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TECHNOLOGICAL INNOVATION APPLIED TO THE PRODUCTION OF CUSTOMIZED PADEL RACKETS*

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Abstract

The current economic system must reintegrate material and energy resources internally and eliminate the concept of waste to replace it with technological innovations based on terms such as recovery, hedgehog and reuse with a view to the circularity of the economy. Through technological innovations it is thus possible to obtain more durable, versatile and innovative products, capable of reducing environmental impact and waste of resources, while providing savings and improvements in the quality of life of consumers. Currently padel rackets, being made up of about 60/70% of expanded polyesters (not recyclable, with methods conventionally opposed to sustainable environmental recycling issues) and 30/40% of composites (also recyclable with non-recyclable costs sustainable) are difficult to recycle except at high costs.
3D printing FDM (acronym for Filament Deposition Molding), or deposit of molten filament, uses thermoplastic materials that can be easily disposed of, recovering over 80% of the manufacturing material, with sustainable technologies. The aim of this paper is to present a new technology based on additive manufacturing (AM) to produce limited edition padel rackets. The current technologies used for the production of racquets are designed only to obtain large volumes which make costs prohibitive for small series of customized products. This is applied to replace the current metal or fiberglass mold with a manual lamination procedure on the spindle itself to obtain the product.

Keywords: additive manufacturing, business plan, circular economy, composite materials, padel

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1. Introduction

Currently, the tendency to replace metallic materials with composite materials is becoming increasingly evident, especially in sectors with a strong technical value. In the aeronautical, aerospace and civil fields, a lot has been spent in economic and manpower terms for the discovery of new materials in order to obtain the best compromise between mechanical/physical performance (strength, weight, durability, etc.) and cost of aeronautical structures. Metallic materials, such as aluminum alloys and titanium, despite having been not discovered recently, did not completely satisfy the researchers for corrosive problems or durability, heaviness, etc. It is precisely the study of new solutions to obtain unattainable performance in terms of absolute value and energy saving in the same conditions of use, which led to the discovery of composite materials (Marchetti and Cutolo, 1991; Visconti, 1975).

Thus, an important way out is born, that of dematerializing the economy: decreasing the demand for materials of entire economies, reducing the intensity of resources in products and services, by increasing the efficiency of materials (Berglund, 1975). In concrete terms, all this can be done by reducing the consumption of materials, by recycling and reusing secondary materials. It is a necessary (but not sufficient) condition for achieving sustainable economic development. To achieve its transformative promise, Agenda 2030 calls for a new approach to address the interconnectivity of today’s challenges. With this aim, human security provides an effective analytical lens and programming framework. Initiatives applying the approach engage closely with people to uncover their specific needs and vulnerabilities, and advance policies and actions based on their priorities. This results in development that is more inclusive and sustainable (Ciampaglia, 2003).

Padel is a tennis-derived ball sport. It is practiced in pairs in a rectangular field closed by walls on four sides, except for two side doors. The game is played with a rigid plate racket with which you exchange a ball aesthetically identical to the tennis one, but with a lower internal pressure, which allows greater control of shots and rebounds on the banks (Li et al., 2000). Proper equipment improves results during the game. Therefore, the racket (and equipment in general) is a determining factor in improving one's performance on the court. However, the correct choice must be made in the midst of a truly infinite proposal. The padel racket is divided into three macro categories based on its shape. Round is the form recommended for players approaching the padel the balance is low, therefore towards the handle and allows for greater maneuverability and control of shots. Also taking into account that where there is more control, there is also less power. A teardrop also called a teardrop, instead offers a good mix between power and control and for this reason it is particularly bitter from a wide range of players, especially those of the intermediate level. Balance is shifted higher than the round one and therefore requires a little more thrust to make the ball travel (Bertolini et al., 2001).

A diamond shown instead for advanced level players, who already have good control and excellent control technique for maneuvering a tool that has the balance on top, and then moved towards the test. There the main feature is the power but you still need to be able to have good control.

2. Case study: CNR Catania/Messina

The headquarters of the Institute, which is part of the National Research Council (CNR), deals with translational research and technological development in the field of intelligent systems for health, neuroscience and child neuropsychiatry. The aim of this project is to develop a new technology based on additive manufacturing (AM) to produce limited edition padel rackets. The current technologies used for the production of rackets are designed only for the production of large volumes which make costs prohibitive for small series of customized products (Grasso and Calabretta, 2002).

