SHREDDER FOR PLASTIC WASTE RECYCLING PROCESS

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ABSTRACT: The idea of this paper was inspired by the Precious Plastic project developed within UPB. following documentation from several sources, I noticed what is the current state of recycling, both nationally and internationally, and the need to involve everyone in the recycling process. thus, we decided to focus on the development of a plastic shredder that can be integrated into a semi-industrial technological line with the aim of achieving several objectives, such as: eliminating the costs of transporting plastic waste, protecting the environment, broadening the area of knowledge for the people who will be involved in the recycling process, the development of new products needed by the faculty. the chopper assembly is composed of several sub-assemblies, and the ones made at the moment are: the chopping mechanism sub-assembly, the bearing-support sub-assembly, the welded frame sub-assembly, the gearing mechanism sub-assembly. the physical realization of the shredder is supported by the company Technobit Automatizări.

KEY WORDS: waste, shredder, recycling, plastic, new products.

1. Introduction

The mechanical recycling flow of the plastic shredder designed by us is a semi-industrial part and it brings to our attention the need for recycling at any level.

The purpose of manufacturing the equipment is to use it and to integrated in the recycling process, within the UPB - FIIR, according to the Precious Plastic project idea.

The technological flow developed within the mentioned project will cover all stages of recycling, from the collection of waste by category to their transformation into other products. The collection of waste within the university institution aims to change it into products needed by the faculty, such as: containers for storage, switches, filaments for 3D printers, test tubes for the Precious Plastic testing lab mechanics, advertising or decorative objects, etc. The design of the plastic shredder was made in 2 variants because we still do not have the entire technological line, which led us to redesign the shredder in a variant that can also be used alone (e.g), while ensuring the safety of the user.

Fig 1.1 PP

The collage from figure 1.2 shows variant 1, the plastic shredder integrated into a technological line composed of 3 equipment, the last one being assigned to the change, respectively the combination with two other process variants.

Fig. 1.2. Plastic shredder integrated into a technological line

The equipment used individually, according to the chosen function is in Fig. 1.3.

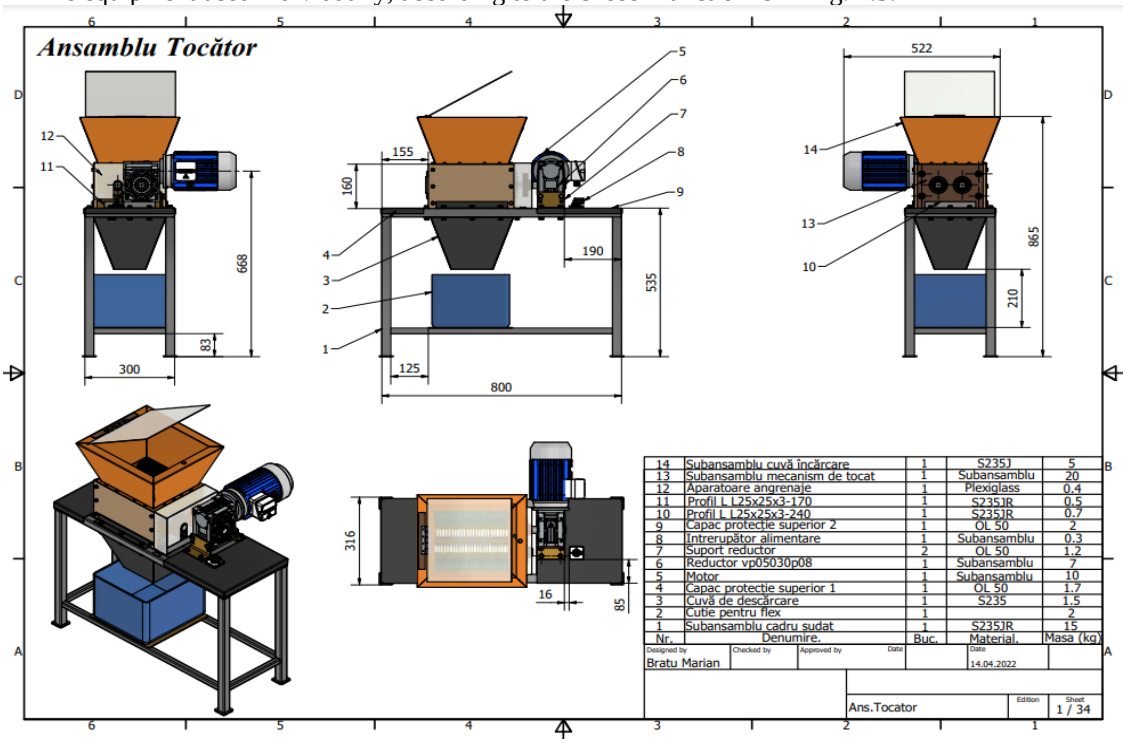

Fig. 1.3. Plastic shredder is used individually

The differences between the 2 plastic shredder models:

1. The tub positioned above the cutting mechanism will have a protective cover attached to protect the user. When the upper protective cover is raised, the sensor will stop the operation of the equipment, thus avoiding the possibility of inserting hands or sleeves.

