Analysis by Means of the Finite Element Method of
the Blades of a PET Shredder Machine with
Variation of Material and Geometry

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Abstract

The blades of the knives that make up the knife drum are the fundamental study component when evaluating the possibilities of increased material flow in a crushing machine. The stresses to which they are subjected result in these parts being easily damaged. To improve crushing efficiency and extend the changing life of the crusher blades, stress and fatigue are important. In this article, the complex force conditions of the crusher the stress characteristics and fatigue life of the blade were analyzed by the transient finite element method of analysis. The maximum stress distribution law of the shredder blade was found and revealed the mechanism of fracture of the deformations resulting from the stresses to which they are subjected. In addition, the reliability of the results of the simulation were verified by the experiment. It was found that when the blades were turned with a speed of 268 RPM, the maximum tension of these is higher than other speeds. Comparison of two working geometries and three construction materials and criteria were established based on the results obtained from the simulations to choose the optimum blade that performs the best possible functionality.

Keywords: FEM, PET, shredder machine, blade
1. Introduction

The demand for polyethylene terephthalate (PET) is currently increasing worldwide and the raw material resulting from the PET recycling process is an important resource for the petrochemical industry\[1\][2]. However, PET recycling in countries such as Colombia is relatively weak. This is due to the fact that they have inadequate waste control measures, in addition to the fact that highly qualified equipment for the recycling process is difficult to obtain [3].

The efficiency of the recycling process depends on the crushing capacity of the PET grinding machine. This parameter is subject to different parameters such as volumetric capacity, engine power and the critical elements that make up the machine [4] [5]. Many scientific articles focus their research on optimizing the performance of the machine by conducting studies of the critical elements of the machine, with the aim of predicting failures and recording better working conditions that provide under stress and little wear to the part. Xianyan Zhou Et al. Studied the stress and life characteristics from the fatigue theory of a crusher shaft-pinner [6], comparing four working modes, it was found that the life of the crusher shaft-pin could be doubled by changing the sides of the past and turning it 180° along its shafts. Ugomandi [7] carried out an investigation which emphasized the design and construction of a plastic recycling machine that minimizes the limitations of existing models in the market, the analysis of the performance test performed shows the characteristics of the machine and shows that at a speed of 268 rpm the machine operates effectively and efficiently in the performance of its task producing a high efficiency in the recycling of waste or recyclability of 97%, It takes 2 minutes to recycle a batch of plastics and has a recycling/yield capacity of about 265 kg/hour, which translates into a reduction in CO emissions this is a cost and energy saving as its specific mechanical energy consumption is low, around 30.23kJ/kg.

Beauson Et al. [8] in its study aims to characterize and understand the mechanical properties of polyester resin compounds reinforced with crushed compounds (SC), and to evaluate the potential of such a recycling solution in the manufacture of blades. A special manufacturing configuration was developed to produce compounds with controlled SC content. The results show that the SC in the compounds was well distributed and impregnated.

The objective of this article is to establish an optimal design model to carry out the best PET crushing process. For this purpose, different geometry options and different materials were established and an analysis was carried out with the help of computer-assisted simulation.

2. Methodology

The blades that make up the blade drum were subjected to different simulations, including Von misses displacements, deformations, safety factors and stresses. The simulations were performed in the SOLIDWORK software, which has a very easy to use interface, as shown in Figure 1.
SOLIDWORK is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systèmes.

2.1 FEM

The MEF or also called FEM is the general numerical method used for the approximation of very complex partial differential equation solutions used in various engineering problems.

The MEF is intended to be used as technological tools in software for computer-aided design by solving very complex differential equations associated with a physical problem on complicated geometries. FEM is used in the design and improvement of industrial products and applications, as well as in the simulation of complex physical systems. The variety of problems to which it can be applied has grown enormously, the basic requirement being that the constitutive equations and equations of temporal evolution of the problem be known beforehand.
Figure 2. Solution in MEF for a stress study.

In figure 2 we can observe the results of an analysis carried out by means of the MEF to one of the geometries studied in this document, basically for the correct accomplishment of the simulation process initial conditions should be considered initially, these conditions are proposed from calculations carried out in a theoretical way, in which it is sought to obtain minimum and maximum working conditions to which the piece will be submitted.

