IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 10, Issue 3, March 2020, ||Series -II|| PP 07-13

Study and characterization of Mechanical Recycling of Drug Blister

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Received 01 March 2020; Accepted 16 March 2020

Abstract: The objectives of this work are to describe and carry out the mechanical recycling process with the medicine blisters. Blister is the medicine carton used by the pharmaceutical industry, which is formed by a Polyvinyl Chloride (PVC) and metal aluminum casing. Its main function is to prolong the shelf life of the medicine, store it and allow it to be transported safely until the moment of consumption. As a consequence of the wide demand for medicines used by the population, a considerable quantity of blisters is also discarded, but they do not have a correct designation for their disposal and, therefore, end up in the common waste, where they are destined for landfills and incinerated, generating new compounds that are toxic and harmful, since they re-enter the environment and, consequently, the daily life of society. The methodology for the elaboration of the project consists of an experimental technical procedure, having as its initial stage the bibliographic survey and, following the steps of extrusion, injection of the test bodies composed of 10, 20 and 30% of blister next to the flexible PVC, for comparison purposes and performance of tests including water absorption test, hardness, density, flammability, conductivity and tensile tests. As a result, the material obtained showed high flame resistance, impermeability and excellent elasticity, allowing wide applicability, such as: soles, replacement of thermoset rubbers, coatings and parts of the construction industry.

Keywords: *Materials. Recycling. Medication Blister. PVC. Aluminum.*

I. INTRODUCTION

Concern and awareness about the waste generated and used by the population have been gaining more space and different approaches in recent decades, due to the increase of collective knowledge related to the environment. The National Solid Waste Policy (NSWP), approved in 2010, had a direct influence on this theme and on the importance that this issue has in the daily life of society in general, and it is necessary to have resolutions and guidelines from states, municipalities and the private sector. Looking for solutions and alternatives when dealing with the wastes that we have daily contact with [1].

The pharmaceutical industry is part of the industrial, medical complex, and can be considered one of the most important private economic activities in the globalized world [2]. Existing legislation in Brazil does not oblige pharmacies to dispose of handled or industrialized medicines expired in the client's hand, and allows the consumer to dispose of the medication in universal waste, in sinks or toilets, from where they go to the sewers [3].

Medicine blister packs are cartons used by the pharmaceutical industry, capable of storing tablets individually. These cards are manufactured using Polyvinyl Polychloride and metallic Aluminum. For the elaboration of the research, the study was divided into four essential steps. First, the processing of mixtures with 10, 20, and 30% of pure blister milled next to the flexible PVC (material also present in the medication package), to allow the evaluation and comparison between the mixtures with a higher and lower percentage of the material. Second, occurred the extrusion of the mixes. Third, it was necessary to provide the injection into the mold of the normalized and samples required to perform the last step. Finally, there was an evaluation of the characteristics and mechanical, chemical, and thermal properties of the material.

II. BIBLIOGRAPHICAL REVIEW

The medicament pack may be considered to be packaging, that is, a removable or non-removable packaging, container, or form intended to cover, package, package, protect or maintain, whether or not explicitly, a medicament. Its shape is usually tray-shaped, with cavities in which the tablets or drugs are accommodated, covered by the material sealed to the molded part, which will be opened or broken upon access to the medication. Some advantages of using this packaging are: good looking; the ease of closing and opening of the cavities; the possibility of printing important information such as expiration date and batch, which can be

printed directly on the molded sheet and the generally small size of the packaging that facilitates transportation, contributing to adherence about its use [4].

The card is composed of Polyvinyl Chloride and metallic Aluminum, and the choice of polymer in the blister composition is necessary because it is a light and resistant material, which has variety and ease of change in design. Already aluminum is part of the composition mainly to answer the questions of preservation and conservation of the drug about the external environment [5].

In Brazil, there is no specific legislation regarding the disposal of medicines (expired or not) and the packaging of these medicines. The closest to the law is the (*Resolução da Diretoria Colegiada*) Resolution of the Collegiate Board (RCB), number 44, of 2009, which deals with the activities allowed to pharmacies and the sanitary control of the operation, dispensing, marketing of products and provision of services in pharmacies and drugstores. In Chapter VII of the final rules in Article 93: Pharmacies and drugstores are allowed to participate in a program for the collection of medicines to be discarded by the community, to preserve public health and environmental quality, considering the biosafety principles of employing technical, administrative and environmental measures [6].

