Analysis of the use of polymeric composite obtained from fabric flaps

Análise do uso de compósito polimérico obtido a partir de abas de tecido

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ABSTRACT
This research has for its objectives obtaining a polymeric composite from fabric flaps (fabric leftovers), that most of the times do not receive the proper discard, what becomes a problem since Brazil produces annually tons of fabrics and cloth pieces, and since there is no adequate regulation for this sort of solid residue, allowing improper discard. The methods used in this essay consists of the obtention of a polymeric composite for the elaboration of an educational instrument. The fabric flaps were superimposed and, to them, added an emulsion of polyvinyl acetate - PVA, a polymer adhesive, insoluble in water, and not toxic. For obtaining the material, was made a box out of SAE 1020 steel, which permits compressing the material for then insert it in a 100º C furnace to grant complete drying, then introduce the material into a hat press. After obtaining the composite in the form of a plate, a geometry shaped puzzle was made from the polymeric material. This toy was elaborated with the assist of the Fundação Liberato's educators. The material obtained shows its proper characteristics, which are good, and the toy is ready for the use of children.

Keywords: Fabric flaps, Toys, Recycling.
RESUMO
Esta pesquisa tem por objetivos obter um composto polimérico a partir de retalhos de tecido (sobras de tecido), que na maioria das vezes não recebem o descarte adequado, o que se torna um problema já que o Brasil produz anualmente toneladas de tecidos e peças de tecido, e já que não há regulamentação adequada para este tipo de resíduo sólido, permitindo o descarte inadequado. Os métodos utilizados neste ensaio consistem na obtenção de um composto polimérico para a elaboração de um instrumento educativo. As abas de tecido foram sobrepostas e, a elas, adicionou-se uma emulsão de acetato de polivinil - PVA, um adesivo polimérico, insolúvel na água, e não tóxico. Para obter o material, foi feita uma caixa de aço SAE 1020, que permite comprimir o material para depois inseri-lo em um forno de 100º C para garantir uma secagem completa e depois introduzir o material em uma prensa de chapéus. Após a obtenção do composto em forma de placa, foi feito um quebra-cabeça em forma de geometria a partir do material polimérico. Este brinquedo foi elaborado com a ajuda dos educadores da Fundação Liberato. O material obtido mostra suas próprias características, que são boas, e o brinquedo está pronto para o uso das crianças.

Palavra-Chave: Flaps de tecido, Brinquedos, Reciclagem.

1 INTRODUCTION
Fabric flaps may have different origins, inherent from the raw material's nature, or are associated with inefficiencies in the fabrication process. These residues of fashion and dressing industries are caused by the necessity of cutting a bidimensional fabric in irregular shapes to create a tridimensional piece of cloth. Besides this waste in fabrication, clothes also have a lifespan, and more residues are made when it comes to an end [1].

Ether motives create a residue's mountain in a short period. Esteem that 10 million tons of fabric from all origins are sent to landfills every year in EUA and Europe [2]. This represents a significant environmental problem, causing several adverse effects, besides is a considerable economic resource waste [3].

In the matter of fibers' manufacture, excluding the residues from inefficient use of water and energy, there is one principal agent of residue's creation in the fiber manufacture, generated for example, in the machines boot and shutdown, which sometimes can be reinserted into the process, or becomes material for other products, generally from other companies. But, if these residues cannot be used, they usually end up in landfills [4].

The lack of concern allied with excessive consumption of fashion products represents a risk to the environment at a world level, due to the immense volume of residues generated, as the Brazilian Textile Industry Association - ABIT (2013) shows of all world production of knitwear, fibers and clothing items Brazil is responsible for 2 million 249 thousand tons, appointing the country as the 5°
biggest producer of textiles and the 4th biggest producer of clothing items [6]. The clothing, socks, and accessories production in Brazil reached 6.4 billion pieces in the same year [7].

Lowest is the concern about the right discard of these residues since, after being collected in the neighborhood, they are taken to other places, far from the suburbs. However, these residues do not disappear, they might need from 10 to 30 years to decompose (if natural fiber) and 100 to 400 years to decompose (if synthetic fiber) [8-9].

The residue generation due to human consumption is almost inevitable. It happens in quantities and varieties due to the community's economic level, population size, and different social traits. However, the disposal and discard or reuse of these products become a necessity of modern society [10-11].

Thereby, it seeks to give this residue a purpose, mainly synthetic fibers, which are more harmful to the environment. Transforming them in plates of overlaid fabric flaps, then transforming into toys for kids may be a useful purpose because it can help motor and cognitive development, which occurs principally in the first years when the nervous system is still flourishing, the better is the motor, visual, logic and auditory stimulus the better is the child development [12].