2.2 Materials and geometries

In figure 3 you can see the geometries that were compared during the study, the variation in the shape of the blade varies the point of contact at the time of cutting and the distribution of the forces along the piece.

(a)  (b)

Figure 3. Geometry of blade blades a) hook shape, b) 'S' shape

For analyses and simulations of the blades that make up the blade drum, the first parameter is the geometry of the blades, and the other parameter is the material of the blades.
The other parameter that varies is the material used, 2 alloys are established and the modeling is performed for the two geometries described above. The alloys are AISI 1045 and D6AC, which have elastic limits of $5.3 \times 10^8$ and $1.31 \times 10^9$ respectively.

3. Result

3.1 Stress analysis of von Mises for blade with hook geometry.

Initially the results of the Von Mises stress load simulations will be presented, the punctual load that was evaluated in the study is 8825 N, this parameter was obtained from the calculations made to obtain the working conditions that the leaves would support.

![Figure 4. MEF solution for hook geometry and material: a) AISI 1045, b) D6AC](image)

The results obtained are shown in figure 4, the analysis obtained allows us to establish a comparison and to select the design that presents the greatest efficiency at the time of being submitted to work. In figure 4a it can be seen that the stresses supported by the part range from a minimum value of $65.429 \, N/m^2$ to a maximum value of $3.74 \times 10^8 \, N/m^2$, it can be seen at first glance that the value corresponding to the maximum stress supported by the blade in the cutting process does not exceed the elastic limit of the material corresponding to $5.3 \times 10^8$ and also provides an additional backup factor corresponding to 29.43%, in other words this blade can be used not only for the task of cutting PET material. On the other hand, in figure 4b, a minimum stress value of $771.923 \, N/m^2$ is recorded for up to a maximum recorded stress value of $3.74 \times 10^8 \, N/m^2$, the value corresponding to the maximum stress
supported by the blade in the cutting process does not exceed the elastic limit of the material corresponding to $1.31 \times 10^9$ and also provides a support factor corresponding to 71.412%.

3.2 Von Mises stress analysis for blade with "S" geometry.

The study was carried out for the "S" geometry of the blades, the point load was maintained at 8825 N.

Figure 5. MEF solution for "S" geometry and material: a) AISI 1045, b) D6AC

The results obtained after the simulation are shown in figure 5, in which it is highlighted that the deformation scale obtained was 165.745 for S-geometry, higher than that obtained in the simulation of hook geometry, which was 143.743. In figure 5a, it can be seen that the forces supported by the part range from a minimum value of $1.39 \times 10^5 \, N/m^2$ up to a maximum value of $2.68 \times 10^8 \, N/m^2$, it can be seen at a glance that the value corresponding to the maximum stress supported by the blade in the cutting process does not exceed the elastic limit of the material corresponding to $5.3 \times 10^8$ and also provides an additional support factor corresponding to 49.43%, which is 20% more than the support factor obtained in the study for the AISI 1045 material with hook geometry. In other words, this sheet is oversized for the job required. On the other hand, figure 5b shows a minimum stress value of $1.4719 \times 10^5 \, N/m^2$ up to a maximum recorded stress value of $2.66 \times 10^8 \, N/m^2$, the value corresponding to the maximum stress supported by the blade in the cutting process does not exceed the elastic limit of the material corresponding to $1.31 \times 10^9$ and also provides a support factor corresponding to 79.694%.
4. Conclusions

Finally, it is possible to conclude that the results obtained by the finite element method showed that in their totality all the case studies are optimal to carry out the work for which they were designed. This is because the stresses to which they will be subjected in the process of cutting and crushing PET material are well below the value of the elastic limits of the selected working materials. It is remarkable to note the high level of oversizing that is registered in the "S" geometry part, this is explained by the shape of the design, as it has two leaves in contact in the process reduces the stress to which the element is subjected.

Although the results were better than expected, it can be said that the best way to obtain more accurate results is through SOLIDWORK® software. Since it is in your mathematical model if you take into account the external factors that cause the deviation found in this work. Finally, the recommended design according to the study carried out is the hook-shaped blade with AISI 1045 material.

References


Received: August 17, 2018; Published: September 22, 2018