The thickness of rigid PVC film generally used by the pharmaceutical industries is 0.2 mm to 0.8 mm. Thickness has a significant influence on the light barrier property, because of the more significant the width, the lower the percentage of light transmission through the material [7-8].

Polyvinyl polychloride has 62 MPa tensile strength, 100% elongation, 4.14 GPa elastic modulus, and its density corresponds to 1.40 g/cm^3. Some of the main applications of the material are pipes, valves, fittings, flooring, wire insulation, and car vinyl covers [4].

Pure aluminum has 62% electrical conductivity, i.e., associated with its low density, which means that an aluminum conductor can carry as much current as a copper conductor (usually more indicated), which is twice as heavy and proportionally more expensive. Being infinitely recyclable without losing its physicochemical properties is one of the main advantages of aluminum [9-10].

III. MATERIALS AND METHODS

To evaluate the material behavior and performance were required three mixtures with different percentages of drug blister. Along with the flexible PVC, the zinc stearate dispersant ($C_{36}H_{70}O_4Zn$) has the function of promoting the separation of particles that are extremely fine in processing. Pigments were added in two of the three mixtures for better identification and visualization of the difference between the samples, but do not interfere with the material characteristics. The first blend contains the following percentage: 69.7% PVC D4550, 30% pure ground blister, and 0.3% dispersant. The second mixture contains: 75.7% PVC D4550, 20% pure ground blister, 0.3% dispersant and 4% pink pigment 4190 DH. The third material blend contains the percentage: 85.7% D4550 PVC, 10% pure ground blister, 0.3% dispersant, and 4% 5346 DH blue pigment, and the fourth blend is pure D4550 PVC only for reference and use. The basis for comparing the change in properties from the indicated mixtures.

The pigments are named according to the color catalog of a chemical company, a reference in the supply and solutions of compounds for the transformation of plastics, from the *Vale dos Sinos* region of *Rio Grande do Sul*.

The purpose of the extrusion was to fuse the material and leave it in the form of grains, to later inject them into samples. The required material can be inserted into the machinery through a feed hopper, where the materials mix by passing through the heated cylinder and the plastic is melted and pushed through a rotating spindle present in the openings of a die that is coupled to a perforator, causing the material from the mixture to come out as granules.

Extrusion of the material occurred in a continuous production machine used for thermoplastic processing and processing. For the extrusion process of all mixtures and pure D4550 PVC, the following parameters were used: temperature of 100 º C in the matrix, 130 º C in the center, and 120 º C in the feeding zone and speed of 734 rpm. Extrusion of 1.5 kg took approximately from each mixture took 10 minutes for each mix.

The purpose of the injection step was to fuse the material and leave it in the shape of tie-like samples as specified in ABNT MB-4. The material, already in the form of granules, added in a funnel, through samples the grains are taken to the thread feeding zone is heated and carried to the cannon. Inside the barrel the material melts and, from this, the material was pressed to the nozzle, making its deposit in the preestablished mold, where the sample was formed according to the standardization, allowing, after the process injection, it is possible to carry out the characterization tests deemed necessary.

For the injection of the mixtures, the following parameters were used: 175 º C temperature in all zones, 35 bar injection pressure, and 50 seconds cooling time. For the injection of the pure D4550 PVC samples, the injection pressure was 25 bar. The injection of the samples lasted approximately 20 minutes, including the

heating time of the material in the machine. In figure 1, from left to right, respectively, we have the flexible PVC and the mixtures with 10, 20, and 30% pure ground blister.

Figure 1 - Injected Samples.

The hardness test on the hardness tester for Shore A scale plastics was performed according to DIN 53505 and ASTM D2240 to measure material resistance to deformation [11-12]. With the samples of each composition, ten measurements were made in all parts of the samples, totaling 40 measurements, and thus allowing to obtain the hardness variation according to the different aluminum concentrations.

To determine the tendency of the material to spread or extinguish the flame when in combustion, i.e., the burning characteristics, the flammability test was performed with the reference material, flexible PVC, and the composite samples. With 10, 20, and 30% pure ground blister.

This test takes place inside a hood with exhaust for the gases generated in the burning. The bunsen burner illuminates, which emits the flame to be used, and, with the aid of a metal forceps to hold the sample, the material is then exposed to the fire for analysis of behavior when it receives heat.

To perform the water absorption test on the samples with the three blister compositions also used in the other tests, the NBR 6470 was adapted [13].

It required a digital scale and samples with percentages of 10, 20, and 30% of the blister and four containers with water.