2. A collection box will be placed in place of the flex conveyor belt. It has an integrated level sensor with a filling level monitoring function. If the filling level exceeds the minimum mark, the belt speed will be reduced and if it exceeds the maximum mark, the machine will stop.

2. State of the art

Shredding plastic waste is an essential aspect of recycling, and using a shredder that has this primary function is inevitable to ensure that the impact of plastic on the environment is minimized. The process of shredding plastic waste has several advantages, including reducing the size of the waste, improving the efficiency of the recycling process, reducing the amount of waste and creating a uniform material for recycling.

Shredders are available in different sizes and types depending on the amount and type of plastic waste to be processed. The equipment designed by our team has the ability to shred different types and sizes of plastic waste, taking into account the dimensions of the loading bin. Adapted accordingly according to the method of use and the purpose for which the currently developed product was designed, the necessary documentation for the production of the equipment was drawn up.

Thus, we determined exactly what the purpose of the project is, we identified the market opportunities and analyzed in detail the competing products, the potential customers and the current state of the chosen theme, thus managing to establish the final specifications and characteristics that the product will have. So, we managed to develop the conceptual design stage, carrying out external research to identify new constructive solutions, but also internal research, carrying out a systematic exploration, establishing the component functions and finally building the architecture of the finished product.

We are currently in the process of detailed design of the complete assembly. We completed the establishment of the component elements and their related manufacturing technologies, the establishment of the materials and treatments used in the manufacturing process, the definition of the elements related to the design of the product and its ergonomic conditions.

We have started the actual manufacturing of the product and we are going to finalize the established technologies for all the specific elements and then carry out the testing of the equipment. Next comes installation, commissioning and product documentation. This will contain how to use, safety measures and maintenance required for the shredder and will be made available to the customer at the time of purchase.

In the end, we will design the homologation technology, respectively that of use and sale of the assembly, this being already sketched, we will come back with small additions extracted after the complete realization and assembly. In addition, we will also perform a new, final economic analysis, performing a financial reassessment of the entire project and establishing exactly what the final costs were and what will be the price and profit obtained from the sale of the equipment. These steps being essential to the sales process.

3. The specific elements components and manufacturing technologies.

It is composed of several subassemblies, and the ones made at the moment are the following:

- *The chopping mechanism subassembly (Fig. 1.4.):*

Being a double-shaft chopper, two shafts were used, main and secondary, on which the knives are mounted progressively.

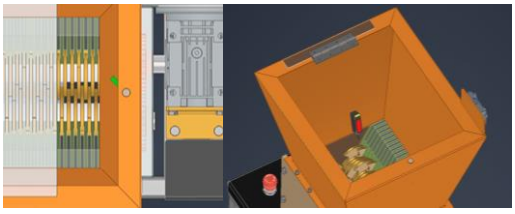

Fig. 1.4. The chopping mechanism – 3D model

The blank (Fig. 1.5. – right) used for the two shafts (Fig. 1.5. – left) is a 32 mm hexagonal bar, made of C45 material. The manufacturing technology used to make them is as follows:

a) The hexagonal bar is cut to the required length with a band saw, for metals, then it is turned at the ends, to the diameter D=25 mm, and the wedge channels are made by milling and the channels for the safety rings, on the diameter from outer end;

b) The turning of the ends was done on a parallel lathe, with a longitudinal turning knife;

c) The channels for the safety rings were made on a parallel lathe, with a cutting knife;

d) Milling of wedge channels was done on a FUS22 milling machine, with a D=8 mm finger mill.

Knives (Fig 1.6.) in 100 pieces, 50 positioned on the secondary shaft and 50 on the main one. They are made of S355 steel and are 5mm thick. The manufacturing technology being:

a) Laser cutting of the outer and inner contour;

b) Turning on both sides, 0.2 mm machining allowance (required for use of spacers).

