Design and Realization of a Compression Molding Press, used to Produce Plate Composite Parts

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Abstract: Nowadays, there is a need to use material resources that incorporate low manufacturing, processing and exploitation costs. Thus, the existence and accessibility on the market of materials with increasing mechanical performance and with the lowest densities possible, under conditions of acceptable production and operating costs, is taken into account. Composite materials arouse a growing interest from many industrial sectors, and their use tends to generalize. For design, the emergence of these new materials represents a major change, which has a profound impact in the design and realization of industrial products. In the same time, compression molding is a high–volume, high–pressure method suitable for molding fiber or fabric reinforcements – unidirectional tapes, woven fabrics, randomly oriented fiber mat or chopped strand – into a polymer matrix material. We'll show how anyone can use this process to create plate composite prototypes using an original designed compression molding press, realized within the Faculty's Composite & Advanced Materials Laboratory, used to produce plate composite parts with post–consumer waste textile inserts.

Keywords: textile wastes; waste reuse; textile–reinforced polymer; compression molding; molding press for plate composite parts; design and realization

1 Introduction

Textiles are part of our lives and mark daily life, through the infinity of decorative, chromatic or functional forms, through the heterogeneity of materials and techniques of realization. It is an inexhaustible, spectacular and versatile textile diversity [1] [2]. From natural fibers to synthetic fibers, textiles play a vital role in meeting people's basic needs and are important in all aspects of life. People adapt and use raw, natural or semi–processed material for everyday use, both for domestic and industrial use, demonstrating the importance of textiles in the daily and extra–daily life of man [1-3]. Textiles are flexible materials, produced by weaving, knitting or pressing processes of natural or synthetic fibers, preferred for the simplicity of working tools, low costs, ease of technique and infinitely diversifiable aesthetic effects.

We often tend to consider textiles only the clothes we wear, and obviously the garment industry is where the vast majority of textiles go, where they are produced and put to use towards the consumer society. Textiles have a very wide range of uses, and besides their use in the creation of clothes can also be used in other industries. Textiles have many uses outside the fashion world [1] [2]. Apart from what is obvious – clothing, textiles are an important part of in the medical and protective equipment industry, in domestic use, in construction and in automotive industry, but they are also used in the arms industry, furniture, agriculture and other unexpected areas [1-3].

Overconsumption, a trend that sustainability advocates are trying to counter, is also manifested at the level of the textile industry, which generates substantial residues annually [4]. Households consume large amounts of textile products. Thus, huge quantities of old clothes are generated annually that end up in landfills – 73% – and so mountains of clothes are thrown away year after year (Fig. 1) [4]. Of the millions of tons of waste generated annually by the textile industry, globally less than 1% is recycled into new clothes, largely due to the absence of appropriate technologies. Also, only 13-15% are collected to recycle in other products, partly due to the fact that the technology of recycling and separating fibers of natural or partly natural origin (such as viscose and cotton) and those of synthetic origin (such as polyester and elastane) is in its early stage [5]. Each year millions of tons of clothes are produced, and every second is burnt or buried in landfill. To solve the problem, we must recycle or reuse [1-5].

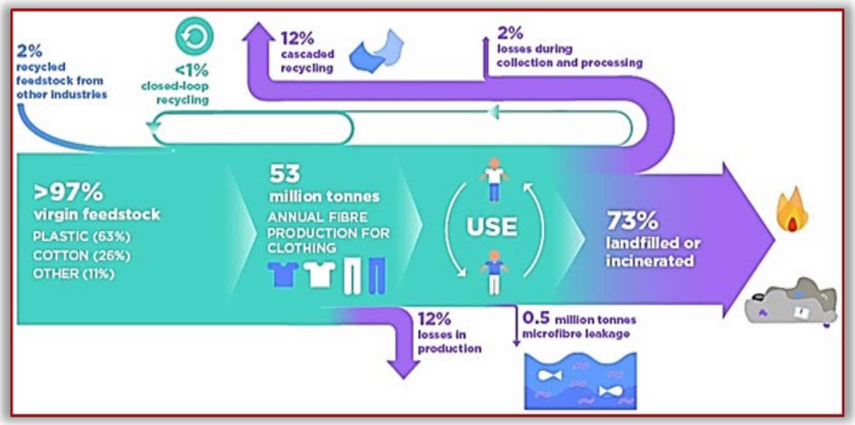

Figure 1

Global material flows in the clothing industry as presented by the Ellen MacArthur Foundation [4]

Not only production, but consumption of textiles, also produces waste [4-9]. Textiles that can no longer be repurposed receive a new chance of reuse in the form of textile fibers or are used in the manufacture of products such as carpets, cloths, industrial beds, protective materials or insulation for the automotive industry [10-16]. Urgent action is needed, as their impact on the environment continues to increase. Tons of waste end up in landfills every year—waste that could be returned to a new production cycle with a view to circular economy and industrial symbiosis [4] [5]. In these conditions, the reuse of materials is a real challenge [10-16].

