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Crushing equipment for the recycling of polyethylene terephthalate (PET)

Equipo de trituración para el reciclado de polietileno tereftalato (PET)

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Abstract

Nowadays one of the materials most used by humans is polyethylene terephthalate (PET), or better known as plastic. However, its high demand causes a large production and waste capacity, which combined with its long resistance to degradation makes it last in the environment for much longer, causing great damage to the ecosystem and becoming a terrible ally for the environmental pollution. In Mexico, we are the second consumer of PET containers for packaged beverages in the world using approximately 450 thousand tons; and the first for bottled water containers, where in 2014 alone, 21 million PET bottles were produced per day, of which only 20 were recycled by the way. The main objective of this project is to build a medium-cost polyethylene terephthalate (PET) crushing dequipment that contributes to the reduction of waste and promotes the recycling culture. This with the idea of being able to replicate it later and implement it in different areas of the region.

Crusher, Recycling, Polyethylene Terephthalate

Resumen

Hoy en día uno de los materiales más utilizados por el ser humano es el polietileno tereftalato (PET), o mejor conocido como plástico. Sin embargo su gran demanda provoca una alta capacidad de producción y desecho, que aunado con su larga resistencia a la degradación hace que perdure en el medio ambiente por mucho más tiempo, logrando causar grandes daños en el ecosistema y convirtiéndose en un aliado terrible para la contaminación ambiental. En México, somos el segundo consumidor de envases de PET para refrescos en el mundo, empleando 450 mil toneladas de este plástico, aproximadamente; y el primero para recipientes de agua embotellada, en donde tan sólo en el 2014 se generaron 21 millones de botellas PET al día, de las cuales solo se reciclaron el 20 por ciento. Es por ello que el principal objetivo de este trabajo es construir un equipo de trituración de polietileno tereftalato (PET) de mediano costo que permita contribuir en la disminución de residuos y lograr incentivar la cultura de reciclaje. Esto con la idea de poder replicarlo más adelante e implementarlo en diferentes zonas de la región.

Trituradora, Reciclaje, Polietileno Tereftalato

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Introduction

Currently, plastic has become a threat to the entire ecosystem and also to society. It is deteriorating our planet and the lives of people as they are products whose manufacture is intended to last hundreds of years without realizing that in most cases they are only used a couple of minutes to then be discarded quickly.

A world without plastics, seems unimaginable nowadays, however, its production and use on a large scale dates back to 1950. Although the first synthetic plastics appeared at the beginning of the 20th century, the widespread use of plastics outside the armed forces was not produced until after World War II. The rapid growth resulting in the production of plastics is extraordinary, surpassing most other man-made materials. (Geyer 2017).

There are several classifications of pollution, but certainly the pollution generated by the activities of man is the most serious. (Arellano 2015). In Mexico, the Environment and Natural Resources Commission estimates that 90 million bottles of soft drinks and water, made with polyethylene terephthalate (PET), are thrown into public roads, roads, forests, beaches, rivers and seas.

At present, the oceans are filled with eight million tons of plastic per year; it is estimated that by 2020 it will be 500 million tons, due to the accelerated production of plastics and that the degradation process of PET in the oceans is slower than in the earth. Derived from the above, the average apparent national consumption (CNA) of PET in Mexico amounts to 745 thousand tons per year. In addition, we are the second consumer of PET containers for soft drinks in the world and the first for containers of bottled water.

	Thousands of tons				
	2012	2013	2014	2015	2016
CNA of PET in Mexico for packaging	715	710	700	722	745
Representation of our associates	64%	64%	64%	67%	60%
Total partners sent to the market	460	457	448	482	450
Recycled post-consumer PCR resin	-	54	76	72	74
Total recovered as a country	414	428	405	364	425
Recovery rate	57.90 %	60.30 %	57.80%	50.40%	57%

Figure 1 Registration of the PET CNA in the last years
Source: ECOCE Magazine 15 years

On the other hand, it should be noted that although Mexico is a leader in the American continent in PET collection and recycling, with 50.4 percent of the material reused and 14 recycling companies is not enough to stop this great waste.

