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DEVELOPMENT OF ROTORS FOR RIBBON BLENDER MIXERS LOOKING FOR GREATER EFFICIENCY

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Abstract. *This article presents the process of mixing solids in industries. A numerical simulation of the efficiency of a mixer model was performed and compared to other models. A bibliographic research was carried out on the mixing processes, the types of mixers used and the various factors that influence the results of the mixing. Based on this information, the system modeling process began. For modeling, SolidWorks software was used, where a standard mixer model was simulated. Based on their characteristics, other blade formats were designed for the other mixers and the results were later compared. The objective is to verify which model presents better mixing efficiency, fulfilling the mixing proposal and which model offers a more homogeneous mixture in a shorter time. With the modeling already configured, the mixture simulation process with pre-defined particles was started, using the Rocky DEM Software. It was possible to configure the mixers to reproduce what happens in a physical model. From the data obtained, it is noteworthy that the standard model reached a homogeneous mixture with only 15 seconds of simulation, while in model two; this time was 11 seconds, meeting the expectations of mixing and homogeneity. In the last model, the mixing time was 28 seconds, and this one did not present an efficient mixing, even having good fluidity between the particles and a good distribution. Thus, it is possible to obtain different configurations for the mixers in order to seek a more efficient optimization in the mixing processes.*

Keywords: *Mixers, Mixing solids; Ribbon Mixer; 3D simulation.*

1. INTRODUCTION

This article is a study and analysis of the efficiency of different types of blades in mixers of the Ribbon Blender model, considering elements, dimensions and predetermined, the study will have as variables the time and the homogeneity of the mixture of the selected elements. The objective is to verify which model presents better mixing efficiency, fulfilling the mixing proposal and which model offers a more homogeneous mixture in a shorter time.

The study is necessary as analyses presented in the literature differ from those already existing in relation to efficiency analysis in mixers. Subsequently, this study will serve as a reference guide for choosing which mixer model best suits the specific work needs.

Mixing are defined by a union of one or more substances without a chemical transformation of these elements. According to Earle (1983), the mixture of solids is the distribution of one or more solid elements over the others.

According to Sastry et al. (1999), the mixture of solids, the focus of this work, different from gases and liquids that mix more spontaneously, made is through the dependence of some factors. Chaudhuri et al. (2006) say that one should consider the density of each element, the size, the mass, and its shape, also the effectiveness of the mixer for this element and finally the shape and distribution of the mixer blades for a certain type of element, this specific factor that will be the focus of the study presented here.

In addition to these factors presented there is also a subdivision in the mixtures, called mechanisms of mixture, these mechanisms will describe the best way to make a certain mixture and which elements should be used. With this, we will have which mechanism best fits and which mixer is most suitable. Among the mechanisms, we have: Convection, diffuse mixing, and shear mechanism (Lacey (1954) apud Gyenis (1999) apud Palma; Junior, 2010).

In convection, the elements move on top of each other according to the rotation of the mixer, in addition to moving within the drum in the direction of rotation thus creating different areas of counting between the elements (Bridgwater, 2012).

The diffusion consists of maintaining a set of elements grouped for a certain time and subsequently, by the action of the mixer, spreading these elements by a different surface, and from there a new formation of contact is obtained between the elements (Bridgwater, 2012; Palm; Junior, 2010).

Finally, shear, also known as diffusion-convection method, because it considered a junction of the two processes mentioned above, in this model the mixture occurs in the sliding of the elements on top of each other within the meter (Fan et al. (1970) apud Palma; Junior, 2010).

This mixer has many models of blades, and can be with a helicoid, with two helicoids, with smooth shovels, blades with teeth among others. However, all obey a helical arrangement in which they assembled so that they act in opposite directions, performing the mixture by means of turbulence. A model mixer is shown can be seen in “Figure 1”.

Figure 1. Ribbon Blender mixer and its different models of blades.

2. **REFERENCE MIXER**

This model initially developed with the simple objective of obtaining data and results from a real model so that it is possible to make a comparison with the mixers that was developed.

The blade of this mixer is composed of a larger helical with an external diameter of 500 mm that accompanies the inside of the mixer, the thickness of the tape is 50 mm and its total length also accompanies the final measurement of the mixer. It also has a smaller helical that has an outer diameter of 300 mm, with a thickness of 80 mm and the length also accompanies the final measurement of the mixer.

