surface area of the plastic to be cut (A plastic)

The surface area of the plastic can be searched by the formula:

l = 6 mm

t = 0.5 mm

$$A_{plastik} = l \; x \; t \quad (1)$$

$$= 6 \; x \; 0{,}5$$

$$= 3 \; mm^2$$

After the surface area of the plastic is known, then look for the force on the knife shredder knife (Fpisau) using the equation:

τplastic = 1 x t

Aplastic = 3mm2

Wknife = 15 N

Number of knives = 2 pieces

$$F_{pisau} = \left(\tau_{plastik} \; x \; A_{plastik}\right) x \; 2 + W_{pisau} \quad (2)$$

$$= (33{,}1 \; x \; 3) \; x \; 2 + 15$$

$$= \; 99{,}3 \; x \; 2 + 15$$

$$= 198.5 + 15$$

$$= 213.6 \; N$$

Based on the calculation results, the cutting force can be determined by:

$$F \; = \; \tau_p \; x \; A \quad (3)$$

$$= \; 33{,}1 \; x \; 3 \; mm^2$$

$$= \; 99{,}3 \; N.mm^2$$

After getting the knife cutting force, the torque can be determined using the calculation:

$$F \; = \; Fx \; L \quad (4)$$

$$= \; 79{,}2 \; N \; x \; 0{,}1 \; m$$

$$= \; 7{,}92 \; Nm$$

So, the power on the motorcycle with the planned rpm is:

$$P = \frac{T \; x \; 2\pi \; x \; n}{60} \quad (5)$$

$$= \frac{7{,}92 \; Nm \; x \; 2\pi \; x \; 2800}{60}$$

$$= 2321{,}08 \; W$$

$$= 2{,}32108 \; W$$

After determining the engine power, then determine the electric motor as the engine drive. It is known that the engine power is 2,321 kW, to determine the electric motor, the motor power is sought whose power is above the engine power:

1 HP = 0.746 kW

$$HP = \frac{2{,}321 \; kW}{0{,}746 \; kW} = 3{,}1 \; HP \quad (6)$$

Considering the performance of the HDPE plastic crusher machine to function optimally and the existence of an electric motor on the market, the electric motor used is an electric motor with a power of 3 HP [15].

In the manufacture of HDPE plastic *crusher* machines, the electric motor used is an electric motor with a power of 3 HP. Therefore, the process of designing an HDPE plastic *crusher* machine uses a 3 HP (2238 *watt*) 1-phase *electric motor* as a drive. The electric motor has a speed of 1420 rpm [16]. The rotation speed of the engine is designed to increase the effectiveness of the engine so that the next calculation is used to use the power from the electric motor:

Electric motor power (P) =2238 Watts

Motor rotation speed (Nr)= 1420 RPM

Based on the power and rotational speed of the electric motor, the torque of the electric motor can be found by the following calculations:

$$T = \frac{P.60}{2.\pi.N.T} \quad (7)$$

$$= \frac{2238\ Watt.60}{2.3{,}14.1420\ rpm} = 15{,}170\ N.m$$

So a 3 HP electric motor with a rotation speed of 1420 Rpm produces a torque of 15,170 N.m. Based on the results of comparison with machines that have been marketed, plastic shredding machines have less power compared to marketed machines. However, with less power, the engine capacity is higher than the marketed machine. This explains that the power used is more effective in destroying HDPE plastic. Table 1 shows the comparison of 2 machines that are marketed with machines that have been made.

Table 1. Comparison of Machine Specifications

Specifications	**Engine 1**	**Engine 2**	**Machines made**
Type	PLT-30B	PLT-50	
Brand	Agrowindo	Agrowindo	
Capacity	30 kg/h	50 kg/h	60 kg/h
Power	5.5 HP	8 HP	3 HP
Dimension	55 x 50 x 135 cm	100 x 90 x 145 cm	50 x 60 x 80
Breakdown Results	10 - 30 mm	±10 mm	±1 mm

2. Crusher Machine Testing

Testing of crusher machines is carried out in two types, namely without using HDPE plastic and testing with HDPE plastic. Testing without HDPE plastic is carried out to find out if the machine components are installed correctly and the machine can work optimally. The test is carried out for a few minutes until it is considered sufficient. After the testing process is carried out, a check will be carried out on the engine components to find out the condition of each engine component. Testing of HDPE plastic crusher machine is shown in Figure 3.

Figure 3. HDPE Plastic-Free Machine Testing

Next is testing using HDPE plastic. This test is carried out to find out if the machine can function optimally and produce the expected output. This test is carried out twice with a time difference applied. The testing of HDPE plastic crusher machine is shown in Figure 4.

Figure 4. Testing Machine With HDPE Plastic

Figure 5. HDPE Crusher Results

The first test using HDPE plastic with a time of 60 minutes produced a fine powder of 100 grams. This fine powder is the final result of the HDPE plastic testing process that has passed through the crushing process. But HDPE plastic fine powder is still mixed with rust because the machine has not gone through the finishing process.

After the HDPE plastic crusher machine has gone through the finishing stage, the machine is tested

for a second time with the same amount of HDPE plastic to produce 100 grams of white fine powder for 60 minutes. The final result of the testing process is a fine white powder that has passed through the cutting process. The fine powder is shown in Figure 6.