The main objective of the test is to determine the amount of water that the material can absorb in an average period of 24 hours. According to the standard, the water absorption content that is considered allowed for the material should not exceed 0.5%. The first part of the procedure consisted of individual weighing of the samples. Then the samples were submerged in the containers with water so that after 24 hours, they were removed and dried.

The density test followed the ASTM D 792 density determination standard for polymers using technique A, which is suitable for plastics that are denser than water and unaffected by it [14]. The density test aims to control the quality and uniformity of the material, as well as to evaluate physical changes. For the test, a sample weighing between 1 and 10 grams and with a hole passing from one surface to another is required. The hydrostatic balance was connected to a heavy wire after the procedure. The value obtained is named air wire mass. With the wire already positioned, the sample is placed on the wire hook and reweighed; the value obtained is called “sample + air wire”.

After weighing all the samples of each composition, following the technical procedure, the wire was placed back on the scale and, on the scale plate, added in a container with sufficient water to cover the samples. The water container was weighed, and the value obtained was named “mass of dipped wire”. Next, the samples were placed on the wire hook and submerged in the water container, and then the weighing was performed in which the value obtained was named “sample + dipped wire”. After weighing all the samples of each material, still following the procedure, the final test step was performed, which consists of calculating the polymer density with the following equation 1:

$$D^{23^{2}C}=[a/(a+w-b)]*0.9975 \qquad (Eq\ 1)$$

The "a" is the mass of the air sample, obtained by the difference between the mass of the sample + air wire and the mass of the air wire; "b" is the weight of the sample + dipped wire; "w" is the weight of the wire dipped in water, and "$D^{23ºC}$," is the polymer density at 23 ° C.

The tensile test performed on the universal testing machine followed the procedure of fixing the sample on the device by its ends, in a position that allows the equipment to apply a specific axial force by pulling the ends of the part. The machine is hydraulic and driven by oil pressure. In the tensile test, the samples used to follow the model of the ABNT MB-4 standard. In the tensile test, the samples used follow the model of the ABNT MB-4 standard [15]. Three compositions were tested with the blister. All samples follow the stipulated criterion.

The conductivity test intended to indicate whether or not there is the presence of ions in different areas of the sample of the material. Electrical conductivity is a property that points out how easily materials can carry electrical charges. The higher the number of free electrons in a material, the higher its ability to transmit electricity. If the material conducts electricity, it is considered conductive; otherwise it is called an insulator. The materials considered good conductors and used as conductors of electricity in homes are metals, and due to the presence of aluminum of the composition of the mixtures is regarded as a necessary test. The verification was performed on ten samples of each of the different forms, 10, 20, and 30% of the blister, using a digital micrometer.

IV. RESULTS AND DISCUSSION

The Shore, A hardness test, made it possible to elaborate the Table 1, which presents the values obtained in each of the ten measurements made for each sample composition and also as the average calculated from these measurements.

Table 1 - Values obtained from shore A hardness test.

	1	2	3	4	5	6	7	8	9	10	Medium
PVC	59	57	56	61	58	53	56	58	56	56	57
Blister 10%	66	65	70	69	71	68	68	66	61	67	67
Blister 20%	72	76	79	71	78	74	75	75	73	81	75
Blister 30%	80	83	79	81	83	82	76	75	74	75	79

For the most accurate and reliable results, the test was performed on a Pure PVC sample to analyze the influence of aluminum on the material.

Shore A hardness value of 57 was obtained from the average of the measurements. This value is within the estimated range for flexible PVC, as the hardness stipulated in the Shore A scale is 50 to 90. In the Table 1, it is possible to observe that the results obtained in each measurement vary in the blister samples since they do not have uniform homogenization of aluminum throughout the material. However, it can be stated based on the average hardness found in the Flexible PVC sample, the addition of aluminum has increased the hardness of the material on all tested samples. The highest average hardness achieved is 78.8 Shore A, in the sample with 30% blister in its composition.

The purpose of this test was to evaluate the safety conditions of the nature of the material to confirm whether or not it has the potential to constitute a fire source. The samples were subjected to heat sources and flames simulating the effects caused by electrical failures that could result in fiery elements, for example. The presence of the drug blister did not change the self-extinguishing flame characteristic of PVC in any of the three proportions tested and analyzed. The material did not melt or shrink when subjected to a flame.

For the analysis of the water absorption test on the samples with the three blister compositions used, and the flexible PVC, the percentages of a mass of water absorbed for each sample tested were calculated. The values obtained by performing the test were calculated using a simple three-rule, which consists of assembling a proportion, where the initial weighing value corresponds to the total proportion, followed by the difference from initial to final mass, corresponding to unknown (mass of absorbed water) you want to find and which are shown in Table 2.