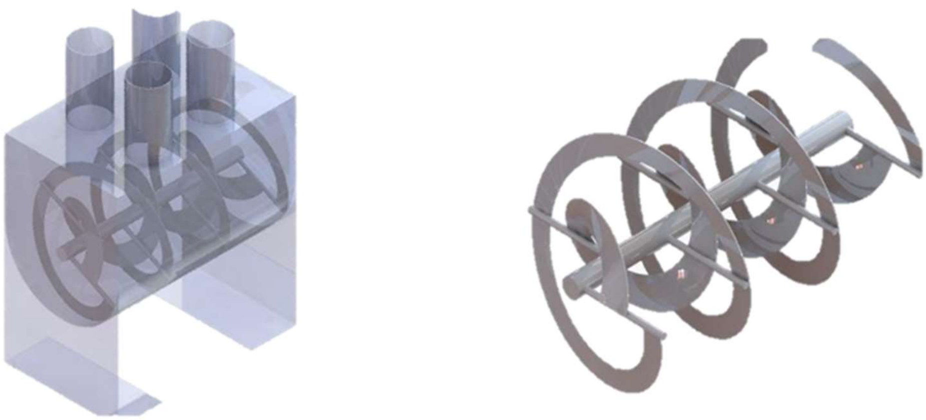


Figure 1. Standard Ribbon Blender Mixer and its mixing paddle.

The outer helicoid has the clockwise rotation, designed to carry the components from left to right, while the inner helical rotates in the opposite direction, in order to take the components from right to left.

The first model of blades developed arose from the concept of the original mixer, with two helicoids a larger one that accompanies the bottom of the mixer, and a smaller coupled directly to the shaft, being smaller than in the original model.

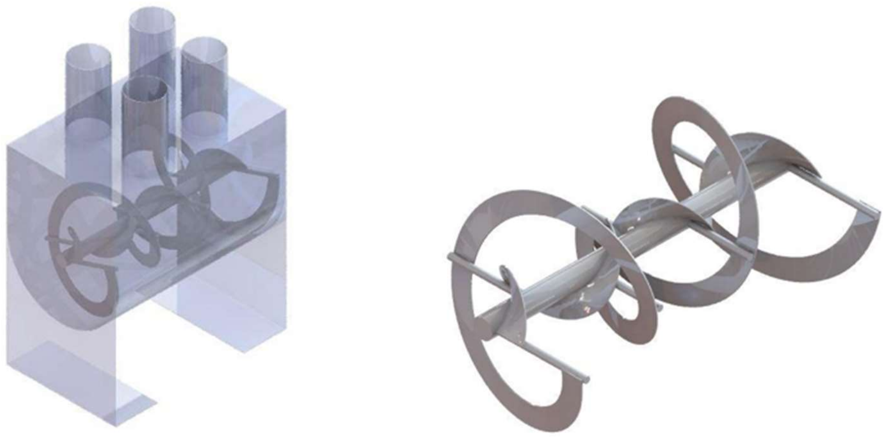


Figure 2. Test Mixer 1 and the conical shovel model.

As special characteristics, this blade model has an inclination of the tips towards the center, both in the largest and in the smallest, so the tips start with a diameter relative to the bottom of the mixer and in the center, this diameter decreases with an inclination of 14º.

Another interesting characteristic of this model is that the helicoids go to the middle of the mixer longitudinally and in the opposite direction in the other half, however, the external in relation to the internal remains inverted.

From the above, we have the largest helicoid leading the elements to the center and the smallest leading them to the ends of the mixer. Thus, the particles stay in the center of the mixer promoting mixing and the internal helicoid leads them to the outside.

So that with this the particles are in the center of the mixer promoting the mixture and the inner helicoid conducts them mixed out.

The second model to approach based on a model of thinner helicoids, as if they were tapes, with fewer revolutions and an increase in the number of tapes that improves its aerodynamics and increases the speed of rotation and mixing.