2 FUNDAMENTALS

2.1 POLYVINYL ACETATE

In this essay was used Polyvinyl acetate glue-based, which is characterized as not toxic and not flammable. It is an aqueous dispersion of polyvinyl acetate (>0.8%), density between 0.8 to 1.3g/cm³, soluble in water, and viscosity between 5 to 8 thousand cP (10 Pa.s). This product may not be discarded in rivers and lakes, and it is not biodegradable. It is a general use adhesive known for more extensive use in the furniture industry.

It is recommended to be manipulated using PPE, avoiding eye and skin contact, and being inhaled, can cause nausea and skin irritation on sensible skins.

2.2 PSYCHOMOTRICITY

Motricity is about the human conscious sensations in intentional and meaningful movements on the time and space that occurs, involving perception, memory, affectivity, emotion, reasoning [12]. It is represented in the construction of intentional movement from the reflex, in planned actions from simple external stimulus, in the structures of new interaction forms from learned patterns, contextualized action on the story, etc. That is, the movement capability of an individual is directly connected to the stimulus received in the construction of its cognition and neural system maturation.
Therefore, a child that receives a great tactile stimulus (other people touch, objects, and surface contact, like water, etc.), visual stimulus (lights, forms, pictures, faces, movements, scenarios...), auditory (human voice, music, nature sound...), olfactory and taste, tends to produce more diverse motor responses and by the time more specific, building a more significant range of possibilities to interact with the environment than other children that had less variety of stimulus [12].

Understood the motricity as a cognitive development created by the stimulus, we look to the children. Such children are in the main development stage and daily receive thousands of new incentives. While playing, they like to manipulate, to move, to build, and assemble objects, to put and take off, to stack up, to stick, to drag, to push, imitate, and having physical contact [13].

The creation of new applications for discarded materials and devices to aid well-being and mobility is fundamental for communities’ local development [14 - 15]. Technological development projects are essential to foster solutions to social and environmental problems [16].

3 EXPERIMENTAL PROCEDURE

All procedures described in this essay, except for some characterizing tests, were executed in laboratories at Technical Foundation School Liberato S.V.C. in Novo Hamburgo/RS.

3.1 BASE MATERIALS

Collaborators donated the PVA emulsion and fabric flaps used in this research. The fabric flaps were presented by Leila Kátia Coelho, owner of Linda Flor Confecções, from Esteio. Were donated two tubes of KISAFIX (PVA emulsion) by Artecola company from Novo Hamburgo.

The total weight received of fabric flaps was 14.5 kg, which were of different kinds of fabrics and fibers, mostly synthetic fiber.

3.2 BONDING TEST

To understand the adhesive properties of the PVA emulsion when applied in fabrics was executed a bonding test. The test consists of overlapping fabrics flaps made of different kinds of fiber, which were carefully selected to include a wide range of fibers. In a beaker, the fabrics were dipped into PVA emulsion and then overlapped. After that, the sample was covered in aluminum foil and pressed, expelling the emulsion excess. The sample dried on a clock-glass in a kiln for six hours, over 45º C (Fig. 1).
3.3 VERIFYING PVA EMULSION DENSITY

Kisafix's density varies every batch from 0.8 to 1.3 g/cm³. To verify the PVA mass applied was made a test. This consisted of weighing a beaker and depositing a quantity of the emulsion in it, considering again. The reason between measures is the reason between Mass and volume (density). It was verified a density of 1.1235 g/cm³.

3.4 MOLD DEVELOPMENT AND IMPROVEMENT

The molds objective is giving the plates the appropriate shape and compressing the layers helping the adhesive process while curing (drying process). The mold was projected using Software CAD 3D Inventor. It is fabricated in plates of Steel SAE 1020. They were welded with a MIG/MAG welding device. The lateral and central plates were pierced with a Ø 8.00 mm drill so that the emulsion excess can drain (Fig. 2).
The fabric flaps were disposed into the mold with the PVA emulsion, on the cover was applied a compression force, which can be verified using Pascal equation $P = \frac{F}{A}$. The mold dimensions are described on the table. These were measured with a centesimal pachymeter (Table 1).

| Items       | Measures   |
|-------------|------------|
| Cover Areas | 326.31 cm² |
| Internal Width | 149.0 mm  |
| Internal Length | 219.0 mm |
| Height      | 50.0 mm    |
| Plates Thickness | 5.0 mm   |

After examining the mold, the contact with the emulsion caused oxidation of the plates. Thus measures were taken to avoid this problem. Initially, the plates were covered with aluminum foil since it doesn't rust like steel. After a better option was used, submitting the mold on electrostatic painting should prevent the mold's plate to oxidate.