Fig. 1.5. Shaft for knives

Fig. 1.6. Knives

Fig. 1.7. The machining process of the shafts used for the radial arrangement of the blades

In Fig 1.9 you can find the threaded rods (4 pieces) made of steel. They have the role of gripping the front and side walls and maintaining their fixed position, without the risk of misalignment over time, especially in the context of the existence of vibrations and fairly significant movements such as the level. They are assembled two by two, on each wall, in the corners of the loading tub to give extra balance.

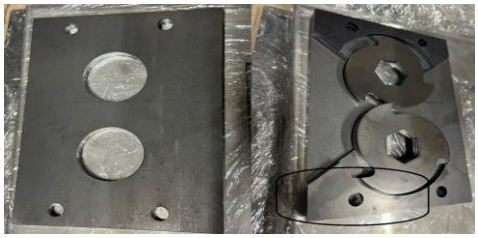

Fig. 1.8. Side and front walls

In Fig 1.9 you can find the threaded rods (4 pieces) made of steel. They have the role of gripping the front and side walls and maintaining their fixed position, without the risk of misalignment over time, especially in the context of the existence of vibrations and fairly significant movements such as the level. They are assembled two by two, on each wall, in the corners of the loading tub to give extra balance.

Fig. 1.9. Threaded rods

Fig. 1.10. Regulation-support

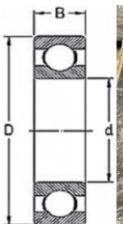

Fig. 1.11. Regulation

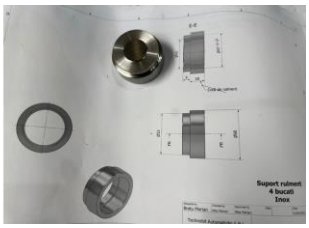

Fig. 1.12. Support

- The bearing-support subassembly (Fig. 1.10.) consists of 4 bearings, model SKF 6005-2Z, shown in Fig. 1.11. They are of the radial type with single row balls and have metal protection on both sides of the bearing. The supports used for the bearings (4 pieces), found in Fig. 1.12, are made on a parallel lathe, using a front turning knife. The material used for this landmark is stainless

Fig. 1.13. Trial assembly of the chopping mechanism subassembly

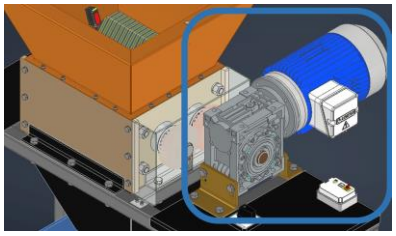

Fig. 1.14. Gearmotor 3D model

- *Motor-reducer subassembly (Fig. 1.14.):*
The technical data of this subassembly, found in Fig. 1.15, the physical version is as follows: Motor-reducer size 50, transmission rate, i=30, tubular output shaft and motor: 220 V, 50 Hz, 1.1 Kw, 1500 rpm, small flange.

Fig. 1.15. Motor-reducer

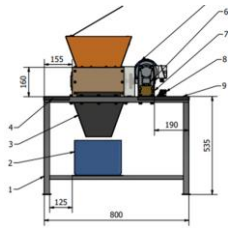

Fig. 1.16. Welded frame

- *The welded frame sub-assembly (Fig. 1.16.):* This has the dimensions indicated in the figure, namely: 535 x 800 mm. At the current stage, its component elements have been cut according to the instructions and are to be welded in the position indicated in the overall drawing. The semi-finished product is of the rectangular pipe type (Fig. 1.17.).

Fig. 1.17. Rectangular pipes

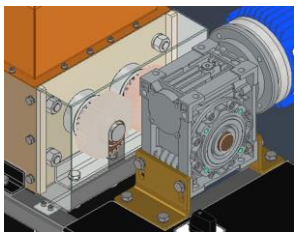

Fig. 1.18. Gearing

- *Sub-assembly of the gearing mechanism: (Fig. 1.18.)* positioned behind the Plexiglas guard and made up of two gears (Fig. 1.19.), cylindrical, with straight teeth, with a wedge channel inside (made on the mortising machine) from material C45 with the following relevant characteristics: m=2.5 mm and z=32 teeth.

Fig. 1.19. Gear

4. The operating mode of the developed product

To start the process of shredding plastic waste it is necessary to integrate it into a complete recycling process. Thus, when the waste reaches the loading tank of the shredder, it is initially collected separately according to the type of waste and sorted according to the identification code of the plastic (the 7 categories). Afterwards, it is necessary to prepare the waste, which consists of cleaning, drying, separation into elements if they are made of different materials (in most cases the label). Once the waste is in the vat, the shredding process can begin. Radial arrangement of blades on 6-sided milled shafts to provide continuous, simultaneous movement through repositioning frequency. This mounting method streamlines the time the waste is trapped between the blades.