The integrated and integral recovery of post–consumer textile waste (Fig. 2) involves identification, design and realization of composite products, as an ecological alternative to classical products usable in various fields, with priority in the field of construction, with beneficial effects on environmental protection and contribution to the achievement of strategic objectives of sustainable development and to increasing the competitiveness of the economy.

Figure 2
Recovery of post–consumer textile waste

Textiles provide a functional response to a wide range of specific requirements: low mass, strength, hardening, filtration, fireproof character, conductivity, insulation, flexibility, absorption, etc. As such, textiles, even those from recycling, are incentives in other industries, proposing and offering [1-9]:

- Alternative materials: lightweight, flexible, soft, (multi)functional, durable
- New technologies: flexible, continuous, versatile
- Reliable, multifunctional, cost–effective functional components, parts of broader user–oriented technology systems and solutions

The implementation of "zero waste" desideratum through efficient capitalization of textile waste in products with high added value through competitive technologies requires [1-5]:

- Strategic facilities for carrying out infrastructure investments and technological networks for waste processing
- Significant development efforts and research with as a starting point a new approach based on the life cycle of products, on the impact of waste generation on the environment, on the introduction of new standards, as well as on measures to prevent the production of waste

The main objective of the research in waste processing areas is to increase the competitiveness of the economy through RDI activities and capitalization of research results, by identifying, analyzing, designing, producing and validating in laboratory conditions some innovative products obtained by recycling and reusing post–industrial textile waste. Natural raw materials and raw materials from recycling are used for manufacturing [10-14]. Therefore, the motivation of this research is:

- New sustainable strategies for the use of alternative materials in the context of the momentum and development of materials science
- Recycling of textile waste collected but not yet valued
- Replacement of classical materials with alternative composite structures that can be used in various applications

An example of a specialized use of textiles are geotextiles, a permeable fabric that separates, filters, strengthens, protects or drains the soil. Geotextiles are commonly used to improve the soil where structures, roads or pipelines are built. These textiles have various types of materials in the composition, such as open mesh textiles, knitted to warp and nonwoven textiles [10-14].

The textile sector is undergoing significant industrial changes with the increasing importance of new applications (aeronautics, automotive, environment, medical sector, sports and recreation industry) and with a radical shift from traditional technologies (knitting, weaving, weaving, etc.) to more recent techniques (such as composite or non–woven technologies) [10-14].

The economic and social reasons, the need to save sources of raw materials and energy, the excessive exploitation of environment by man, as well as the fact that production has experienced a rapid and continuous increase have led to development of new materials and non–traditional technologies. Composites are the future of engineering, as they are the most advanced class of materials invented by man. Composite materials combine the properties of two or more constituent materials, achieving a synergistic effect, using the best properties and diminishing defects [10-14].

2 Materials

Majority of textile waste comes from household sources [1-5]. Textiles exist on the market in a wide range of compositions, colors, prints and qualities. Textiles (Fig. 3) may refer to:

- Textile fibre, as a thin, non–woven yarn of vegetable, animal or mineral origin or produced synthetically, usually used as a raw material in the manufacture of yarns for fabrics
- Textile yarn, as a product of a long and thin shape, obtained by the manual or mechanized spinning of textile fibres
- Textile fabric, as a network–type textile product obtained by weaving by crossing several natural, synthetic yarns or a mixture thereof, in the form of finished products (fabrics, knitwear, fabrics)

Figure 3
Textile forms

Textile fibers are basic raw material in obtaining yarns, which in turn are processed into fabrics and knits, can be braided in form of ropes and strings, can be braided (known as non–woven materials: felts, cloths, etc.) or, the very resistant ones, are used as a strengthener in composite materials [6-8, 10-20]. Currently, within this large group of goods are included: fibers (natural, chemical and synthetic), yarns, fabrics, non–woven materials, knits, including the entire range of finished products of clothing and other types of products that are made of fibers and textile yarns. In addition to finished products, intermediate products for textiles such as fibers, yarns and fabrics are produced. From the point of view of the quality of fabrics they are classified into fabrics: of inferior quality, ordinary, intermediate, evolved and of high quality. We can classify agrotextiles, automotive textiles and other specialized textiles according to their specific use of industry. Although they may consist of similar components, their use is very different. For this reason, the classifications of technical textiles are made according to the industry, not the components [10-14].

The raw material used to make textiles influences the characteristics of the resulting materials. The most well-known and used fibers are those of natural origin (cotton, hemp, linen, wool, natural silk and bamboo) and synthetic ones (viscose, acetate, nylon, polyamide, polyester, polyacryl, polypropylene) or mixtures of the two categories. Due to the nature of the fibers (polyester, polypropylene, viscose, cotton, carbon, glass, aramid, etc.), as well as the choice of the most appropriate manufacturing techniques (spinning, weaving, weaving, knitting, non-weaving techniques, etc.), including finishing processes (painting, printing, etc.), both technical textile manufacturers and consumers of textiles for home use and for personal use are able to propose textile solutions that correspond to various specific needs of end-users. In fact, these textiles can be part of a wider field of composite materials, essential components of textile reinforcements [6-8, 14-20].

