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ADVANCES OF COMPOSITE MATERIALS IN COMPACTION EQUIPMENTS FABRICATION. A REVIEW

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Abstract: *In this paper, the authors address an actual aspect regarding the introduction into manufacturing of parts of compactors made of advanced composite materials. In this sense, types of materials, their technical requirements, examples of component elements whose traditional material has been replaced by composite materials are presented. The benefits of implementing these materials in the current manufacture of compactors have been quantified according to the statements of the major manufacturers of equipments for compaction.*

Keywords: *compactor equipment, advanced composite materials, requirements, benefits*

1. INTRODUCTION

Nowadays, advanced composite materials are widely used in various applications such as aerospace, automotive, wind energy etc. due to superior strength-to-weight ratios, corrosion resistance and customizable properties [1,2,3]. The use of advanced composite materials in manufacturing of equipments for terrain compaction (Figure 1) significantly influences their performance and efficiency and implicitly the technological processes in which they are incorporated on construction sites [4,5].

Figure 1: Examples of compaction equipments:
a) Roller machine; b) Rammer; c) Vibratory plate; d) Mini roller.

Common composite materials used in the manufacture of parts into compactors structure (as rollers, rammers or vibratory plates) are [6-9]:

- Fiber-Reinforced Polymers (FRP) as: carbon fiber-reinforced polymer (CFRP), glass fiber-reinforced polymer (GFRP), aramid fiber-reinforced polymer (AFRP) that offer high strength-to-weight ratios, corrosion resistance, and durability;

- Kevlar Reinforced Composites with epoxy, rubber, polypropylene, and thermoplastic materials, used where impact resistance is crucial, providing protection against wear and tear while maintaining a lightweight structure;

- Natural Fiber-Reinforced Composites (NFRC) using wood, Kenaf, rice, flax, hemp etc. offering a balance of good mechanical properties and sustainability, as environmentally friendly alternatives to synthetic fiber composites.

The important aspects that influence decision-making regarding the change of materials [10] in the construction of compactors equipment are the following:

a) The complexity of the compaction machines is an important criterion that must be considered when designing vibratory systems (requiring strict control of technological parameters, such as frequency, amplitude of vibrations [11-14]) with component elements made of composite materials.

b) The sensitivity of the material to the intensively dynamic work regime of the technological equipment can lead to the shortening of the life of the respective components because of the damage of the fibers or the resin used [15,16].

c) Integrating new materials into existing production lines can be challenging, requiring consideration of costs and compatibility with older compaction equipment [17-19].

2. TECHNICAL REQUIREMENTS

New composite materials often have different thermal, mechanical, and chemical properties compared to traditional materials. This affects how they interact with existing equipment, particularly compaction tools, which might not be designed for the specific needs of these materials, changing the lifetime [20], adding heating elements [21,22], enhancing precision controls [22]. For the mechanical characterization and damage diagnosis of advanced composite materials, non-destructive techniques based on the propagation of high-frequency sound waves through materials are used to detect internal characteristics, measure material properties and identify structural damage [23,24].

The component parts of mini equipment for vibratory compaction made of composite materials have the following constructive and visual characteristics:

a) textured appearance, especially those made of carbon fiber, if they are not covered with a layer of paint.

b) versatility in choosing the constructive form, designing curved shapes, with smooth edges and an ergonomic design, which gives a modern and aerodynamic appearance.

c) light weight because these materials are lighter than steel, resulting in a slim but robust construction.

d) lifespan of components made from composite materials is longer compared to those made from conventional materials.

In particular, the beneficial aspects of manufacturing some parts of the constructive assembly of the usual compaction equipment from composite materials will be exemplified. It is known that the chassis or main frame provides structural support for all other components of the compactor. The material from which it is made is based on composites with glass fiber or carbon fiber. Thus, the use of composite materials reduces the overall weight of the equipment, making it easier to handle and transport from one job to another, without compromising its structural strength. The drum or base plate are the component of the equipment that come into direct contact with the ground or other materials that require compaction. These are typically made of either steel or cast iron, but it can be made is based on glass fiber or carbon fiber composites, conferring high resistance to abrasion compared to traditional materials and reducing the transmission of unwanted vibrations to the user operator. The insulation mount reduces the transmission of vibrations from the vibratory tool to the structural elements of the equipment, but also to the attendant operator. Making it from elastomeric materials (such as fiber-reinforced elastomers) improves vibration damping, increasing operator comfort and extending the life of compaction technology equipment. The engine housing has the role of protecting it, but also other internal components from dust, dirt and impacts. The use of fiberglass or carbon fiber composites provides increased corrosion resistance in harsh working environments and has the benefit of reducing overall weight. The control lever and handles are slightly easier to handle and more comfortable for the operator if they are made of fiber-reinforced plastic composite materials, offering an ergonomic design, increased resistance to wear and harsh operating conditions. The joining parts and supports in the structure of the equipment that ensure the connection and support of the different components of the compactor can also be made of composite materials with carbon fiber or glass, thus offering increased resistance to traction and bending, being ideal for parts that must be light and durable at the same time. Also, rubber-fiber composites are used in drive belts due to their high durability and flexibility. The gallon tank is made from fiber-reinforced polymers (FRPs) because these materials offer high strength-to-weight ratios, corrosion resistance, and durability.

