ANALYSIS OF COMPOSITE MATERIALS USED IN COMBAT UAVS (ADVANTAGES OF COMPOSITE MATERIALS IN AEROSPACE)

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Abstract: The growing use of composite materials (especially in combat UAVs) has arisen from their high specific strength and stiffness, when compared to the more conventional materials, and the ability to shape and tailor their structure to produce more aerodynamically efficient structural configurations. In this report, it is argued that fiber reinforced polymers, especially carbon fiber reinforced plastics (polyacrylonitrile) can and will in the future contribute more than 50% of the structural mass of an aircraft.In this report a brief explanation on how the component is manufactured by the use of composite materials and also the strength of the manufactured material is calculated and compared with the other metals which shows the benefits of using these composite materials.

Keywords: carbon fiber reinforced plastics, fiber reinforced polymers, polyacrylonitriles.

I. INTRODUCTION

The UAV is an acronym for Unmanned Aerial Vehicle, which is an aircraft with no pilot on board. UAVs can be remote controlled aircraft (e.g. flown by a pilot at a ground control station) or can fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems. UAVs have most often been associated with the military but they are also used for search and rescue, surveillance, traffic monitoring, weather monitoring and fire fighting, among other things. The term composite usually refers to a "matrix" material that is reinforced with fibers. For instance, the term "FRP" (for Fiber reinforced plastic) usually indicates a thermosetting polyester matrix containing glass fibers and this particular composite has the lion's share of today's commercial market. The figure shows a laminate fabricated by "cross plying" unidirectional reinforced layers. The matrix dilutes the properties to some degree, but even so very high specific (weight adjusted) properties are available from these materials. Metal and glass are available as matrix materials, but these are currently very expensive and largely restricted. The fibers may be oriented randomly within the material, but it is also possible to arrange for them to be oriented preferentially in the direction expected to have the highest stresses. Such a material is said to be anisotropic (different properties in different directions), and control of the anisotropy is an important means of optimizing the material for specific applications. Many composites used today are at the leading edge of materials technology, with performance and costs appropriate to ultra demanding applications such as spacecraft.

II. WHY TO USE COMPOSITE?

Materials are selected for a given application based principally on the materials properties. Most engineering structures are required to bare loads, so the material properties of the greatest interest are very often its strength. Strength alone is not always enough; however, as in aircraft are many other structures a great penalty accompanies weight. It is obvious an aircraft must be as light as possible, since it must be able to fly. As another example, a bicyclist wants her bicycle to be light, since that makes it easier to climb hills (and to carry it upstairs to keep it from being stolen).

In some other applications, the importance of light-weight is not so obvious: consider an energy-storage fly wheel, which can store energy in a kinetic form via the inertia of a rotating mass. Some subway cars use this approach in regenerative braking as the car brakes to a stop at the station, motor/generators driving the wheels are used in a generator mode to supply current to the flywheel motor. This causes the generator shaft to apply a braking resistance to the wheel, and the generator current speeds up the flywheel and raises its kinetic energy. When the subway car wishes to accelerate backup to speed, the flywheel motor is switched to generator mode and used to supply the current back to the wheel motors; the original kinetic energy of the car is thus saved for later reused rather than the dissipating it as heat in the conventional braking.

III. WHEN TO CONSIDER COMPOSITES?

Composites bring many performance advantages to the designer of structural devices among which we can list:

- Composites have high stiffness, strength and toughness, often comparable withstructural metal alloys. Further, they usually provide these properties at substantially less weight than the metals: their "specific" strength and modulus per unit weight is near five times that of steel or aluminium. This means the overall structure maybe lighter, and in weight-critical devices such as airplanes or spacecraft this weight savings might be a compelling advantage.

- Composites can be made anisotropic i.e., have different properties in different directions and this can be used to design a more efficient structure. In many structuresthe stresses are also different in different directions; for instance in closed-end pressure vessels - such as rocket motor case – the circumferential stresses are twice the axial stresses. Using composites, such a vessel can be made twice as strong in the circumferential direction as in the axial.