Figure 6. HDPE Plastic Fine Powder After Finishing

CONCLUSION

Based on the results of the design and testing process of the HDPE plastic *crusher* machine, it was concluded that the type of motor used in the HDPE plastic *crusher* machine is an electric motor of 3 HP, 1 phase, with a rotation of 1420 rpm. After going through the calculation results, the cutting force data of 99.3 Nm^2 was obtained. The components in the HDPE plastic *crusher machine* transmission system have a pulley diameter size with a ratio of 2:1 with a size of 150 mm on the electric motor. In the design *of this HDPE plastic crusher* machine, it produces grams of fine powder within 60 minutes

BIBLIOGRAPHY

[1] N. Triadi, B. Martana, and S. Pradana, "Design of Shredder-Type Plastic Shredder and Reel-Type Cutting Tools," *Journal of Mechanical Engineering,* vol. 15, p. 144, 09/01 2020.

[2] C. Azhari and D. Maulana, "DESIGN OF CRUSHER-TYPE PLASTIC SHREDDING MACHINE 50 kg/h," *STT MANDALA TECHNOLOGY ISSUE,* vol. 13, no. 2, 2018.

[3] W. Dian Anisa Rokhmah and S. Agung, "DESIGN AND CONSTRUCTION OF PLASTIC WASTE SHREDDING MACHINE," *Steam Engineering,* vol. 4, no. 1, pp. 9-13, 09/21 2022.

[4] R. Napitupulu, M. Subkhan, and L. D. Nita, "DESIGN AND CONSTRUCTION OF PLASTIC WASTE SHREDDING MACHINE," *Manutech Journal* vol. 3, no. 1, pp. 1-5, 2011.

[5] R. Huzein and T. Hasballah, "DESIGN AND CONSTRUCTION OF A PLASTIC SHREDDING MACHINE OF PET TYPE (POLYETHLENE TEREPHTHALATE) WITH A CAPACITY OF 50 KG/HOUR," *Journal of Mechanical Technology; Vol 1 No 1 (2020): DECEMBER,* 2021.

[6] R. Aang Khunaefi, H. Dudung, A. Syahrul, and F. Tugiman, "AUTOMATIC CONVEYOR REDESIGN IN PLASTIC BOTTLE SHREDDING MACHINE," *Bolting and manufacturing,* No. Vol 5 No 1 (2023): Journal of Bolts and Manufacturing Volume 5 No. 1 of 2023, pp. 44-53, 2023.

[7] Firmansyah, "No Design and Construction of Plastic Bottle Waste Shredder with a capacity of ± 33 Kg/Hour," presented at the TEKNOKA, 2019.

[8] A. Masruri, Z. Saleh, Z. Satria, and M. Hastarina, "Design of a Laboratory-Scale Plastic Shredding Machine Using the Quality Function Deployment (QFD) Method," *Integration: Scientific Journal of Industrial Engineering; Vol 6, No 1 (2021): Integration: Scientific Journal of Industrial Engineering,* 2021.

[9] H. O. Wensen, "Design and Construction Test of Shredded System Plastic Waste Shredded System and Claw Blade Model Cutting Knife," *THE JOURNAL OF THE SACRED HEART,* vol. 1, no. 1, pp. 57-68, 05/15 2021.

[10] T. Yusnita, F. Muslikhah, and M. Harahap, "Education on Plastic Waste Management from Households to Ecobricks," *El-Mujtama: Journal of Community Service,* vol. 2, pp. 117-126, 12/15 2021.

[11] R. N. Selan, E. U. K. Maliwemu, and K. Boimau, "DESIGN OF A TRANSMISSION SYSTEM OF A PLASTIC WASTE SHREDDING MACHINE WITH AN ENGINE ROTATION OF 2800 RPM," *Al Jazari - Scientific Journal of Mechanical Engineering,* vol. 6, no. 1, 2021.

[12] B. S. A. Purwono, H. Purnomo, A. Setiawan, Masroni, and Rahbini,

"NOVATION OF RAILWAY BEARING TECHNOLOGY MADE FROM PLASTIC WASTE RAW MATERIALS," vol. 7, no. TM 64, 2017. SENTRINOV PROCEEDINGS

[13] R. Subagja, "Analysis of the Influence of Rotor Rotation Speed on the Results of Plastic Waste Destruction Using a Crusher Machine," *Journal of Industrial Technology and Agricultural Products,* vol. 23, no. 1, pp. 39-46, 2018.

[14] R. S. Khurmi and J. K. Gupta, *A Textbook of Machine Elements and Machines*. John Wiley & Sons, Inc., 2005.

[15] M. Syaukani, F. Paundra, F. Qalbina, I. D. Arirohman, P. Yunesti, and S. Sabar, "Design and Analysis of 20 Ton Capacity Composite Press Machine," *Journal of Science, Technology, and Visual Culture; Vol 1 No 1 (2021): Juli 2021,* 07/14 2021.

[16] M. Margono, N. T. Atmoko, B. H. Priyambodo, S. Suhartoyo, and S. A. Awan, "Design and Construction of a Grass Chopper Machine to Increase the Effectiveness of Animal Feed Consumption in Sukoharjo," *"Your Excellency,* vol. 1, no. 2, pp. 72-76, 05/28 2021.