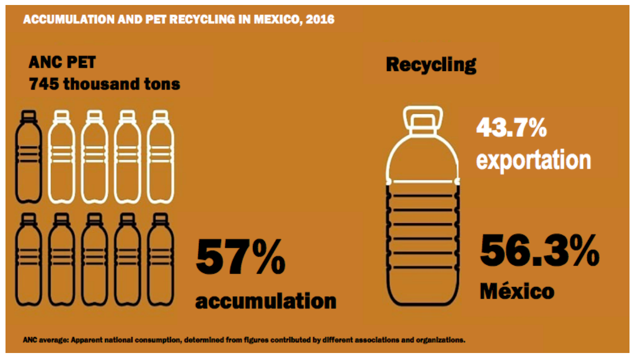

Figure 2 Collection and recycling of PET in Mexico, 2016
Source: Magazine ECOCE 15 years

Keep in mind that all the plastic that is around you is a resource, not a waste. (Hurtado 2012).

Through the valuation of post-consumer PET packaging waste in pesos / kilogram, the mass collection of these has been promoted and increased, year after year. In 2001, PET waste in bulk was worth $ 0.30 / kg, while in 2017 they reached values of $ 3.50 / kg in bulk. Therefore, it can become a source of income and an educational tool for our community. Recycling represents a frontier in the development of society, as technology advances, consumption levels accelerate. Now it is essential to consider the design of the cities and plan the techniques that will be used to reduce this problem. (Szécsi 2006)

With this project we want to show the importance that the plastic waste have to reduce or eliminate the existing pollution by this material. By reducing the demand for new virgin plastic and closing the cycle of materials, we can improve the lifestyle of people around the world, especially due to the growing environmental impact and the rising generation of waste produced by human consumption today. (Davis 2005)

Methodology to be developed

The following research work seeks to solve the problem of waste reduction, by means of a crushing equipment. This device is an important part of the process of recycling PET bottles.

For the development of this technology, descriptive research is applied and the main stages of its development are mentioned:

1. Selection and assembly of three-phase motor-reducer for the required power.
2. Design and manufacture (plasma cutting) of the blades to be used contemplating the final assembly.
3. Design and manufacture of base and equipment supports. This activity also includes the assembly of the insulation box for PET reduction.
4. Purification and adjustment of the equipment. This section includes the coupling of the motor, adjustments in the blades and insulation box and finally the visual presence of the equipment.

Selection and Assembly of Motor-Reducer

The main problem of this equipment is to find adequate cohesion between the reducer and the engine, which provides the expected revolutions to achieve the torque required 85 - 95 RPM. The motor gives a speed of 1410 RPM and a power $P = 1.5\ KW$ which is coupled to a reducer with ratio 1:15 giving an output speed of 94 RPM.

Output speed:

$$\omega s = 94\ rpm \quad (1)$$

Being a one-stage reducer, the axles rotate at the input and output speeds, respectively, these being 1410 rpm for the input shaft and 94 rpm for the output shaft. In addition, the torque on each axis is calculated with the following formula:

$$T(Nm) = P(w)\ \omega(rad/s) \quad (2)$$

$$Te = (1500 \cdot 60) / (1410 \cdot 2\pi) = 10.15\ Nm \quad (3)$$

$$Ts = (1500 \cdot 60) / (94 \cdot 2\pi) = 152.38\ Nm \quad (4)$$

Since the axes must transmit a uniform power, the torsional deflection is limited to 1.5º / m in length.

The rotation produced by a torsion moment T, on an axis of diameter d, on a length L as it is a circular section is:

$$\theta / L = (32 \cdot T) / (\pi \cdot d\ 4 \cdot G) \quad (5)$$

All known data being known that the modulus of torsional stiffness G of steel is $G = 7.92 \cdot 1010 N / m^2$. Obtained through the analysis of the following data:

– Young's Module E = 206000MPa
– Poisson module (elastic) $\vartheta = 0.3$

$$d = \sqrt{}\ 32 \cdot T\ \pi \cdot 7.92 \cdot 1010 \quad (6)$$

d=∜((32T)/(π(7.92)(⟦10⟧^10)(2.62)(⟦10⟧^(-2)))) (7)

From the previous formula the minimum diameters of the input and output axes are obtained.

$$de = 0.0205m = 2.26cm \approx 2.5\ cm \quad (8)$$
$$ds = 0.0270m = 2.97cm \approx 3\ cm \quad (9)$$

Design and manufacture of the blades

The machine parts (crusher) were designed in AutoCAD for assembly. The area is subject to the cutting characteristics provided by the motor-reducer torque.