- Any structures experience fatigue loading, in which the internal stresses vary with time. Axles on rolling stock or examples; here the stresses vary sinusoid ally from tension to compression as the axle turns. These fatigue stresses can eventually lead to failure, even when the maximum stress is much less than failure strength of the material as measured in a static tension test. Composites of then have excellent fatigue resistance in comparison with metal alloys, and often shows evidence ofaccumulating fatigue damage, so that the damage can be detected and the part replaced before a catastrophic failure occurs.

- Materials can exhibit damping in which a certain fraction of the mechanical strain energy deposited in the material by a loading cycle is dissipated as heat. This can advantageous for instance in controlling mechanically-induced vibrations compositegenerally offers relatively high levels of damping, in further mode the damping can often be tailored to desired levels by suitable formulation and processing.

- Composites can be excellent in applications involving sliding frictions, with tri-biological (“wear”) properties approaching those of lubricated steel.

- Composites do not rust as do many ferrous alloys, and resistance to this common formof environmental degradation may offer better life cycle cost even if the original structure is initially more costly.

- Many structural parts are assembled from a number of subassemblies, and the assembly process acts cost and complicity to the design. Composites offer a lot of flexibility in processing and property control, and this often leads to possibilities for path reduction and simpler manufacture. Of course, composites are not perfect for allapplications, and the designer needs to be aware of the drawbacks as well as their advantages.

- Not all applications are weight-critical. If weight-adjusted properties not relevant,steel and other traditional materials may work fine at lower cost

- Even after several years of touting composites as the “material of the future”, economics of scale are still not well developed. As a result, composites are almost always more expensive often much more expensive-than traditional materials, so thedesigner must look to composites various advantages to offset the extra costs.

- During the energy-crisis period of the 1970’s, automobile manufacturers were so anxious to reduce vehicle weight that they were willing to pay a premium for composites and their weight advantages. But as worry about energy efficiency diminished, the industry gradually return to a strict lowest-cost approach in selecting materials. Hence the market for composites in automobiles returns to a more modest rate of growth

IV. CARBON FIBER

Carbon fibre composites have revolutionized the aviation industry since their inception into aviation on the Boeing 737 in the mid-20th century. Demand for the lightweight material from industry has grown significantly in recent years. The positive impact carbon fibre composite materials have had in aviation has been significant, especially with fuel consumption and emissions. Aviation companies such as Airbus and Boeing are at the forefront of carbon fibre composite technology and its application into their fleet. The introduction of such relatively new generation materials does bring its challenges, however, the opportunities of successful integration are highly rewarding, both financially and environmentally.

Graphite (graphene sheets that contain carbon atom layers) and carbon fibre share a similar atomic structure and can be arranged in either a rhombohedra or hexagonal stacking arrangement as shown in figure 1 (Huang 2009, p. 2371). Graphite is a three dimensional structure where crystalline order is observed, where grapheme is considered a two-dimensional structure (Huang 2009; IUPAC 2003). Rhombohedra graphite is an allotrope of graphite and is considered thermodynamically unstable. On heating rhombohedra graphite to temperatures in excess of 1600K, its structure slowly transforms into the hexagonal modification. This particular allotrope is “best considered an extended stacking fault of hexagonal graphite”, and is the result of hexagonal graphite shear deformation (IUPAC 2003).

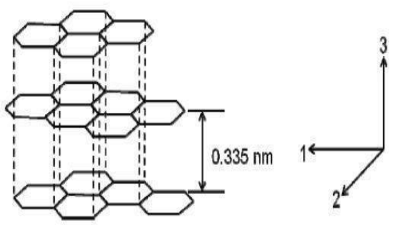
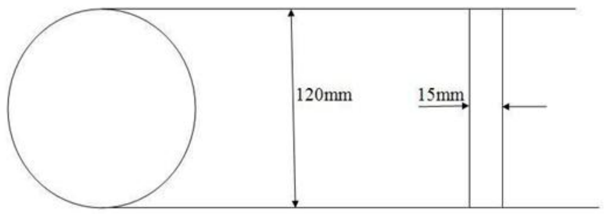


Fig : Structure of graphitic crystals and crystal directions.

Carbon fibre layer planes can be either graphitic, turbostratic, or a hybrid structure, depending on manufacturing processes. The interaction between sheets of grapheme layers exhibit weak Vander Waals forces, where the spacing between two layers is approximately 0.335 nm for a single graphitic crystal (Huang 2009). A turbostratic structure, which is the basic structure of many carbon fibres, consists of arbitrarily stacked, parallel grapheme sheets that may even be split or folded. The haphazard method of developing a turbostratic structure may increase layer spacing as much as 0.344 nm, thus, further decreasing the sum of the attraction forces between molecules, or the Vander Waals forces (Huang 2009, p. 2371).