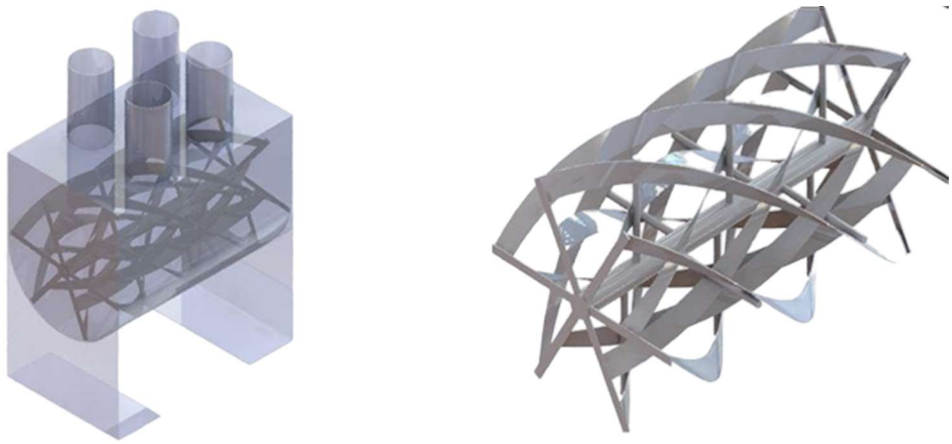


Figure 3. Test Mixer 2 and the Tape Blade Model.

The characteristics of this model are mainly the helically distributed tapes, the external diameter accompanies the mixer, and the internal one has the measure of 300 mm, just like that of the original mixer. The direction of the mixing rotation also resembles that of the original mixer, with the outer ribbons leading the particles from left to right and the inner ribbons taking the opposite path, to optimize the interaction of the particles, performing a more homogeneous mixture with more speed.

The third and last model developed starts from the same idea of the previous model, using tapes instead of a continuous helical only, continues to follow the same measurements of the previous one, but with an important difference, the direction of mixing.

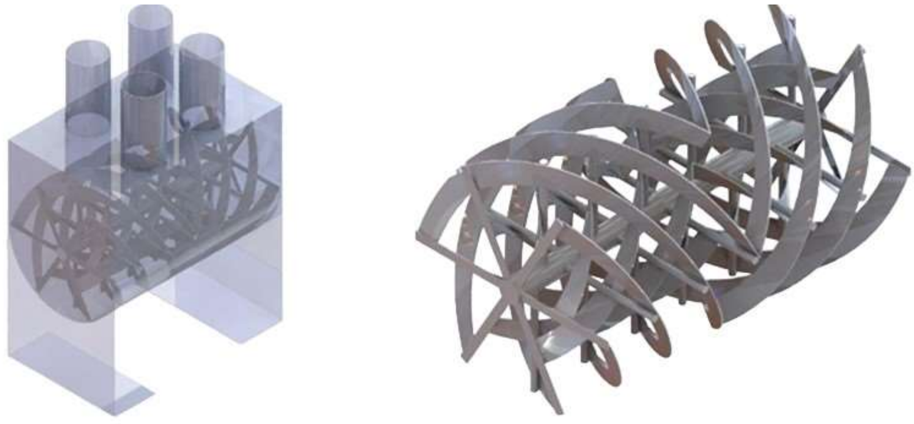
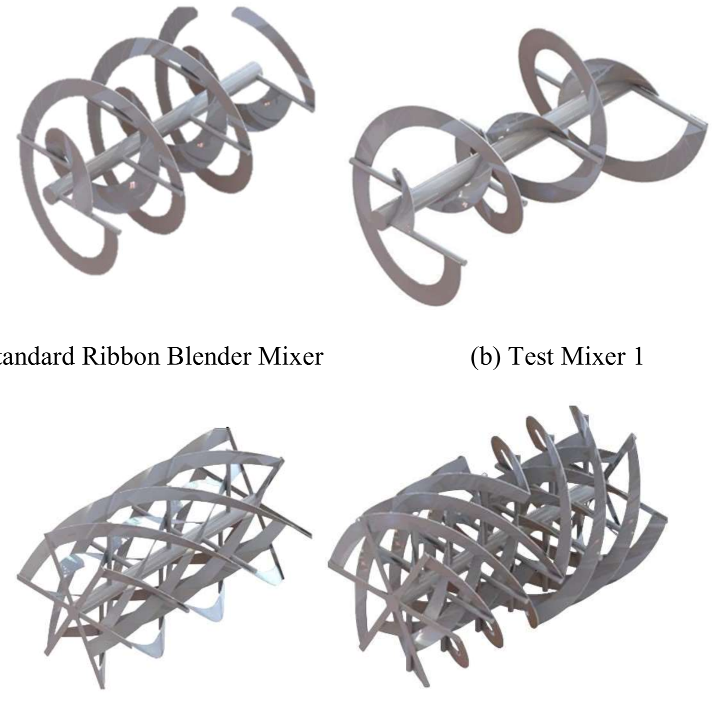


Figure 4. Test Mixer 3 and the inverted tape Paddle Model.