3 Methods & Technology

Obtaining products from composite materials is conditioned by the simultaneous presence in the manufacturing process of materials that form the matrix and its reinforcing elements. The process and technology of making the product from composites is determined by the nature and physical state of the material of the matrix and reinforcing elements [13] [14].

The first problem that arises in the manufacture of fiber–hardened composites is the choice of component materials according to the conditions of use. For example, for high temperature uses, the fibers must have mechanical hot resistance, and the matrix must be resistant to wear. It is very important that in a composite the mechanical stresses are supported by the matrix fibers having the role of protecting the fibers against oxidation, corrosion, hitting and friction. It is obvious that manufacturing processes must ensure the exercise of this role from the moment when composite is formed [10-14].

The second problem is the incorporation of fibers into the matrix, an operation that must respond to three fundamental requirements: [6-8, 10, 16]

- Uniform distribution of fibres
- Aligning them in a common direction
- Making a connection between fibres and matrix

Compression molding is one of the oldest manufacturing technique used to rapidly cure large quantities of complex fiber–reinforced polymer parts on a rapid cycle time. In fact, the compression molding is a manufacturing process in which three-dimensional shapes are sandwiched between two matching molds, using heat and pressure. The composite material is molded and placed in a temperature-controlled cavity – defined between two heated metal molds mounted in hydraulic or pneumatic presses – then shaped under intense pressure and heat (from 120-200^{0}C) until the part cures. Therefore, the process parameters includes molding time, temperature, and pressure. Compression molding features fast molding cycles and high part uniformity and it provides design flexibility and nice surface finishes. In addition, it is one of the lowest cost molding methods compared with other methods such as transfer molding and injection molding, due to the labor costs are low, the trimming and machining operations being minimized.

Fibers have been used to strengthen materials for thousands of years. More recently, they have been used in combination with polymeric materials. Textiles, as reinforcement, have recently attracted the consideration of researchers because of their compensation for other established materials. They are abundantly available and have a low density. Textiles are light compared to glass fibers, carbon and aramid, so they are even more economical. With the increasing importance of new applications in the innovative fields (automotive, medical, sports and relaxation, aeronautics, environment) we have switched to techniques such as technologies in the field of composites or non–woven materials. The reinforcing material gives mechanical strength and rigidity to the composite material, used in different forms, depending on the final performances targeted for the composite material:

- Yarn - veils of overlapping threads, parallel, united by a thread, bi– or three–dimensional fabrics, with cloth structure
- Fibres - cut and ground fragments, or in the form of a "agglomerated veil" as non–woven or reinforced fibre felt with a binder

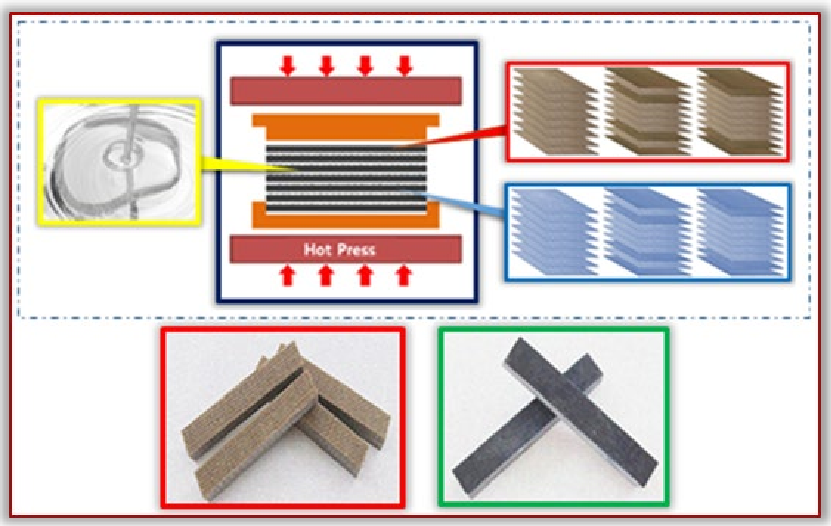

Figure 4
The principle of compression molding press and its products

Perfect alignment and uniform distribution are achieved in most cases through manual operations [13, 14, 17-20]. The individual fibers or in the fabric version are assembled layered and are then subjected to pressing, an operation performed so that the position of the fibers is not changed. Pressing (compression) always occupies an important role in obtaining quality products. Better accuracy is obtained using punch molds (Fig. 4).

Productivity is higher, but the method is recommended for parts of small size. The matrix-armature mixture is inserted into the mold. The punch is pressed mechanically at 1-6 bar. Polymerization can be done by hot or cold process. It is used, mostly, in the automotive industry and in aeronautics [14, 17-20].