V. PREPARATION OF A COMPONENT USING CARBON FIBER

Materials Required: Carbon Fiber (400 GSM), Scissor, Resins, and Rulers & Compass etc.
Resin Used:-LY556 (Araldite)
Hardener Used:-HY951



The dimensions of the component to be made are considered from the American Society for Testing Materials (ASTM) standards which also gives the description of the material requirement for manufacturing.

Procedure:

- Firstly the carbon fabric material is cut into required size and into required number oflayers. As the fabric material we considered is of 0.3mm thickness, we need to cut the fabric into 45 layers in order to achieve the required thickness.
- After cutting into required number of layers then the resin system is prepared. Theratio of the resin to hardener is maintained as 100:10. That is, if the resin LY556 of 100gm is taken then the hardener HY951 of 10gm must be considered.
- Later the layers which were cut before are joined one after the other by applying the resin system uniformly throughout the pieces of the layer.
- During this process ensure that there will not be any air bubbles while joining the fabric layers.
- After completion of applying the resin system, vacuum bagging process has to bedone in order to settle the resin properly and also for the removal of excess air bubbles by sucking the air out to make the finishing properly.
- This vacuum bagging process takes 4hours time to settle the entire resin system properly. The settling time may vary for different types of resins used.
- Then the formed component is to be cured for nearly for 24 hours of time at the room temperature. For any composite materials the cure cycle will be of the sametime generally though the post curing may vary for different types of composites.
- After completion of the cure cycle, the formed component is to be finished and anychanges needed to be done regarding the conventional methods (like grinding etc.,) are to be done.
- Then the component is to be cured by keeping it at a temperature of 80°C (by keepingit in an oven), which is termed as post curing process.
- The time for completion of post curing process is nearly 8 hours for the resin which we have used and may vary differently for other resin systems.

After post curing has done then the component obtained is finished neatly.

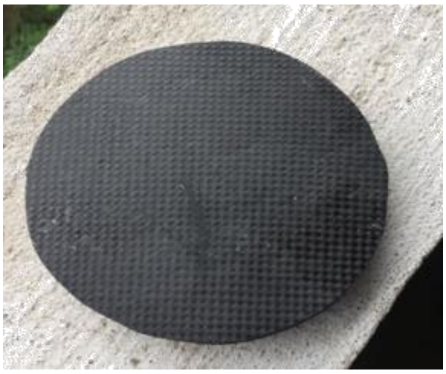


Fig : Circular plate made of Carbon Fiber

Types of Glass Fiber

As to the raw material glass used to make glass fibres or nonwovens of glass fibres, the following classification is known:

1. A-glass: With regard to its composition, it is close to window glass. In the Federal Republic of Germany it is mainly used in the manufacture of process equipment.
2. C-glass: This kind of glass shows better resistance to chemical impact.
3. E-glass: This kind of glass combines the characteristics of C-glass with very good insulation to electricity.
4. AE-glass: Alkali resistant glass.

Generally, glass consists of quartz sand, soda, sodium sulphate, potash, feldspar and a number of refining and dying additives. The characteristics, with them the classification of the glass fibres to be made, are defined by the combination of raw materials and their proportions. Textile glass fibres mostly show a circular.

- Mechanical strength: Fiberglass has a specific resistance greater than steel. So, it is used to make high-performance
- Electrical characteristics: Fiberglass is a good electrical insulator even at low thickness.
- Incombustibility: Since fiberglass is a mineral material, it is naturally incombustible. It does not propagate or support a flame. It does not emit smoke or toxic products when exposed to heat.
- Dimensional stability: Fiberglass is not sensitive to variations in temperature and hygrometry. It has a low coefficient of linear expansion.
- Compatibility with organic matrices: Fiberglass can have varying sizes and has the ability to combine with many synthetic resins and certain mineral matrices like cement.
- Non-rotting: Fiberglass does not rot and remains unaffected by the action of rodents and insects.
- Thermal conductivity: Fiberglass has low thermal conductivity making it highly useful in the building industry.