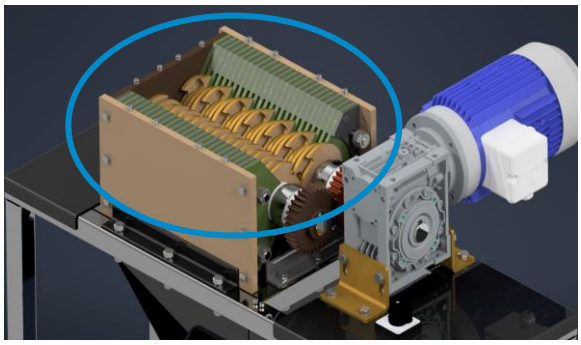

Fig. 1.20 the blades of the cutting mechanism

Fig. 1.21. Gear mechanism protective cover

For the safety of users, multiple precautions have been taken to avoid possible ways of injury. Thus, in order to avoid the introduction of hands or clothes when the gearing mechanism is working, but also to prevent premature wear of the gears, the use of a protective cover, made of Plexiglas, was implemented, as can be seen in Fig. 1.21..

Also, for emergency protection, a mushroom-type safety button (Fig.1.22.) is used, with an immediate stop function in case of necessity. It is placed within easy reach of the user, on the work table.

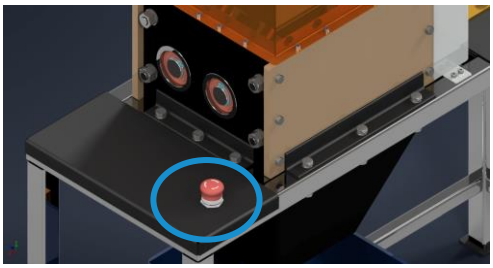

Fig. 1.22. Safety button

In addition, there are multiple sensors that we are considering for introduction within the chopping assembly, such as the one for disconnecting the electric current, positioned on the loading tank, with the role of stopping the operation of the equipment,

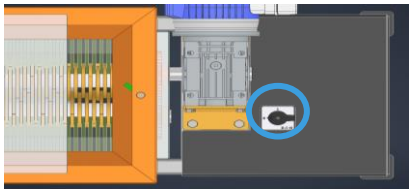

Fig.1.23. Buton pornire/oprire

to prevent the introduction of hands or clothes into the chopping mechanism, but also the use of level sensors, with the function of determining the degree of filling.

The on/off button contributes effectively to reducing time and energy consumption. It is also positioned on the work table, for easy operation, being in the immediate vicinity of the user operating the function at the time. This is a switch type button, being very intuitive and easy to handle.

The following usage scenario (mode of operation) for the equipment was drawn up.

a) As a first step in the recycling process within the project, containers are placed (fig. 1.24. and 1.25.) in which students/teachers/other people involved can throw different types of waste separately. Anyone can be an integral part of the process, even if they participate to a minimal extent. This fact can convey to others who are around that person that there is an opportunity to contribute effectively.

Fig.1.24. Selective containers [1]

Fig.1.25. Containers located in the recycling section

b) Following is a sorting of the plastic categories carried out by the parties directly involved in the Precious Plastic project. Fig. 1.26 and 1.27. presents the categories of plastic but also some examples of products made from each category. Their purpose is to make it easier to select plastic by category.

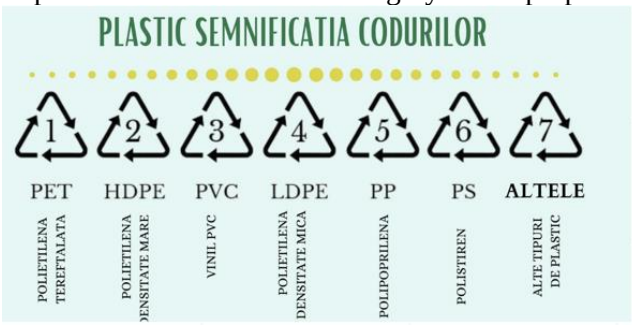

Fig. 1.26 Plastic categories and associated codes [2]

Fig.1.27 Examples produced - different types of plastic [2]

c) The sorted plastic will be taken to the place where recycling is carried out. The first equipment will be mechanically loaded with the prepared plastic. This equipment will wash and dry the waste.