3. CASE STUDIES: ADVANCES OF COMPOSITE MATERIALS IN COMPACTION EQUIPMENTS FABRICATION

The choice of composite materials appropriate to the technical or constructive requirements of the compaction equipment is made following a rigorous selection according to their application role, such as: weight reduction (Table1), wear resistance, structural integrity, etc. Already major compactor manufacturers have replaced traditional materials with composite-based ones and have noted improvements in performance, durability and operator comfort, and implicitly more efficient operation. In the following, some case studies will be presented regarding the current situation regarding the introduction of advanced composite materials into the current manufacturing of compactor structural components.

Table1. Weight reduction vs. traditional material when using composite materials

Parts of compactor equipment	Manufacturer	Materials	Values
Drum roller, plate base (rammer, vibratory plate)	Bomag	CFRP	30%
	Volvo	CFRP + steel	40%
	Caterpillar	CFRP + aramid fibers	35%
	Ammann	CFRP + aramid fibers	40%
	Wirtgen Group	CFRP	n.a.
Frame and chassis	Bomag	GFRP	20%
	Volvo	CFRP + Kevlar	30%
	Ammann	GFRP + carbon fibers	30%
Operator cab	Bomag	GFRP	20%
	Volvo	GFRP	25%
	Caterpillar	GFRP	30%
	Ammann	GFRP	30%
	Wirtgen Group	GFRP + carbon fibers	
Engine hood and side panels	Volvo	CFRP + Kevlar	30%
	Wirtgen Group	GFRP	n.a.

Vibration isolators are usually made from elastomeric materials like rubber, but with the advanced composite materials (ACMs), these damping systems are becoming more efficient and durable (Table2). Their applications in compactors equipments are used in several critical areas: engine mounts (isolating the engine from the rest of the compactor structure to reduce noise and vibration transmission), operator cabin mounts (ensuring a smoother and more comfortable ride by isolating the operator's cabin from the vibrations of the compactor's frame) and component isolation (protecting sensitive components like hydraulic systems and electronics from excessive vibrations, which could lead to premature failure).

Table2. Incorporate isolation mounts made from ACMs

Manufacturer	Materials	Model
Bomag	CFRP + rubber	BT 60/4, BT 65, BT 120
Volvo	CFRP + rubber	SD160B
	GFRP + rubber	DD120C
	Kevlar + rubber	SD75B
	Thermoplastic composites reinforced + carbon nanofibers	CR30B
Ammann	GFRP + rubber	ARX 91
	CFRP + rubber	ASC 110, APR 5920
	Kevlar + rubber	ARS 122
	Thermoplastic composites reinforced + carbon nanofibers	ARX 26-2
Caterpillar	CFRP + rubber	CS56B, CP74B
	Kevlar + rubber	CB10
	GFRP + rubber	826K
Hamm	CFRP + rubber	HD+ 120i VO, GRW 280i
	Kevlar + rubber	H 13i
	GFRP + rubber	3410 VIO
	Thermoplastic composites reinforced + carbon nanofibers	HD 14i VV

The use of advanced composites in compactor vibration isolators results in increased operational performance characteristics, providing further improvements in vibration isolation, durability and cost effectiveness.

All manufacturers estimated the increasing of the service life of the compactor's parts fabricated with composites materials compared to traditional materials (e.g. Bomag: 25 %, Volvo CE: 30 %, Caterpillar: 20 – 25 %, Ammann: 25 - 30 %, Wirtgen Group: 30 %).

Also, reducing of the fuel consumption of these machines represents another strength point that require implementation of these kinds of materials in the current fabrication (e.g. Bomag: 15 %, Volvo CE: 20 %, Caterpillar: 15 %, Ammann: 15 - 20 %, Wirtgen Group: 15 %).

4. CONCLUSIONS

The use of composite materials by major compaction equipment manufacturers is currently increasing due to their multiple benefits, the most significant of which are: weight reduction, increased strength and durability, and improved operator efficiency and comfort. In this direction, as production technologies evolve, the use of composite materials is expected to become even more widespread in the construction equipment industry.

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