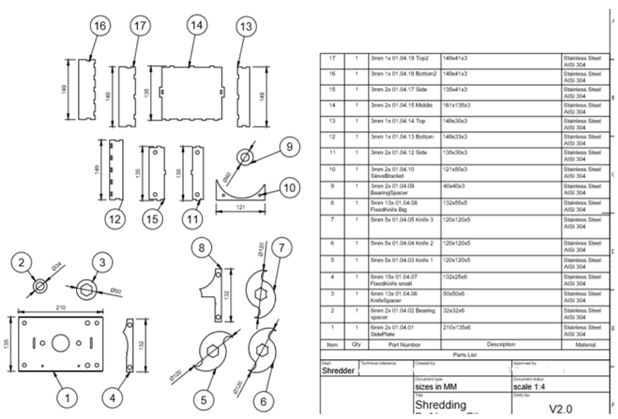

Figure 3 Blade design

Figure 4 Blade manufacturing

Design and manufacture of base and equipment supports

In this stage the structure was designed where the crusher machine will go along with the motor and reducer. The total weight of the equipment and the dimensions of the devices used were taken as reference. Likewise, ergonomics for human-machine interaction was endeavored.

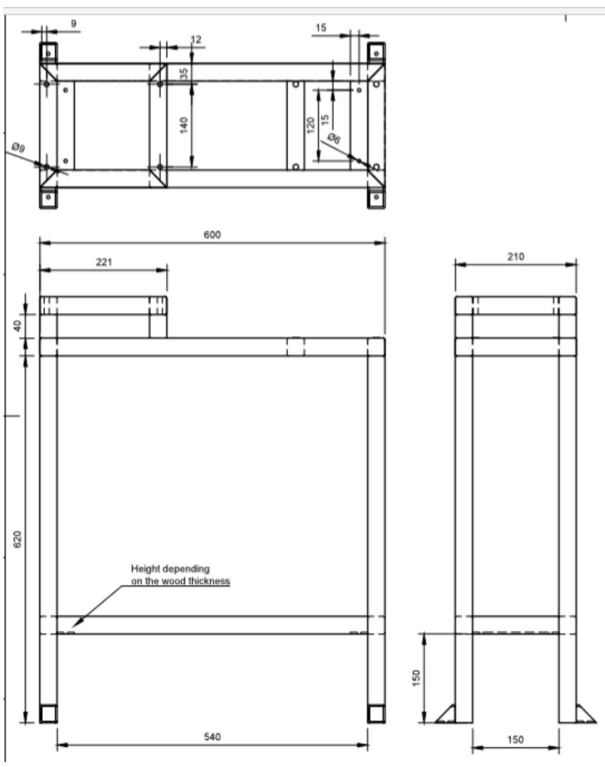

Figure 5 Structure design

Figure 6 Structure manufacture

Tasks were performed such as cutting and welding metal parts for the base, the crusher insulation box was assembled to protect the operator and was fixed to the supports of the metal base.

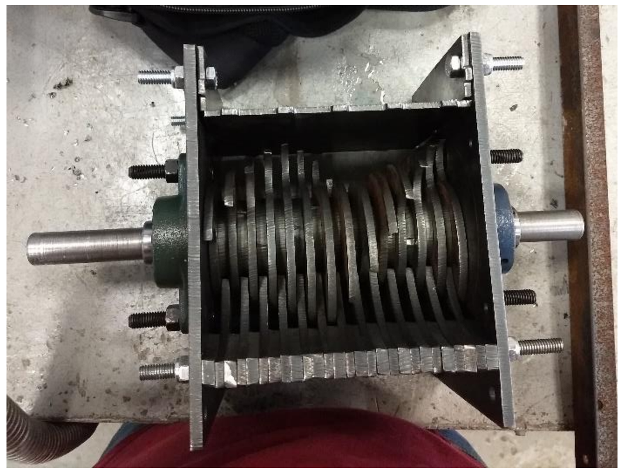

Figure 7 Assembly of blades to the structure

Purification and adjustment of equipment.