The initial preparation process, which consists of sorting, washing, drying and separation (for waste consisting of several types of plastic, e.g. label, cap, etc.), can be done entirely by hand or as a combined process (so as shown in Fig. 1.28 – 2 views), both manual and automated, depending on the available resources that are cost-effective to allocate to the process.

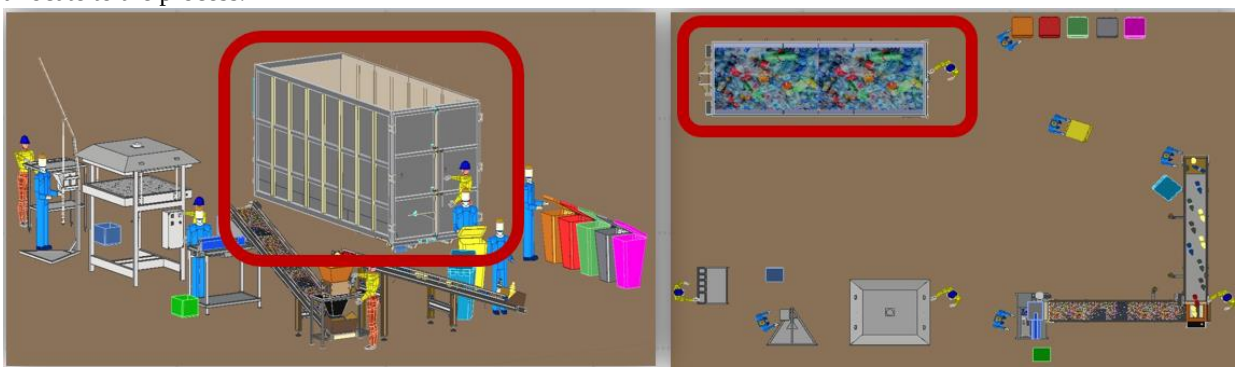

Fig. 1.28 Waste washing and drying equipment

d) The second equipment, is the one developed by our team, namely the chopper.

e) The sheet press (models of sheet presses are shown in fig. 1.29) works by introducing the flex, which will be pressed between two plates, at a high temperature. The result obtained are rectangular

plastic sheets, the size of plates. The press can take any type of flakes (small, medium, large), but it is recommended to use the large ones, because the time for shredding is reduced.

Fig. 1.29 Sheet press [3]

f) The injection machine (examples of injection machines in Fig. 1.30) has fast and high-precision production, but it takes a little more effort at the beginning to design and make a mold. The medium shredded plastic enters the hopper and is heated and pressed through a long shaft into the mold

Fig. 1.30 Injection machine [3]

g) Extrusion is carried out with the help of an extruding machine (examples of extruding machines can be found in fig. 1.31) and is a continuous process in which the finely chopped plastic enters a hopper, heated and pressed with a screw through a long shaft, and the result obtained are pieces of plastic, cylindrical in shape. With this machine, filament can be created, the obtained material being wound on a spool.

Fig. 1.31 Extruding machine [3]

5. Conclusions

Considering both the sub-assemblies made up to now (the chopping mechanism sub-assembly, the bearing-support sub-assembly, the welded frame sub-assembly, the gearing mechanism sub-assembly) and those that are to be physically made we can say that the chopping machine we are developing it represents a complex piece of equipment, the manufacturing process being a detailed one.

We can also state that the aforementioned plastic shredder differs from other products on the market in several ways:

- It is a semi-industrial equipment that allows the recycling process to be carried out within companies, faculties, hospitals or other institutions that do not have recycling as their main field of work, but want to actively participate in this process;
- It eliminates the costs of transporting plastic waste to institutions specialized in the recycling process, it gives an advantage to the companies that opt for the purchase;
- Improves the area of knowledge for the people who will be involved in the recycling process, helping to raise a better awareness of the need for recycling and the negative effects that its lack brings, and implicitly it can become a powerful influential act, easily spread;
- Participates in the process of creating new products needed by each institution where recycling will be carried out, eliminating the costs necessary to purchase these products.

In conclusion, we can say that the shredder developed by our team is an indispensable machine for the recycling technological line, which participates in keeping a cleaner and less polluted environment, as we all want, and according to our research it can be a real success on market.

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7. Notations

The following symbols are used throughout the paper:

Fig. = the figure
UPB = Polytechnic University of Bucharest
FIIR = Faculty of Industrial Engineering and Robotics
mm = millimeters
d = diameter
i = transmission rate
v = volts
hz = hertz
kw = kilowatts
rot/min = revolutions/minute
m = module
z = number of teeth