4 Design Consideration & Ergonomic Principles

4.1 Choice of Design and Automation of a Production Equipment

The need for automation is in direct agreement with the increase in the competitiveness of products: [21-24]

- Search for a quality constant (product advantages, reliability, quality consistency, etc.)
- Increasing production with limited investments (equipment, flexibility, automation, etc.)
- Availability of equipment (arrangement of didactic and research laboratory, assembly)
- Saving raw materials and energy (low costs)
- Reducing or eliminating work in hazardous environments (use of resins)

For the realization of these adapted mechanical assemblies, several technologies are associated:

- electrical, hydraulic and/or pneumatic, for the power part
- electrical, electronic or pneumatic, for the control side

The fact that it uses compressed air, which is available, and can be customized to achieve a simple movement for a work equipment makes pneumatic automation an essential place in its design [10-14]. Pneumatic automation is now part of the norm in the manufacturing industry. But in a didactic laboratory, where operations can be numerous but discontinuous, production equipment has long remained in the artisanal field [10-14]. However, here too, automations have progressed on different levels:

- Automated (or robotized) workstation, partially or totally, through which the production equipment assists the operator in repetitive or consecutive movements
- Semi–automatic production equipment, where the operator intervenes in each cycle, producing elementary parts or assemblies (e.g.: loading parts or unloading parts)

The choice of design and automation of a production equipment cannot be completely dissociated from the design and optimization of manufactured products, following the product–process–equipment triptych concept. The main manufacturing process stages of composites from layered textiles, in accordance with the purpose of designing a pneumatic laboratory press, consisted of:

- Design and optimization of manufactured products, i.e. design of layered textile structures joined by adhesion with resins, on the principle of composite materials
- Choice of manufacturing processes, i.e. obtaining composites by hot and cold compression
- Design (and automation) of production equipment, i.e. design of a pneumatic press that produces the same object or set of objects in each cycle

4.2 Choice of Constructive and Functional Characteristics

Production equipment must remain, as far as possible, supple and flexible: supple so that they can be easily modified when they are to be perfected and flexible to adapt to several manufacturing processes. Pneumatic drive systems are preferred in a large number of applications, in the most diverse sectors, due to undeniable qualities such as: robustness, simplicity of construction, productivity, high reliability and last but not least the lower cost price [10-14]. Among the press forming processes, the most used is uniaxial compaction in presses. The labor force is applied to the textile layers impregnated in the resin in a single direction, most frequently through an upper (movable) and a lower (fixed) punch.

In order to achieve a corresponding quality of the pressing, as well as to ensure a good durability of the pressing tools, the design takes into account the observance of specific rules, which result from the particularities of carrying out the operations of forming layered assemblies by compacting the textile fabrics into a resin, by pressing [10-14]. Among the different types of actuators, pneumatic cylinder actuators best meet the requirements of the equipment, both in terms of simplicity of installation and of working with them.

The designed pressing equipment can simply reproduce the operator's manual actions through automation: push/retract, position or adjust [10-14]. This ensures the realization of a quality product, through a hot and/or cold pressing process, on a pneumatic press designed for laboratory conditions (educational, research, even micro production). Characteristics of actuators of the control elements (direction of pressing, distance of movement of pressing plates, applied force) correspond to the characteristics of the effects achieved as a result of these actuations. Thus, the observance of the "movement stereotypes" (closing/opening of the press) as well as the correspondence between the movement's amplitude, duration and/or intensity of pneumatic actuation, are all ensured.

4.3 Design for Ergonomical Functionalities

The constructive and functional characteristics of a basic and auxiliary technical equipment (installations, machinery, apparatus, devices, tools, equipment, etc.) must be adapted to the constitutive and psychophysiological particularities of the human operator, as an integral part of the work system. In this regard, the equipment followed the ergonomic design principles and was designed and placed in such a way as to facilitate the performance of all operations, to reduce the space and travel time, to allow the optimal sequence of movements and, in general, to ensure functioning of the work system in optimal conditions. Also, the supply and rhythmic evacuation of raw materials and the final composite assemblies, avoiding the crowding of workplaces and/or traffic routes.

4.4 Design for Micro production of Layered Composites

The design for micro production of layered composites from textiles addressed issues such as the complexity of pressed assemblies, the selection of reinforcing materials and the production (pressing) of the composite, as well as the optimization of the design of layered products for efficient and cost-effective manufacturing processes [10-14]. The choice of the right manufacturing process (pressing) based on the material (textile layers impregnated with resin), the quantity and complexity of the structures made, the quality of the surfaces obtained are essential to obtain the best results.

Of course, our analysis also involved taking into account production capacities and limitations from the early stages of the design process to ensure that the composite can be produced efficiently and cheaply. In this phase prior to the creation of stratified prototypes, we can ensure that the proposed models are functional, aesthetically attractive, taking into account their manufacturability even in laboratory conditions, replicable even for micro production.

Choosing the right material for the product early in the product development stage significantly influences cost and quality, as a wide variety of materials are available to produce different composite items, for various applications. In the design process of the composite product, the idea of creative solving of problems due to various types of textile waste was promoted. Addressing these practices of reusing as many types of textiles as possible in composite structures provides innovative solutions to create competitive products that it needs in the market.