VI. CARBON FIBER VS FIBER GLASS

The vast majority of fibers used in composites are carbon fiber and fiberglass. The choice of whether to use carbon or fiberglass in your application depends on many factors.

Below is a breakdown of the most important carbon and fiberglass characteristics.

Carbon Fiber Composites:

- Dielectric permeability: This property of fiberglass makes it suitable for electromagnetic windows.
- Lightweight
  70% lighter than steel, 40% lighter than Aluminum
- High stiffness-to-weight ratio
  Also known as specific stiffness, this ratio allows materials of different mass to be compared quickly in rigidity-sensitive applications where weight is still a factor. Carbon fiber is about 3 times stiffer than steel and aluminum for a given weight.
- Low thermal expansion
  As opposed to most other materials, carbon fiber has a negative coefficient of thermal expansion. This means that it expands when the temperature lowers. The matrix will have a positive coefficient, resulting in a near neutral for the composite. This is a desirable quality for applications that have to operate in a wide range of temperatures.
- High fatigue level
  Carbon fiber composites keep their mechanical properties under dynamic loads, rather than deteriorating slowly over time.
- Corrosion resistant
  Carbon and fiberglass composites alike perform well in an acidic or otherwise chemically challenging environment. Additives in the resin can enhance this property.

ADVANTAGES OF COMPOSITES

Summary of the advantages exhibited by composite materials, which are of significant uses in aerospace industry are as follows

- High resistance to fatigue and corrosion degradation.
- High 'strength or stiffness to weight' ratio.As enumerated above, weight savings are significant ranging from 25-45% of the weight of conventional metallic designs.
- Due to greater reliability, there are fewer inspections and structural repairs.
- Directional tailoring capabilities to meet the design requirements. The fiber pattern can be laid in a manner that will tailor the structure to efficiently sustain the applied loads.
- Fiber to fiber redundant load path.
- Improved dent resistance is normally achieved. Composite panels do not sustain damage as easily as thin gage sheet metals.
- It is easier to achieve smooth aerodynamic profiles for drag reduction. Complex double- curvature parts with a smooth surface finish can be made inone manufacturing operation.
- Composites offer improved torsional stiffness. This implies high whirling speeds,reduced number of intermediate bearings and supporting structural elements. The overall part count and manufacturing & assembly costs are thus reduced.
- High resistance to impact damage.
- Close tolerances can be achieved without machining.
- Material is reduced because composite parts and structures are frequently built to shape rather than machined to the required configuration, as is common with metals.

DISADVANTAGES OF COMPOSITES

Some of the associated disadvantages of advanced composites are as follows:

a). High cost of raw materials and fabrication.
b). Composites are more brittle than wrought metals and thus are more easily damaged.
c). Transverse properties may be weak.
d). Matrix is weak, therefore, low toughness.
e). Reuse and disposal may be difficult.
f). Difficult to attach.
g). Repair introduces new problems, for the following reasons:

- Materials require refrigerated transport and storage and have limited shelf life.
- Hot curing is necessary in many cases requiring special tooling.
- Hot or cold curing takes time.

h). Analysis is difficult.
i). Matrix is subject to environmental degradation

However, proper design and material selection can circumvent many of the above disadvantages. New technology has provided a variety of reinforcing fibers and matrices those can be combined to form composites having a wide range of exceptional properties. Since the advanced composites are capable of providing structural efficiency at lower weights as compared to equivalent metallic structures, they have emerged as the primary materials for future use.

VII. APPLICATIONS OF COMPOSITES

Glass Fiber

The use of E-Glass as the reinforcement material in polymer matrix composites is extremely common. Optimal strength properties are gained when straight, continuous fibers are aligned parallel in a single direction. To promote strength in other directions, laminate structures can be constructed, with continuous fibers aligned in other directions. Such structures are used in storage tanks and the like.

Random direction mats and woven fabrics are also commonly used for the production of composite panels, surfboards and other similar devices.

Fiberglass also used in the telecommunications industry for shrouding the visual appearance of antennas, due to its RF permeability and low signal attenuation properties. It may also be used to shroud the visual appearance of other equipment where no signal permeability is required, such as equipment cabinets and steel support structures, due to the ease with which it can be molded, manufactured and painted to custom designs, to blend in with existing structures or brickwork. Other uses include sheet form made electrical insulators and other structural components commonly found in the power industries.