Also was used a spray release agent in the place of aluminum foil. For that decision, a test was made, which consisted of painting a piece of steel with 05.00mm of thickness and after, simulating the obtaining process on the piece. After the complete cure (drying) was verified, the sample was stuck on the plate. Therefore, it was opted to use a release agent, water, and silicon-based, not toxic.

3.5 PLATE PROCESSING PARAMETERS

Resuming the obtaining process is about overlaying the fabrics with PVA emulsion into a cast to shape like a plate and then drying the material. Initially, the mold + material was submitted to heat, then the same drying process, but the material only. Lastly, while the methods were being executed, improvements were added. Given this, there are different groups of parameters, which results from a gradual process and needs to be analyzed as a procedural evolution.
Group One: The first plate was obtained using the mold without protection (which caused the plates' oxidation) and then compressed. The tension made from a known mass was of 25.9 kg. The cure occurred with two different temperatures, and the material's plate was considerably more significant than the ones after. The parameters are disposed of in Table 2.

| Mold       | Compression | Cure (w/mold) | Cure (w/o mold) | Temperature    | Thickness  |
|------------|-------------|---------------|------------------|----------------|------------|
| w/o Covering | 7.786 kPa   | 48 Hours      | 48 Hours         | Natural/45°C   | 40.00 mm±5 |

Group Two: Due to the observed problems from Group One, like the rust deposition, the lack or absence of cohesion caused by the plate thickness, a new Group of parameters was taken. This time the material was covered with aluminum foil. The plates were thinner and also submitted to higher temperatures in the kiln. These parameters are disposed of in Table 3.

| Mold          | Compression | Cure (w/mold) | Cure (w/o mold) | Temperature | Thickness  |
|---------------|-------------|---------------|------------------|-------------|------------|
| w/covering    | 7.786 kPa   | 2 Hours       | 4 Hours          | 100ºC       | 20.00 mm±2 |

Also, Table 4 shows the mass relationship between the plates after processing and PVA emulsion.

| Plate | Plates' Mass(g) | PVA Mass (g) |
|-------|-----------------|--------------|
| 1     | 99.2            | 225.0        |
| 2     | 134.2           | 157.5        |
| 3     | 118.9           | 145.6        |
| 4     | 97.1            | 89.6         |
| 5     | 62.4            | 56.1         |

Group Three: There were several good results in Group Two of the parameters. However, improvement is needed. A big issue is that there is some aluminum foil stuck to the material, although it prevents the cast from rusting. Painting the cast with electrostatic painting showed as a solution for both problems. Another modification is the load applied in the compression, which is more significant than before due to a manual press.

Furthermore was added two new processes to the method. After the cure (drying), the samples got covered with a thin layer of PVA emulsion, then were compressed in a hot hydraulic press (Fig. 3) over a specific temperature and pressure. For the last part, was used silicone paper to avoid the material to stick on the press plates.
The Group Three of parameters is the most ideal until the present moment. The plates have the following mass relation:

| Table 4. Mass relation of PVA used and plate after processing. |
|---------------------------------------------------------------|
| Plate | Plate's Mass (g) | PVA's Mass (g) |
|-------|------------------|----------------|
| 1     | 93.35            | 140.3          |
| 2     | 117.28           | 156.8          |
| 3     | 111.75           | 89.6           |
| 4     | 100.84           | 134.4          |

3.6 PRACTICAL APPLICATION

Was chosen to produce a puzzle toy like a Tangram, as it is an excellent way to assist motor development in childhood. Among the cutting options of the plates tested, vertical band saw cutting is chosen. Thus, a plate 150 mm wide and 150 mm long was cut into 8 (eight) pieces with different shapes and sizes (similar to tangram). The burrs formed in the cutting process were removed using general-purpose hand scissors.

To determinate the best way to cut the material, some cutting tests were necessary. At those, plates from the material were submitted in different processes (Fig.4), like guillotine shear (a); Manual Press (b); Hydraulic Press (c); and vertical band saw.

Figure 4. Cutting tests. a) Guillotine shear. b) Manual Press. c) Hydraulic Press.
3.7 PROPERTIES ANALYSIS

Several properties analyses were performed on the material to evaluate its characteristics. The following were carried out on the premises of the Technical Foundation School Liberato S.V.C.: Determination of Surface Hardness; Impact Test. The following were executed at the Brazilian Institute of Leather, Footwear, and Artifacts Technology - IBTeC: Detection of Soluble Metals; Flame resistance; Behavior to water; Determination of the composite's density; and Flexion index. A tensile strength test was performed with the help of machinery at the company Killing S.A., and a flexion test was carried out at the Universidade do Vale dos Sinos (UNISINOS).