Table 2 - Values obtained in water absorption test.

	Initial weight (g)	Final weight (g)	Difference between starting weight and final (g)
PVC	3.50	3.50	0
Blister 10%	3.67	3.67	0

Blister 20%	3.75	3.75	0
Blister 30%	3.62	3.63	0

Through a digital precision scale of two decimal places, which implied the value obtained in the test of the reference sample, composed of pure flexible PVC, had zero weight, since it exceeds the precision granted by the equipment. The most recommended index for flexible PVC is 0.15 to 1.0% water absorption. However, the result of this percentage, according to the standard used to perform the procedure in polymers in general, should not exceed 0.5% of the water absorption index and, if so, the sample fails the test.

From the data presented in Table 2, it is possible to analyze that the samples, or not absorbed a practically insignificant amount of water. In the case of the composition with 30% blister, this result can be seen in Table 3, including the 0.5% considered as a determinant in the verification and approval of the tested samples. Thus, it can be stated that the addition of the blister r to the flexible PVC, regardless of the percentage tested, did not alter the real water penetration properties of the material, as the results were satisfactory.

Using the data obtained in the density test performed was possible to demonstrate in Table 3. It is possible to verify the weight of each sample. The sample with the wire suspended or immersed in water, the density of each sample, and the average density of each composition. The values used for the density calculation obtained in the test are respectively, the air suspended wire mass of 0.1823 g and the water immersed wire mass of 0.1795 g.

Table 3 - Density test values.

	PVC	Blister 10%	Blister 20%	Blister 30%
Sample 1 - Suspended Wire	3.7288	3.7501	3.9492	3.8846
Sample 1 - Plunged Wire	0.6186	0.6804	0.6289	0.9324
Sample 2 - Suspended Wire	3.6820	3.8475	3.9342	3.8117
Sample 2 - Plunged Wire	0.6146	0.7445	0.8484	0.6146
Polymer Density at 23 ° C from S1	1.1413	1.1633	1.1355	1.2553
Polymer Density at 23 ° C from S2	1.1420	1.1822	1.2170	1.1362
Average Density of Polymer at 23 ° C	1.1416	1.7279	1.1762	1.1957

The density identified in the simple, flexible PVC test, used as a reference, was 1.1416 g/cm³, a value that is within the indicated density range for elastic polymers, which suggests a density of 1.10 - 1.45 g/cm³. Using the density value of pure flexible PVC as a basis can be affirmed that the values achieved in the density test in the blister samples were lower than the reference. The highest value found in the 30% blister sample test is 0.0541 g/cm³ more. The presence of aluminum in the material resulting from recycling does not affect the quality and uniformity of the material, as well as its changes in physical properties.

Because it is a fabricated machinery commonly used for tensile testing of metallic materials, the equipment is not sized and specific for polymeric materials, especially those with high elasticity properties, so even with the use of the adapted claw For polymer testing, the machine slider was not sufficient to reach the required parameters for material breakage. As it was not possible to rupture the material, the graph does not record precisely the data needed to generate the figure of the strain curve, but by performing the test and using the maximum cursor distance, it was possible to arbitrate the material elongation, as well as the load that is supported without breaking.

The analysis performed on the 30% blister sample showed satisfactory results, such as elongation of approximately 300 mm under a pressure of 30 kgf/mm², without showing rupture or apparent wear of the material, allowing better visualization of the graphs in figure 2.

After removal of the body and proof of the claw used, the size is noticeably maintained, even with an elongation of only 10 mm concerning the original size, showing that the material presents significant elastic behavior, i.e., the elastic deformation is proportional to the applied effort. And they are deformations considered reversible since by removing the applied strain deformation, the material practically returns to its initial state.