CARBON FIBRE COMPOSITES IN COMMERCIAL AIRCRAFT

Carbon fibre composites are making their way into modern day gas turbine engines. Typically, due to the extreme temperatures of aircraft engines, carbon fibre has been reserved for aircraft structures. Where the engine operating temperature is less than 1500 C, carbon fibre is a suitable and appropriate material (ATSB 2008).

Due to the anisotropic nature of carbon fibres, varying the orientation of the layers simulates an isotropic material. A quasi-isotropic stack is orientated in a specific sequence.

Demands for Carbon Fibre

A market report into the rapidly growing carbon fibre industry is provided by Roberts (2011). In the report, Roberts provides a forecast to 2020 and the estimated percentage of CFRP consumption for the top four countries, see figure 7. Roberts estimates the annual production of carbon fibre and CFRPs in 2020 will reach 140,000 tons, compared with production in 2011 of 46,000 tons, an increase of approximately 33%.

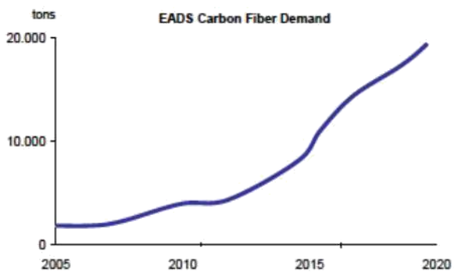


Fig : Carbon Fiber Demand

Environmental Objectives

With approximately 5.5 million jobs within the aviation sector alone and an annual passenger movement exceeding 2.2 billion, the aviation industry is tightly woven within global culture. Given the significant impact aviation has on our way of life and the natural resources required to maintain the current tempo of operations, sustainability for the future is a requirement for today. The volume of production required to fulfil next generation platforms has an equal counterbalance in managing the waste component. ACARE recognises the significance of sustainability and has devised a plan to minimise environmental impact by establishing the following targets for the year 2020 (Aviation & Environment n.d.):

1. reduce fuel consumption and CO_2 emissions by 50%
2. reduce NOx emissions by 80%
3. reduce perceived noise by 50%
4. progress in reducing the environmental impact of aviation waste

The research and development of CFRP composite materials has assisted in working toward achieving these objectives by the following methods:

- Efficient aircraft 20-25%: Increasing % of CRFP composites used.
- Efficient engines 15-20%: Carbon fibre nacelles, inlet blades, and nose spinners

VIII. ANALYSIS OF CARBON FIBER

CALCULATION OF COMPRESSIVE STRENGTH

- To calculate the compressive strength of the manufactured component, it is placed Universal Testing Machine.
- Place the test specimen between the upper and lower jaws of the UTM with thehelpof hydraulic system associated with it.
- Now gradually apply the compressive load on to the component.
- Note the value of the load in the UTM when the component breaks.
- Calculate the compressive stress by using the following formula:

Stress, (σ) = $\frac{Load(F)}{Area(A)}$

Details of specimen :

- Diameter d= 120mm
- Thickness t= 15mm

Calculation:

- Area, A=πr2

r= d/2 = 120/2= 60mm^2

Breaking Load in UTM noted, F=395KN = 395000 N

 Stress σ = F/A = 395000/11304

= 34.9MPa = 34.9 N/mm^2

 This indicates that a compressive load of 3, 95,000 N is required to break the circular disk made of carbon fiber.

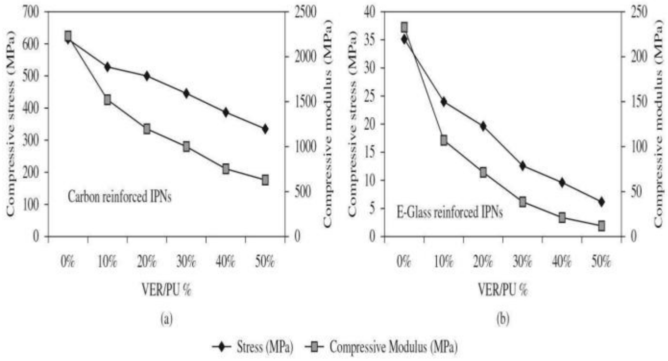
Note:

 The Ultimate compressive strength of the standard carbon fiber is 570 MPa.