4 RESULTS AND DISCUSSIONS

The bonding test satisfied the expectations since the PVA emulsion kept the fabrics bonded after drying, giving the necessary cohesion to be one material only. The PVA gave more characteristics like turning the fabrics harders and rigid. This test allowed the other steps in the research.

The cast was essential for obtaining the material, also is very efficient since it has long durability and supports higher loads. Although there are disadvantages of a steel cast, without a painting, the cast reacts with the emulsion and rust on all surfaces. The paint solved this problem but created another: the consumption of the release agent. Besides, the cast design doesn't help the curing process properly.

Figure 5. Mold for sample obtaining.

The groups of parameters are the most important part of this research because different testing parameters could gradually develop a method more ideal, fast, and economical. Given that, the parameters from Group Three are the most suitable for this process. We can see the significant improvement between the plates from "Group Two" to "Group Three."
The obtained plate above shows an interesting material, with good cohesion and rigidity, although hardly proper to be used in a toy because of its inadequate dimensional control and surface finish.

The cutting tests were necessary to verify the best form to cut the material, not just for obtaining the toy, but the samples as well. Razor cuts in the presses, or even the guillotine, are not proper. Because of the applied tension and the material properties, the plate breaks into strips. This phenomenon can be seen in figure 7.

In Figure 8, we can see a significant improvement. This obtained plate, besides having excellent cohesion and rigidity, has a great finish and dimensional control, which happens through the pressing process. This process, similar to rubber vulcanization, allowed eliminating the “empty” spaces in the material, thus creating much greater proximity between the fibers than previously found. Also, the
adhesive between the layers can keep the plate more cohesive, and it gives a significant improvement in properties, which can be noticed when redoing the cutting tests. In these plates, the problems found before do not occur.

Figure 8. Plate obtained in "Group Three" of parameters.

For obtaining a puzzle toy as the tangram, cutting with the vertical band saw showed up as the most efficient cut because it doesn’t damage the plates cohesion, produces a clean amount, and is a fast method. The proposed toy is a set of pieces of different shapes and sizes. For demonstration, a model was obtained (Fig. 8). With this toy, children can assemble several different shapes, like animals, houses, people, etc.

Figure 8. Assembly toy Tangram style.
Once the pieces present similar plastic properties to other board games, they are wear-resistant enough to play, not toxic, and are colorful (taking the kids’ attention). The properties analysis follow:

With a Woltest Durometer, the material's hardness was verified as 71 Shore A, which is similar to the hardness between a rigid plastic and a rubber. The tensile strength test executed an EMIC dynamometer, with a load of 5kN, indicated a maximum tensile strength of 5.11Mpa or 52.11kgf / cm², a significant resistance. The flexion test performed on a dynamometer showed that the material has a large deformation capacity in its plastic regimen and a small deformation in the elastic regimen. As for the impact test, using an angle of 120º and Izod specimen, we verify that it is necessary, at least 2.3J of energy the material can absorb before breaking. The other tests determined that: no heavy metal is detectable in the composite; when exposed to the flame, the material prolongs the flame and burns for a considerable time. However, the flame did not burn when exposed to the center of the plate, only at the edge; the material's density is 0.550 g/cm³ according to a dimensional method of determination; The material has a high rate of absorption and desorption, and when absorbing water it loses its rigidity; Regarding the material flexion index, a high flexion index was evaluated, being evaluated that for direction B (of the plate width) it resists more than 147,000 flexions. In direction A (of the plate length), it resists more than 235,000 flexions.

5 CONCLUSION

A composite is defined as a union of heterogeneous substances or materials that haven't natural affinity. A union of different types of plastic fibers made by superposition and a polymeric adhesive becomes a composite. It is observed the plates obtained in the superposition process is characterized as a multiphase composite, which presents distinct properties and characteristics like hardness and rigidity compared to the initial state (before methods).

All fabric flaps by this research can be restructured and transformed into something new and different from the original function. Making this essay an alternative not just to combat the pollution caused by wrong discarded fabric residues, yet can be an educational instrument for children, helping them to develop logical and motor abilities and teaching the value of sustainability.

The currently developed toy is already proper to be used by children since it is proven not toxic, therefore harmless to interaction. There will be an improvement to the toys so the responsible agency can evaluate them. As a next step, more toys can be produced and as an experiment played by children to demonstrate the teachings here proposed.
Through the runned tests, it is possible to establish some understanding of the composite characteristics and properties. Currently, it has been used as an educational instrument to demonstrate the sustainability value, also, is known the excellent potential for other applications due to its rigidity, flexion capability, low density, massive plastic regimen, and relative hardness. Put forward more studies about the possible composite applications into productive chains from different industry sectors, as footwear and civil construction, then can be determined the final application and the economic production viability.

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