In this case, the outer ribbons positioned so that the two ends rotate in opposite directions until they meet in the middle of the mixer, in the sense that both take the particles from the ends to the center of the mixer, where it would generate more interaction of the elements. The inner ribbons do the opposite path, carry the particles that accumulate in the center and lead in the direction of the ends.

For comparison purposes, Figure 5 shows the studied models, side by side, for a better visualization and understanding of these models. In the figure presented, it is possible to visualize the profiles of each type of mix used in this work.



(a) Standard Ribbon Blender Mixer (b) Test Mixer 1

(c) Test Mixer 2 (d) Test Mixer 3

Figure 5. Mixer comparison.

3. **METHOLOLOGY**

To carry out this study, the construction of the projects and the analysis of the results obtained were approached differently. For the development of the project, tabulated data collected to develop a type of mixer that resembles a model already used in the industry. With this data was elaborated the modeling of this mixer through the SolidWorks software of 3D drawings, and with the original mixer developed was replicated the same conditions to the later models to maintain a regularity in the measurement, with the variations of mixtures being exclusively with respect to the blades created for the other models.

The results obtained were from a 3D simulation placing the engineered mixer in contact with previously determined particles. Using Rocky DEM software was possible to simulate the rotational movement of the propellers in such a way that it resembles a prototype, but without the need to assemble a full-scale model to determine the efficiency of the mixture, which within an industry is a very important saving of time and resources.

Rocky DEM quickly and accurately simulates the flow behavior of bulk materials with complex particle shapes and size distributions. The Rocky DEM software models the particle system as accurately as possible using Discrete Element Modeling (DEM). DEM is essentially a first principal physical method that treats each particle as an individualized granular layer. Each particle represented is through a specific shape and size that interacts with other particles and with the geometry of the equipment.

All forces acting on a particle added are together and the acceleration of the particle is calculated. This is numerically integrated with time to obtain particle velocity and position. From this process, it is possible to visualize and predict the temporal and spatial evolution of the granular system.

The models used based is on commercial equipment, where it was possible to determine data such as mixer dimensions, blade rotation and particle density.

Through the simulator, the 3D models of the mixers were imported, the rotation movements of the blades were created, the particles to mixed and their respective characteristics were created, and the simulation can initiated by counting the time required for a homogeneous mixture to occur.

In the case of this study, it decided not to use a specific product to be mixed, due to the various types of materials that can be mixed in this specific model, so whether it is a real product becomes irrelevant to the result of the simulations. Because of this, four standard elements of equal size, shape and mass were chosen, differing in their colors so that it is possible to observe the behavior of the particles. Inside the mixer and how they interact with each other.

The particulates chosen to have a spherical shape, of size equal to 10 mm and of mass equivalent to 11.17 g each particle. Inside the mixer will be mixed 25 kg of each element, totaling 100 kg used in the mixture.

The belt mixers known are as Ribbon Blender, it has a fixed structure with a rotating axis crossing it horizontally, and fixed on this axis has blades that are responsible for performing the mixture (Bridgwater, 2012).

For a study a strap mixer model used because it is a mixer model that we can used in various types of mixtures and different from the others is a model widely used in different areas of the industry, only with variation in the models of blades, exactly what is sought for this study. Just modifying and doing some tests with different types of blades, analyzing which model performs a more homogeneous and efficient mixture in a shorter time. For this, modeling software (SolidWorks) was used, and one for simulations of mixing the defined elements (Rocky DEM).

The structure of the mixer will be made with a total capacity of 100 kg, with a total length of 800 mm, width of 550 mm and height of 600 mm manufactured in AISI 304 stainless steel with a thickness of 3 mm and with industrial finish (pickled and passivated).

4. RESULTS

Once the simulations were completed, it observed how the mixture occurred in each of the models presented for this study. Thus, it was possible to determine the most efficient model for this specific type of operation.

For the original reference model, a homogeneous mixture expected because it is a model widely used in the industry today and in an efficient time.