In addition, the use of standard manufacturing techniques hinders design freedom. The aim of the project is to develop a new approach that manages to combine additive manufacturing technology, also called 3D printing, composite materials will make the production of limited numbers (<1000 rackets per year) technically and economically feasible without design constraints.

3. Materials and methods

In the project, reinforced commercial materials suitable for AM production will be tested with regard to their mechanical properties and, in particular, to take into account the effect of printing parameters and anisotropic behavior. The CAD derived from the state of the art of construction will serve as the basis for the racquet design. The logic will be to review / replace the use of the metal and / or fiberglass mold, in which the composite is cured for the realization of the product, with the design of only the "customized" mandrel in CAD and produced in AM where the usual lamination of the composite will then proceed (Perviaz et al., 2016). Depending on the information obtained from this design phase, the current polymer formulation will be optimized by creating mixes for the mandrel with customized properties. These blends, in order to ensure the industrial scalability of the developed system, will always be based on the use of commercially available materials and mixing techniques (Matarazzo and Baglio, 2018).

An FEA study will then be carried out, to evaluate the mechanical resistance of the racket with respect to the mechanical properties of the AM polymers selected and developed. Should any structural deficiencies be measured, especially in relation to the most critical areas such as the handle and belly and to ensure higher performance, we will proceed with the use of composite materials integrated into the racket during the lamination phase.

4. Results and discussion

Most padel players and practitioners do not know how snowshoes (padel rackets) are made and what materials are used in the process. They are therefore not aware of the advantages or disadvantages of using a racquet model depending on the components. Here is the list of materials that can be found in a racket, multiplicative parameters have been inserted due to the processing carried out in a prototype printed in PLA filament. The details are present in Table 1.

Carbon fiber: more familiar, the essence of graphite particles. It is expensive, but offers excellent results in terms of lightness and strength, hence its use in Formula 1, motorcycles and many other sports. Few brands produce 100% carbon rackets because the cost is very high (Arfò et al., 2019).

Glass fiber: the material par excellence in the manufacture of Padel rackets, a little softer than carbon, but less light. Combined with graphite or carbon it offers exceptional qualities with excellent impact resistance. It is more elastic than carbon fiber, so it provides more depth at the output but less power. Having flexion qualities, it is ideal to incorporate it on the surface of the racquets allowing to absorb more impacts and also on the frame as additional protection (Visco et al., 2011, 2012). Fiberglass is used by most padel brands. The strengths of this material mainly concern the economic savings compared to the more expensive carbon fiber (Vazquez et al., 1999).

Table 1. Economics data of padel racket technology production.

Material	***Price per unit***
Vacuum bagging	0.3x4.4€
Laminating raw materials	1h x (10€ - 15€)/h
Carbon fiber prepegs	0.3x54€
Sealant tape	0.1x8€
Freezer -18°C	-
Vacuum pump, tube hoses connectors/valves Vacuum regulator	0.01x480€
Laminating tools	0.01x150€
Dremel, accessories, flexible mandrel	0.01x120€
Air Compressor filters	0.01x200€
Mask	0.1x50€
Gloves Overalls Trimming box Painting Box	0.1x12€
Spry paint	0.1x40€
3D printing filament mandrel	0.5x24€
	Total Price: 44,05 € -

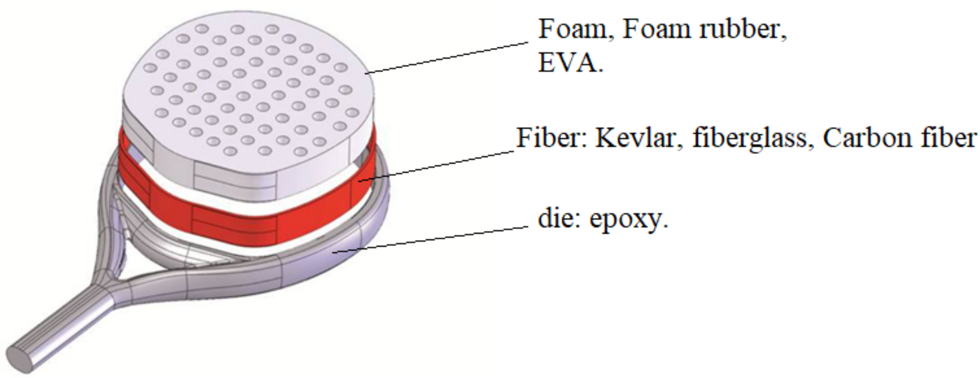

Fig. 1. Tipical materials of a padel racket (www.padelpaddle.it).