The raw material is represented by the various textile materials, the compaction itself being preceded by their impregnation with resin and their staggered layering. The quality of the composite assembly is conditioned by the quality and cut of the fabric standards used, the quality of the resin, the way of impregnation, the thickness and number of layers applied, the actual pressing, the application of heat on the mold when pressing, the time of resin hardening and demolding. The raw materials used for the reinforcement of the composite material may conform to optimal textile layering recipes (heterogeneous or hybrid) that can be obtained within the proposed experimental plans. The reinforcement can be composed of pre–consumer (unused textile waste) or post–consumer waste (from collections) of cotton–type fabrics (cotton and polyester mix or cotton–elastane blends or viscose from denim–type fabrics) or jute, hemp and linen type [10-14]. The thermoplastic matrix used within the composite material is composed of resins. The interaction between the two key components of composite structure (reinforcement–matrix) makes factors such as orientation and layering more important than in other materials. A regular pattern in the fibers of a composite, without "defects", results in a stronger part [10-14].

Composite material can solve the problem generated by the increasing flow of textile waste by decongesting landfills, thus reducing the ecological impact, and by transforming and transferring to another field where the demand for materials is constantly increasing, it can help reduce the demand for new and innovative materials [10-14]. Thus, textile waste can replace the need for raw materials.

5 Proposed Solution: Experimental–Applicative Model of Pneumatic Press

The pneumatic press that was designed and made to function properly and was used for the compaction of stratified composite structures [10-14]. Further developments will allow the use of the press in experimental research applications and its integration into a more complex manufacturing system. The aim of the laboratory project was to design and build a pneumatic press for obtaining composite textile stratified structures, based on fabrics from post-consumption textile wastes [10-14]. The objective was to achieve a pneumatic press that would serve to press composite structures with thicknesses between 5-15 mm.

The main conditions imposed for the design of pneumatic circuit were to obtain a stroke of 100 mm at the pressure of 1-8 atm, with controls for closing and opening the pneumatic circuit made manually. The pneumatic cylinder was chosen in such a way as to meet the conditions relating to maximum force, required travel and working pressure [10-14]. Also, in order to have control over the movement of the cylinder rod, a cylinder with double action and variable braking was chosen.

For the design of press setting, a simple solution was adopted, for technological and economic reasons. The design of press setting started with the main condition of obtaining the distance from the mass to lower end of the 220 mm punch. This distance is necessary to allow maximum pressing and displacement of the rod. The clamping part of the table was then designed, followed by the design of the grip of the pneumatic cylinder. Also, the clamps for distributor, the box with electronic components and the hoses were designed.

The distributor was chosen so that commands could be generated for two–way movements, and the movement of the rod could be controlled both when going up and down. In choosing the distributor, it was taken into account that the voltage for the control of closing and opening the circuit to be 12V. Taking into account the conditions listed above, it was chosen the pneumatic distributor bistable with three–position coil. To ensure the air flow at required parameters, a compressor equipped with a working pressure of 1–8 atm was chosen. Pressure monitoring will allow the press to operate only if pressure in the compressor buffer vessel falls within the specified limits. In choosing the pressure transducer, the 8 atm value of the pressure generated by the compressor was considered as a condition.

The pneumatic press driven by programmable logic controller (PLC) is constituted as an experimental–applicative model regarding the study of pressing between two metal turntables (with one fixed lower turntable). The press is constructed in such a way that it can be used to obtain by compression composite materials with textile insert, by hot/cold pressing between flat shapes [10-14]. Pneumatic presses are processing machines, in which the pneumatic energy (air under pressure) produced by converting the mechanical energy into the generating system is converted into the energy of movement of the working organ of the receiver (pneumatic cylinder).

The press itself, represents in most cases only a part (the main one) of an installation and has the following main parts: the working cylinders (which perform the compression), the lower crossbeam (which contains the fixed platform), the mobile sleeper (which contains the mobile platform), the guide columns (or the frame), the lifting cylinders (which performs the return from compression). The component of the proposed solution includes [14]:

- A pneumatic cylinder with double effect (which performs compression and return from compression, mounted on the mobile crossbeam, with guidance and positioning of the pressing device) (Fig. 5)

- Pneumatic distribution elements (pneumatic manifolds with two ways and two working positions) directly connected to the inputs–outputs of the pneumatic cylinder, as well as pneumatic manifolds with the role of pilot.

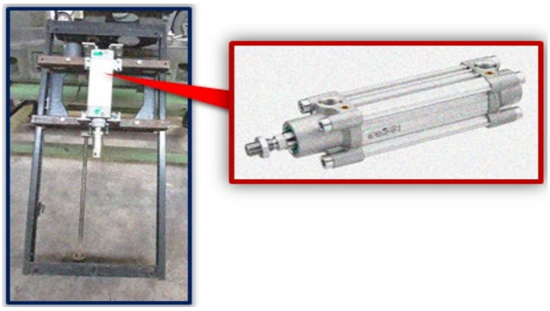

Figure 5
Mounting the pneumatic cylinder – initiation stage

The connections are made in "fast" mode with the help of specific connection elements, easy to handle. The ducts through which compressed air is transmitted (coming from a compressor or compressed air network) are in the form of flexible connecting hoses, easy to handle and use. The programming of movements and the control of positions of pneumatic cylinder piston is done with the help of a programmable logic controller.