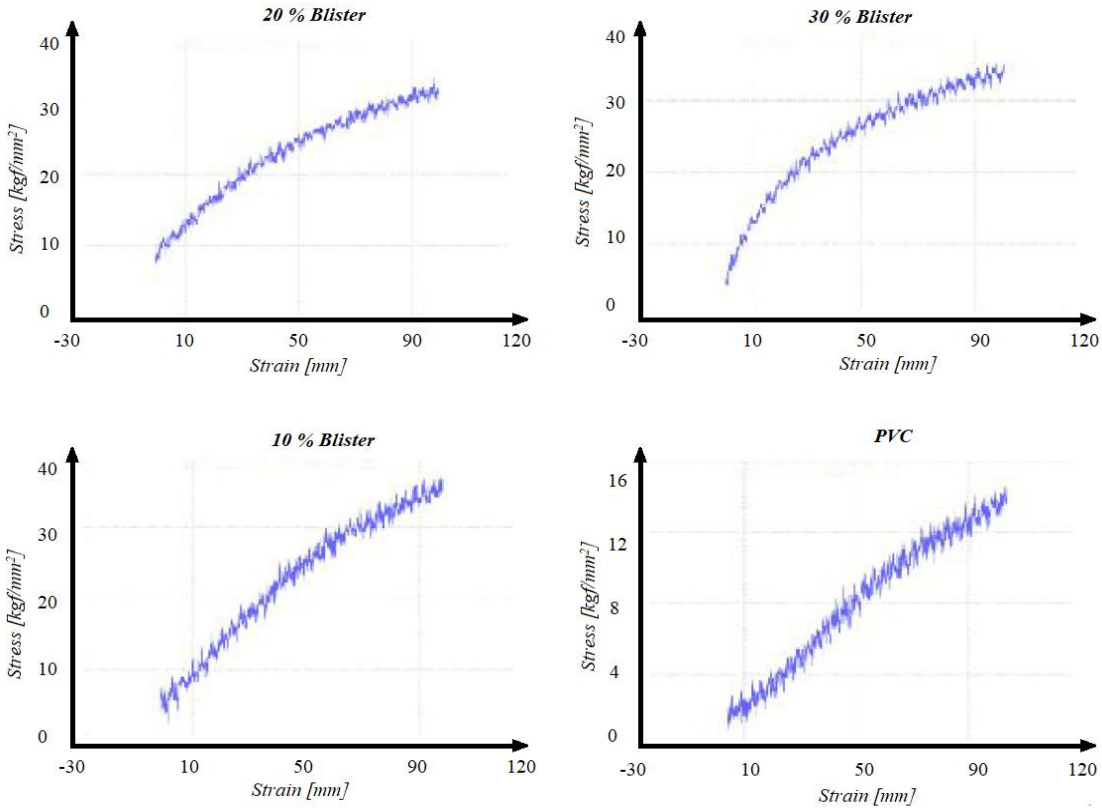

Figure 2 - Stress *versus* strain graphs.

As mentioned before, the test was performed in 4 different areas of each sample (10 samples for each material composition), using two tips connected to the megohmmeter, which has 2kΩ resolution, indicating the capacity of the instrument. Measurement, approximately 1000 V of electric voltage, was applied to each area.

All samples tested exceeded the 1MΩ (megaohms) scale of electrical resistance in the micrometer, showing some conductivity due to the presence of aluminum. This happens when the electrons present in the sample are further away from the atomic nuclei, which allows greater mobility, ie, the transition of electricity through the material when a charge is applied. Further testing is required for a complete analysis of the data obtained.

V. CONCLUSION

This study presented, through literature review and experimentation, the finding that the mechanical recycling of the drug blister is possible. This happens because it is not only an economical recycling method and does not generate waste that can cause any environmental damage or risk, but mainly because it turns a residue that is disposed of every day into a consistent material with its satisfactory characteristics.

With this research, it was possible to state that the method used in the study to carry out the project continuity stage presented satisfactory results and, as found, better than those found in the first stage of the project, which was carried out in 2089.

The choice of PVC (material already existing in the composition of the blister) to use it as a reference material and also as a basis for the mixtures allowed to obtain excellent results in the tests performed. The aluminum present in the blister and consequently in the mixtures did not affect the mechanical, chemical, or thermal characteristics of the base material, but increased the material hardness and its impermeability. Some tests and trials to verify the thermal features of the material are still ongoing.

With the known characteristics of the material, it is possible to survey possible uses in which they include: use in parts and objects of the construction industry, panels, partitions, adaptation of insulation boards, replacement of thermoset rubbers, decorative pieces, furniture corner protectors, flooring and soles.

ACKNOWLEDGEMENTS

This study is part of projects of a group of researchers of Teachers and Mechanics Students of the Fundação Escola Técnica Liberato Salzano Vieira da Cunha (http://www.liberato.com.br/) from Novo Hamburgo, Brazil. The research group does not receive any funding to support it.

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José de Souza,etal. "Study and characterization of Mechanical Recycling of Drug Blister." *IOSR Journal of Engineering (IOSRJEN)*, 10(3), 2020, pp. 07-13.