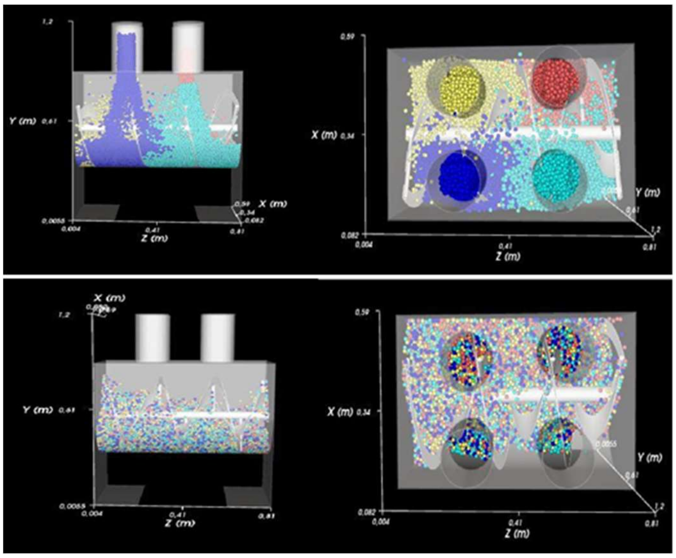


Figure 6. Simulation of the original model.

It initially observed how the elements introduced into the mixer and how they agglomerate in the initial stage. As the central axis begins to rotate, the particles begin to mix until they reach a more homogeneous mixing state, as noted at the bottom of Figure 6.

In this example of the reference mixer, it was possible to reach this homogeneous mixing state with only 15 seconds after the beginning of the simulation, which represents an excellent performance, with a high efficiency, as expected from a model already established in the market and widely used. This homogeneity given is by checking the distribution of particles during the mixing process. The more scattered the particles are, in relation to each other, the better the homogenization in the presented time.

The blades rotate and, in this case, it be noted that the particles tend to maintain a good distribution along the mixer, with a slight concentration in the upper left but that in general, can take and bring the particles with enough fluidity, which helps in the mixture and makes the process faster.

Subsequently, the first test analyzed and how this model created done in the simulation of the mixture.

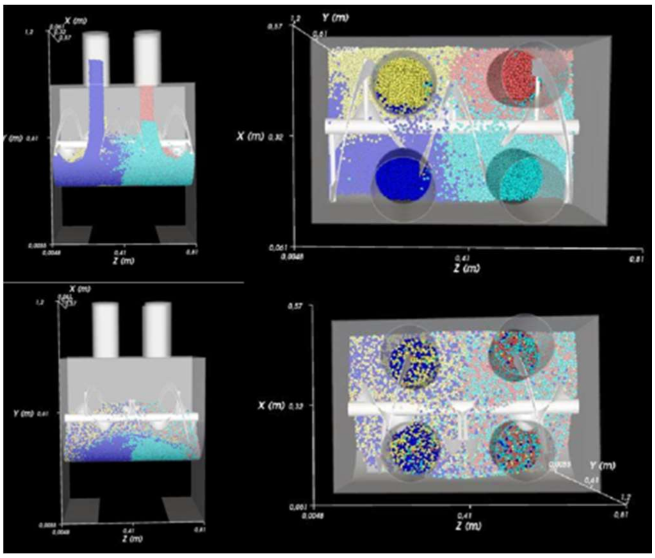


Figure 7. Simulation of the first model developed.

This first test did not obtain a satisfactory result with the proposal presented, as seen in Figure 7. The particles only mixed with those that fell on the same side. Scrape at the bottom of the mixer, increasing the contact area between the particles.

As the helicoids decrease in outer diameter, this contact area also decreases, which results in a buildup of the elements in the center of the mixer. Thus, the particles do not interact with each other. As a result, the two particles that fell on the left obtained a fluid mixture, as well as those on the right, but a homogeneous mixture not obtained between all the particles used in the simulation.

The second model proposed for this article, is different from all the blades used today and because it has this difference, it is very interesting to make this analysis of how efficient it is.

In this presented model, its predominant characteristics, such as the high concentration of particles in the upper left part of the mixer, is due to the movement performed by the external ribbons, which ended up pulling much more than the internal ones can pull to the opposite side. But unlike the previous model, the particles accumulate, but they are in constant movement, they keep mixing all the time, because this model does not leave free spaces for the particles to remain at rest, they are in constant contact.

As planned, this model met the expectations of a fluid mixture with a high efficacy, which managed to achieve a homogeneous mixture after 11 seconds of simulation. It still opens the possibility of a good flow if necessary, adding an exit mouth exactly in this area of agglomeration.

The last test proposed, with an idea like the previous model, but also has its own characteristics such as the fact of not going towards one end and conducting the particles towards the center.