On the stand there are also pneumatic cylinders with simple action (with the role of guiding–fixing), gauges to indicate the working pressure, the electrical control–buttons elements, the electrical protection elements of automatic safety type and the corresponding electrical wiring (Fig. 6).

The main peculiarity of the presses, the pressing movement is obtained with the help of a pressing mechanism. The mobile mass operated by the actuator system can be brought to the central position and is lowered respectively raised by the lifting device from the mobile mass. With the help of the pneumatic installation, two maneuvers can be performed:

- lowering the mobile table
- lifting the mobile table

The adjusting device in the mobile mass consists of four pneumatic cylinders with double action. He serves to raise the mobile table.

Figure 6
The mounting stages

The press (Fig. 7, Fig. 8) is made by metal construction, obtained from profiles by welding, and the crossbeam is fixed by means of metal bolts. The structure of pneumatic press is simple, but with a robust construction, made completely of steel with resistant joints and painted in electrostatic field, ensuring a long period of use, easy maintenance and operation in optimal conditions. The press has a pneumatic operation through the membrane that presses gradually, gently, in order to achieve compression. The control panel contains an electronic PLC device, programmable, and the times and durations of different work phases can be customized according to the requirements of the pressing operations, use of the press can be done automatically.

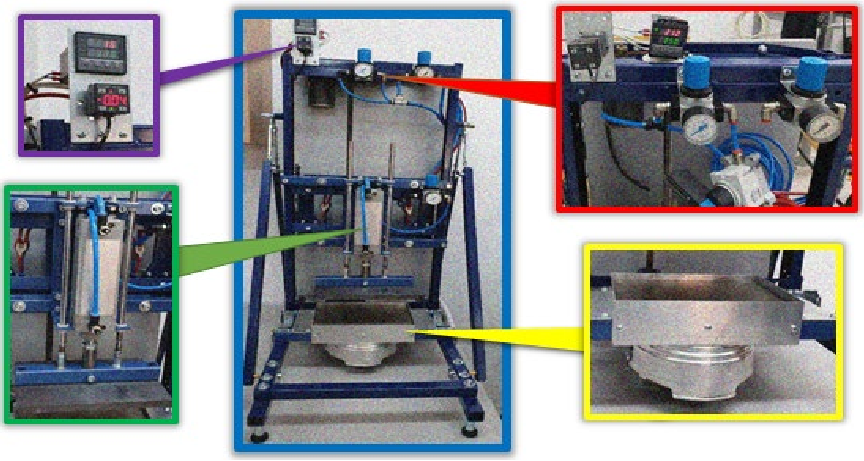

Figure 7
The laboratory press – front view

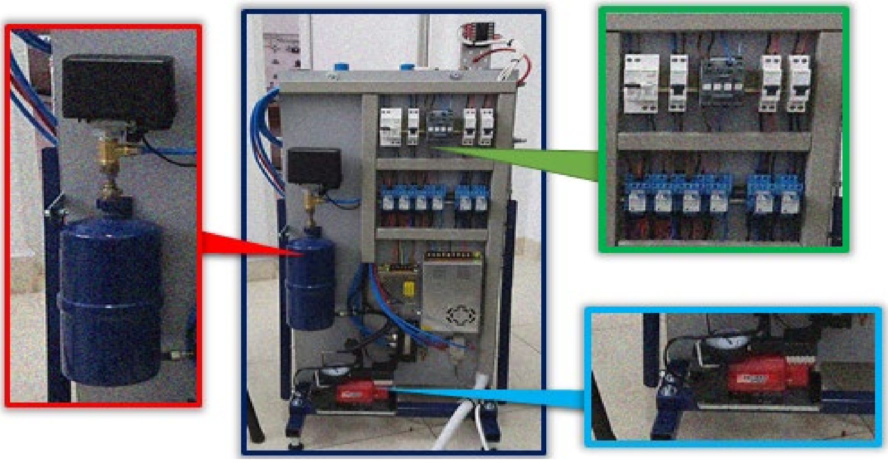

Figure 8
The laboratory press – back panel

Connected to a compressor, the upper turntable descends and automatically lifts at each transfer operation. The lower turntable is heated with a special heating installation, with adjustable temperature, mounted on the fixed crossbeam, under the turntable. The pressing stage begins with compression cycles interspersed at low pressure. Pressure is constant throughout the work surface.