Once all the devices have been assembled, excess and imperfections to the base are eliminated and the couplings for the motor, reducer and arrow are machined.

Figure 8 Manufacturing of couplings for the engine

Figure 9 Manufacture and assembly of bearings to the arrow

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Results

The proposed mechanical design for the construction of the structure of the crushing equipment worked properly, complying with the basic technical specifications that should cover this type of machines.

On the part of the electrical system had some complications at the time of making the first tests, since not all the engines that were counted could be coupled with the motor-reducer, for which adaptations were made in the size of the arrow and it was adjusted for its correct functioning. Obtaining in this way a reduction in the number of revolutions granted by the engine and a greater torque, which translates into PET being crushed in a more efficient and faster way; otherwise, when increasing the speed, the blades were not able to press the bottles and they went to the sides, not being able to be crushed at the first attempt.

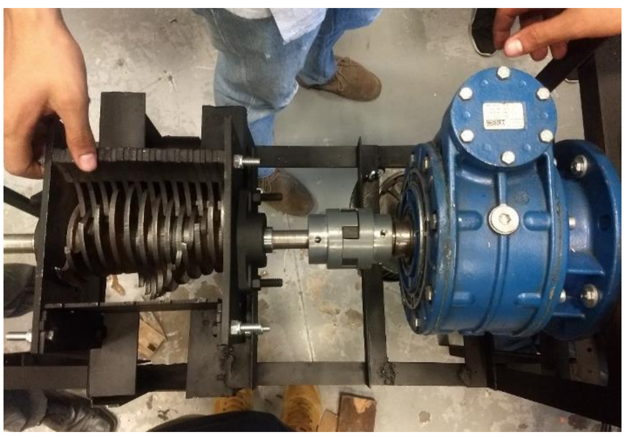

Figure 10 Engine alignment

Once stabilizing the crushing system, we continued to adapt a hopper and a lid with which it is ensured that the bottles to be crushed remain in place without running the risk that some surplus or excess of plastic could jump towards the user that is operating the machine. With all of the above already well assembled and secured, the final tests were continued, from which the following data were obtained:

Amount of PET crushed in one minute:

50 bottles of 20 grams each
(1 kilogram)

Amount of PET crushed in one hour:

3000 bottles of 20 grams each
(60 kilograms)

Conclusions

The present project beyond a pilot team is an initiative with the premise of helping to implement viable solutions for the conservation of our environment and environment, since the development of economic and efficient technologies will make a positive impact on society.

The project has areas of opportunity, such as seeking to improve the crushing control and monitoring system to allow better management and production of the recycled material; as well as looking to be able to handle in the future another type of waste material that is feasible to be used in recycling.

References

Arrellano Díaz J., Guzman Pantoja J. (2015) Ingeniería Ambiental. ALFAOMEGA mexico D.F.

Davis M.L, y Masten.S.J. (2005). Ingeniería y ciencias ambientales. McGraw–Hill. México, 705 pp.

Geyer R., Jambeck J.R. (2017) Production, use, and fate of all plastics ever made. Science advances – Research article. 17 de Julio 2017. Washintong, D.C.

Hurtado Moreno, J. J. (2012). Aprovechamiento de la Basura Doméstica Como Medio de Sustentabilidad en la Ciudad de México. 1er Foro Interdisciplina y Espacios Sustentables 25 al 27 de Mayo 2011 Universidad de Guanajuato, Guanajuato, México.

LGEEPA (2007). Ley General del Equilibrio Ecológico para la Protección al Ambiente. México. Diario Oficial de la Federación 5 julio 2007.

LGPGIR (2007). Ley General para la Prevención y Gestión Integral de los Residuos. México. Diario Oficial de la Federación 19 junio 2007.

Szécsi, A. E., & e-libro, C. (2006). Reciclado de ciudades: Nuevas herramientas de planificación y diseño urbano para intervenir en ciudades existentes. Buenos Aires, Argentina: Nobuko.

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