 The maximum load of the UTM which is used to test is 1000KN and the load required to break the specimen was found to be 395KN, which shows the enormous strength of the material.

To achieve high sustainability in the aviation industry the ability to recycle waste is critical. Recycling airframe materials, in regards to carbon fibre composites, has a positive impact on the natural resources required to introduce the new material, thus reducing oil and chemical use that negatively impacts the environment. Identifying and investing in new technologies to develop carbon fibre from a renewable energy point of view is only half of the solution to sustainability. Using landfill, or incineration, for disposal of carbon fibre reinforce plastic (CFRP) is not an appropriate long-term solution.

The compressive stress and compressive modulus of VER/PU IPN Glass fibre and VER/PU IPN Carbon fibre composites are shown in Figures a, b. From the figures it is observed that the neat VER Glass fibre composite and carbon fibre composite has a compressive stress of 613 MPa and 35 MPa respectively. On increasing the PU content the compressive stress of both carbon fibre and glass fibre reinforced composite is found decrease by 47%, 23%, 55%, 33%, and 50% for 10%, 20%, 30%, 40%, and 50% of VER/PU Glass fibre composite, and 15%, 7%, 11%, 16%, and 15% for 10%, 20%, 30%, 40%, and 50% of VER/PU Carbon fibre composite. A similar decreasing trend in compressive modulus is observed with VER/PU Carbon fibre and glass fibre composite. The reason for this decreasing trend in compressive stress and modulus may be attributed to ether linkages present in PU Pre polymer which offers flexibility to the IPN formulation



IX. RESULTS AND DISCUSSION

S.no		CARBON FIBER	GLASS FIBER
1	Tensile strength	The tensile strength of carbon fiber is 4127 Mpa.	The tensile strength of glass fiber is 3450 Mpa.
2	Density	The density of a carbon fiber is 1.58 gm/cc.	The density of a glass fiber is 2.66 gm/cc.
3	Strength -to-weight ratio	The specific strength of a carbon fiber is 2457 KN.m/kg.	The specific strength of a glass fiber is 1307 KN.m/kg.
4	Young's modulus	The modulus of elasticity of a carbon fiber is 125-181 Gpa.	The modulus of elasticity of a glass fiber is 30-40 Gpa.
5	Electrical conductivity	Cabon fiber does conduct electricity.	Fiber glass composites are insulators, which means they do not respond to an electric field and resist the flow of electric charge.
6	Thermal expansion	The thermal expansion of a carbon fiber is 2 or less.	The thermal expansion of a glass fiber is 7-8.
7	Corrosion resistant	Carbon fiber perform well in an acidic or chemically challenging environment. Additives in the resin can enhance this property.	Glass fiber perform well in an acidic or chemically challenging environment. Additives in the resin can enhance this property.
8	Radiolucent	Carbonfiber composites are radiolucent, which can allow radiation to pass through it partially.	Glassfiber composites are very radiolucent, which means they allow radiation to pass through it freely. This makes glassfiber rods very capable antennas.
9	Cost effective	The cost effective of a carbon fiber is more expensive.	The cost effective of a glass fiber is less expensive.

FUTURE SCOPE

In the machining of CFRP and GFRP composite materials with conventional machining methods (turning, milling, drilling, etc.), increasing feed rate resulted in higher compressive forces; and higher hole surface quality could be obtained as a result of increased cutting speed and reduced feed rate. Some other researchers, on the other hand, obtained the lowest delaminating factor with low cutting force and low feed rate. In general, average surface roughness was found to be reduced with use of high cutting speed and low feed rate.

Demand for carbon fibre is increasing, globally, and is not only contained within the aviation sector. Such high demand gives concern for eco-friendly manufacturing and improved recycling processes. Lignin development is currently the key to future production of carbon fibre from an environmentally sustainable position. Greater investment and research is paramount to maximise this technology for the future.

From this report it is clear that the composite materials (especially CARBON FIBER) have high mechanical properties such as Tensile, Compressive stress and Impact strength when compared to other non metals (Glass Fiber) as well as most commonly used metals in aviation sector. And it is the most recommended material for combat UAVs for long endurance and several other benefit-able factors.

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