The pneumatic compressive test press has the following technical characteristics:

- The maximum opening between the rigid head and adjustable head (used for compression), with position of working piston closed is 400 mm
- The piston stroke is maximum 100 mm
- The adjustable piston lead speed measured during idling is from 0 to 50 mm/min
- The return is achieved by unloading the pneumatic cylinder with double action;
- The size of the turntables, which constitute the working surface (same as maximum size of the obtained composites), is 240x160 mm;
- The thickness of working turntables helps to maintain a high and constant pressure during the pressing operation
- Is equipped with digital display for setting and displaying temperature functions, pressures and working time
- The adjustable working temperature is a maximum of 400ºC
- The possibility of adjusting working pneumatic pressure depending on material and on number of pressed layers

- The electric power supply is 220V/50Hz
- The constant pressure and speed mean increased speed for process controls

Preparation of materials, preheating, molding, curing, and demolding are all essential processes in the compression molding process [10-14]. To improve its flowability, the material—which is frequently in the shape of preforms—is first heated. After that, it is inserted into the mold's open cavity. Pressure is applied as the mold closes, causing the material to take on the shape of the mold. Until it cures, the material is kept hot and under pressure [10-14]. At last, the solidified portion is taken out of the mold by opening it.

The benefits include extremely easy operation and safety for the operator, the pressing being done by pressing only two buttons, but also good repeatable results at each press. After curing, mold is opened, and the composite product is removed for further processing. The production rate in compression molding technique is high due to less mold cycle time. The maintenance cost is also low in this case.

Conclusions

Textiles have a long history, since humans discovered the use of certain vegetal elements, to make complex and resistant fabrics. Today, modern trends have evolved. However, even today, be it elements of clothing, or simply various fabrics, they wear out physically and/or morally, becoming mere waste. Textile scraps are a direct result of the degradation of materials, be it physical degradation, through prolonged wear or sudden wear, such as material tearing, or moral degradation, that is, getting out of current trends. The best solution is for any remaining fabric to be reused or repurposed.

Properly processed textile waste can be brought back to life by using it in new applications. The efficient and rational use of textile raw materials is an important feature of the new economy model (circular and sustainable), which aims to reuse, repair, refurbish and recycle existing materials and products. The reuse of textile waste is a challenge. The development of alternative solutions for waste recovery in products with high added value by making unconventional products with recovered fibre content is an ecological alternative for the recovery of textile waste. The diverse range of products that are now produced by compression moulding, using recycled fibres or textile structures, are bringing to life a new group of composites for a number of applications.

As engineers continue to search for ways to make lighter, less-costly components, the compression molding of composites is one of the original processing methods, a fairly simple technology and is widely used for manufacturing composite parts. Compression molding is a method of molding in which, the molding material, generally preheated, is first placed in an open, heated mold form (or cavity) using a two-part mold system. The mold is closed with a top force and pressure is applied to force the textile material into contact with all mold areas, while heat and pressure are maintained until the molding textile material has cured. Using a hand lay-up approach followed by compression molding helps to solve the challenge of incorporating a high proportion of fibers or textile structures into resin (epoxy, usually). Unlike other composites processing systems, the compression moulding press is capable of reproducing fiber-reinforced polymer parts in significant volumes, with high degrees of accuracy, repeatability and speed. From an economic point of view, the solutions adopted are feasible.

Compression molding presses have existed for many years, yet they continue to evolve, according to the demands of the composites sector, aiming to address the swiftly growing market for wet-pressing / liquid composite compression molding techniques. In contrast to older monoblock-type presses (featuring a large, singular central frame and enclosed sides), the latest advancements in methodical presses are recognized for their more open design and “open-side” structures, allowing direct access to the molding tools – facilitating material insertion and formed part removal – for the previously mentioned wet–chemistry processes. Additionally, they are lighter, possess a more open design, and exhibit a smaller base area and reduced height above ground. These are presses with short strokes.

Although they are often smaller than industrial scale presses and specifically designed for research, development and testing of applications. In the field of composite materials, compression molding laboratory presses operate on the same principle as their large industrial cousins, using pressure and heat to shape various materials. For laboratory research conditions, they offer a silent operation, small bed sizes and control options, that may be quickly adjusted. This concept is adaptable for other uses, such as plate composite materials, since it applies an appropriate pressure force from the top. In the manufacturing of stratified fabric reinforced composites, compression molding is essential, because it combines ease of use, effectiveness and adaptability.

Acknowledgment

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References

[1] B. Ütebay, P. Çelik, A. Çay, Textile wastes: Status and perspectives. Waste in textile and leather sectors, IntechOpen, (2020) 39-52, https://doi.org/10.5772/intechopen.92234

[2] J. P. Juanga–Labayen, I. V. Labayen, Q. Yuan, A review on textile recycling practices and challenges. Textiles, 2(1), (2022) 174-188, https://doi.org/10.3390/textiles2010010

[3] A. Patti, G. Cicala, D. Acierno, Eco–sustainability of the textile production: Waste recovery and current recycling in the composites world. Polymers, 13(1), (2020), 134, https://doi.org/10.3390/polym13010134

[4] *** Ellen MacArthur Foundation. *A new textiles economy: Redesigning fashion's future*, (2017) Available from https://ellenmacarthurfoundation.org/topics/fashion/overview