Graphene: is a two-dimensional crystalline carbon material. It is the finest component known (with a single atom thickness), the lightest (1 square meter of graphene weighs 0.77 milligrams), the best conductor of heat at room temperature, and is also the best conductor of electricity. Another property of graphene is its strength, it is the strongest material discovered with a much higher tensile strength than steel and Kevlar. Graphene is currently very expensive and difficult to obtain artificially although production techniques are constantly improving. By reducing costs and complexity. Very resistant, very hard and very strong but expensive and of dubious effectiveness. Brands like Head now feature rackets that incorporate graphene on its high-end models (Anastasi et al., 2020; Gentile et al., 2019).

Foam: with Eva Rubber, the most used material in the production of racquets. It is a rubber whose main property is that of shock absorption and its main component is latex, a resin that is extracted from trees or oil. We can meet an EVA racquet with different density and quality, which makes it more or less compact, rigid, flexible, flexible, elastic, etc.. The effects on a racquet would be more or less flexible to impact with the ball, giving us different sensations of strokes, power, control ... sometimes mixed with other materials in the end to get more lightness, the mixing will still lose its original properties against shock absorption. In theory, EVA rackets have greater control and longer durability, as they are a less elastic material. They have a lower bullet output than FOAM and polyethylene rackets. In EVA rubber there are different hardnesses: EVA Hyperasoft (softer), EVA Supersoft ... the rubber deforms very little in contact with the ball, forcing us to hit harder to get the same speed as the ball, but with the advantage that we will not have a limit to the hitting point, with respect to the speed that we can print on the ball, as in the case of FOAM. In addition, the snowshoes are more durable, and these finishes are of better quality.

Aluminum fiber: also called Alufiber, it is a harder material than fiberglass, but more flexible than carbon. Blended with carbon, this fiber offers excellent results in terms of power and control, producing a very characteristic metallic noise (alternative to fiberglass). It is little used, it depends a lot on the blends on which the fiber is mixed.

Kevlar: it is a fabric with a special treatment that gives it a very strong resistance, one of the most resistant materials. Being very stiff, it is very expensive to work with this material, but it can be added as an additional reinforcement in a part of the racquet. Carbon-woven Kevlar offers exceptional durability results. Currently only a few brands use it because it is too difficult to work with, but given its much stronger strength than carbon and glass, it offers amazing power and good control. On the other hand, no elasticity and therefore no effect of balls (ball exit). Compared to carbon fiber, it has better control but considerably reduces the impact power with the ball and also the lamination processing is more difficult. It is used as a reinforcing factor in the most critical areas as an alternative to carbon fiber (Munda and Matarazzo, 2020).

5. Concluding remarks

The continuous technological evolution that has made it possible to create innovative composite materials with increasingly performing characteristics and the growing sensitivity of the market for energy saving, have made composites particularly versatile and suitable for different applications. The 3D printed mandrel facilitates the lamination operation and allows product customization. The cost, compared to the state of the art, differs by about 12-15 compared to the use of the metal or fiberglass mold. This innovation also makes it possible to consider the possibility of disposing of thermoplastic in a more sustainable way.

The contribution of new technologies has also given rise to new composites with highly interesting functionalities. It is possible to develop completely new products or solve specific project problems or even create products with materials that require less energy in their production and transformation into semi-finished products. Finally, we can affirm that advanced composite materials will make it possible in the future to face the important challenges of energy and environmental sustainability linked to the production and end-of-life phases.

As a demonstrative result of the project, the aim of the project will be to provide the prototyping of six padel rackets (2 for each common shape found in commercial literature) to measure critical processing parameters such as variations in production times. The rackets will also be used to evaluate, on the basis of qualified tests, properties such as mechanical impact / impact and impact / impact resistance, static and degradative traction studies in UV and wet conditions. Smart manufacturing systems of the future must be adaptive, self-autonomous but also resource-efficient in their own manufacturing process as well during their utilization phase. To reach this target within a cost-efficient development and production process, holistic and integrated development methodologies are necessary. We show that it is possible to combine different development methodologies at an early stage to achieve a cost reduced lightweight design.

The combination of the analytical methods function mass, requirement and value analysis with simulation-based topology and frequency optimization in the product development process leads to a resource-efficient and economic manufacturing system in lightweight design. Using the example of a corrugated board conversion machine, this article shows the implementation of this combined development approach regarding lightweight design. A few examples of the estimated costs that are included and considerate in the project:

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