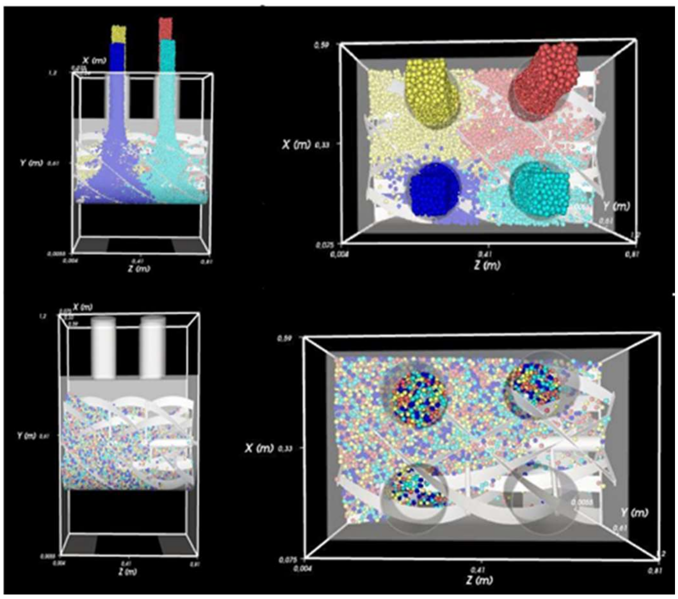


Figure 8. Simulation of the second model developed.

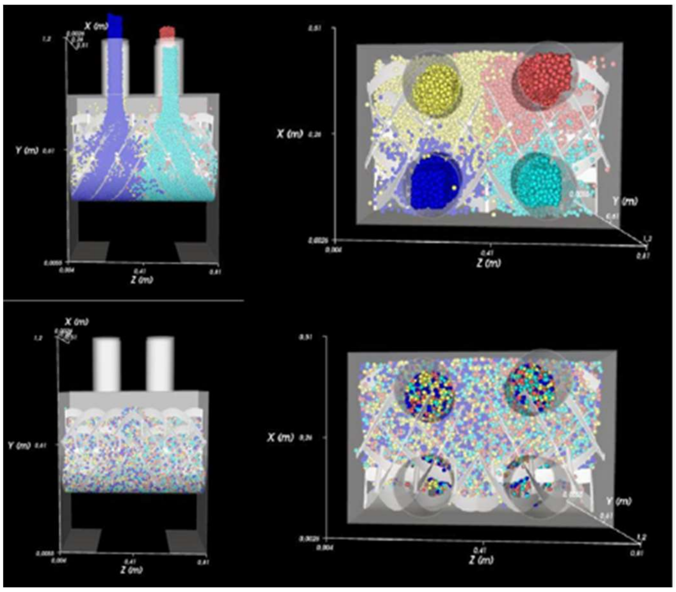


Figure 9. Simulation of the third model developed.

This example is very interesting because it has the best particle distribution inside the mixer, in the sense that there is almost no agglomeration point for the elements.

However, this model ended up not being efficient as its predecessor, even with a good distribution and fluidity it was only able to reach a homogeneous mixing point after 28 seconds after the start of the simulation.

Unlike the previous model, this one tends to lead the elements towards the center by means of the outer ribbons, and the lower ones lead them towards the ends, however, for this movement to occur.

The design has a weak point that is when the ribbons are in the center and need to reverse to create that sense of rotation. It happens that in a small area there is no contact with the particles. This factor turns out to be decisive in the result of the mixture, and the main divergence from the second model created.

5. CONCLUSION

Through this study, it is presented a perspective that there may be different designs for industrial mixer blades from those used today, and an even better result can be obtained in terms of efficiency, depending on what will be mixed and what the result expected by the manufacturer.

It is possible to have an idea of what done in general, so tabulated parameters were used on the mixer structure and the use of standardized parts to show that this process replicated in any situation.

As seen the first model created well below expected with respect to mixing, it would be a model that would need a rework. To obtain a more satisfactory result it is necessary to use a new approach.

The second example showed good results, even better than the model used today in the industry, and which applied in a manufacturing process, after carrying out the proper tests.

The last test is also an interesting model and although it did not have as good a mix processing time as the reference mixer and the second example, this is a model that has a very fluid mix. This test showed good results for elements that cannot receive as much friction, with good distribution inside the mixer. It presented a satisfactory result within what was expected and is a model that analyzed for a possible development for the industry.

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