[5] S. Tedesco, E. Montacchini, From textile waste to resource: A methodological approach of research and experimentation. *Sustainability.* (2020) 12(24):10667, https://doi.org/10.3390/su122410667

[6] Ch. Cherif, Textile materials for lightweight constructions: Technologies – Methods – Materials – Properties, *Chapter: Introduction*, (2016) 1-7, https://doi:10.1007/978-3-662-46341-3

[7] J. Hausding, O. Diestel, Textile materials for lightweight constructions: Technologies – Methods – Materials – Properties, *Chapter: Pre-impregnated Textile Semi-finished Products (Prepregs)*, (2016) 361-379, https://doi:10.1007/978-3-662-46341-3

[8] G. Sandin, G. M. Peters, Environmental impact of textile reuse and recycling – A review, *Journal of Cleaner Production*, 184, (2018), 353-365, https://doi.org/10.1016/j.jclepro.2018

[9] H. Dahlbo, K. Aalto, H. Eskelinen, Ha. Salmenperä, Increasing textile circulation—Consequences and requirements, *Sustainable Production and Consumption*, 9, (2017), 44-57, https://doi.org/10.1016/j.spc.2016.06.005

[10] M. P. Todor, C. Bulei, I. Kiss, V. Alexa. *Recycling of textile wastes into textile composites based on natural fibres: The valorization potential.* IOP Conference Series: Materials Science and Engineering, 477(1), (2019) 012004, http://doi:10.1088/1757-899X/477/1/012004

[11] M. P. Todor, C. Bulei, I. Kiss. *Composite materials manufacturing using textile inserts with natural origins fibres*. IOP Conference Series: Materials Science and Engineering, 393(1), (2018) 012088, http://doi:10.1088/1757-899X/393/1/012088

[12] M. P. Todor, C. Bulei, I. Kiss, V. G. Cioată. *Recycling of textile wastes into textile composites based on natural fibres: The reinforcement type and the architecture*. IOP Conference Series: Materials Science and Engineering, 47(1), (2019) p. 012055, http://doi:10.1088/1757-899X/477/1/012055

[13] M. P. Todor, C. Bulei, T. Heput, I. Kiss. *Consolidated composites with natural textile fabrics*. IOP Conference Series: Materials Science and Engineering, 416(1), (2018) 012098, http://doi:10.1088/1757-899X/416/1/012098

[14] M. P. Todor, I. Kiss, V. G. Cioata, Development of fabric–reinforced polymer matrix composites using bio-based components from post-

consumer textile waste, *Materials Today: Proceedings*, 45(5), 2021, 4150-4156, https://doi.org/10.1016/j.matpr.2020.11.927

[15] M. Saxena, A. Pappu, A. Sharma, R. Haque, S. Wankhede, Composite materials from natural resources: Recent trends and future potentials (2011) InTech, http://www.intechopen.com/

[16] M. I. Misnon, Md. Mainul Islam, J. A. Epaarachchi, K. Lau, Potentiality of utilising natural textile materials for engineering composites applications, *Materials & Design*, 59, (2014) 359-368, http://dx.doi.org/10.1016/j.matdes.2014.03.022

[17] A. Rubio-López, A. Olmedo, A. Díaz-Álvarez, C. Santiuste, Manufacture of compression moulded PLA based biocomposites: A parametric study, *Composite Structures*, 131, (2015) 995-1000

[18] L. Medina, R. Schledjewski, A. K. Schlarb, Process related mechanical properties of press molded natural fiber reinforced polymers, *Composite Science Technology*, 69(9), (2009) 1404-1411

[19] D. M. Corbridge, L. T. Harper, D. S. de Focatiis, N. A. Warrior, Compression moulding of composites with hybrid fibre architectures. *Composites Part A: Applied Science and Manufacturing*, 95, (2017) 87-99, https://doi.org/10.1016/j.compositesa.2016.12.018

[20] J. Ružbarský, J. Žarnovský, Optimization of parameters in the compression moulding process of thermoset products. *Advanced Materials Research*, 801, 2013, 61-66, https://doi:10.4028/www.scientific.net/AMR.801.61

[21] M. Fette, M. Hentschel, F. Köhler, J. Wulfsberg, A. Herrmann, A. Automated and cost-efficient production of hybrid sheet molding compound aircraft components. *Procedia Manufacturing*, *6,* (2016) 132-139

[22] A. A. Hassen, S. I. Talabi, V. Kumar, Innovations in high–rate composite manufacturing: integrating additive manufacturing with compression molding process. *Hybrid Composite Materials and Manufacturing: Fibers, Nano-Fillers and Integrated Additive Processes*, 115 (2024)

[23] C. H. Park, W. I. Lee, Compression molding in polymer matrix composites. *Manufacturing techniques for polymer matrix composites (PMCs)* (2012) 47-94

[24] J. Fial, M. Harr, P. Böhler, P. Middendorf, Automated wet compression molding of load-path optimised TFP preforms with low cycle times. *IOP Conference Series: Materials Science and Engineering* 406(1) (2018) 012018