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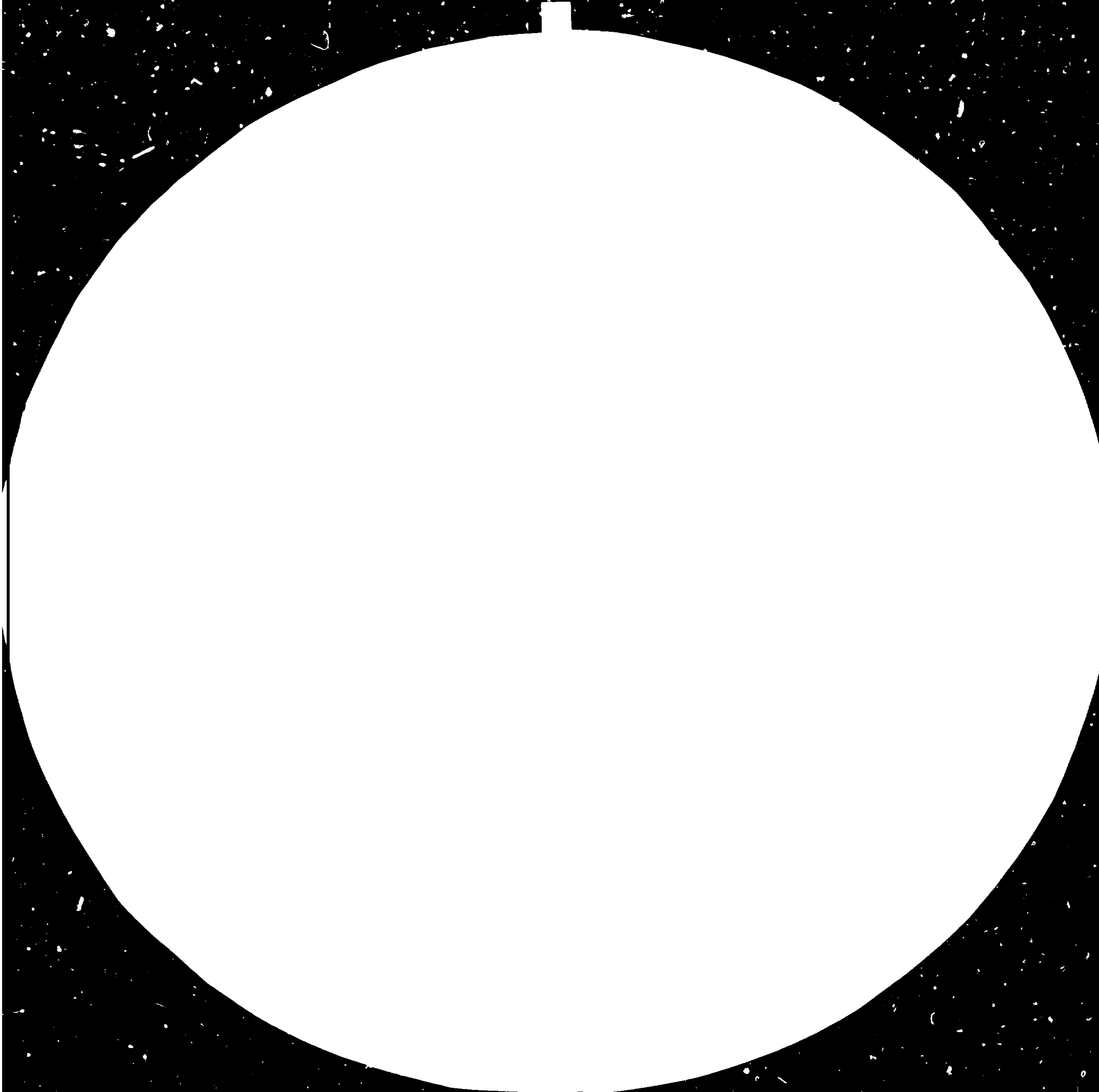

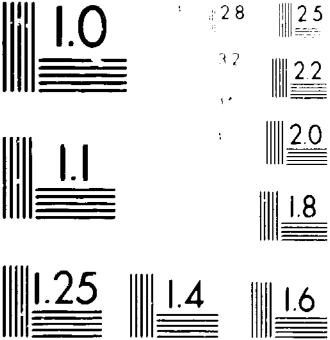

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INDUSTRIAL AND FURTHER APPLICATIONS OF CARBON FIBRES -
SPECIAL EXPERIENCE IN EUROPE*

by

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Unlike the United States and the Western Pacific countries, the use of carbon fibre in Europe for sporting goods applications has been rather small in volume terms. This is probably due to large scale, low unit price, production outside Europe resulting in the import of inexpensive basic fishing rod blanks, racquet frames and golf shafts. Nevertheless, European manufacturers compete in all the prominent application areas and have pioneered some new ideas as well.

More detailed attention has been given to the use of carbon in composites in the transport industry where many of the Formula I racing cars, endurance cars and economy cars have incorporated these materials with great success.

Highly sophisticated design and fabrication approaches have resulted in the production of torque tubes and drive shafts which are under practical road and aerospace evaluation today and which are confidently expected to be in series production for some applications in the near future.

A wide range of small to medium size components for general industrial applications are produced by injection moulding of carbon reinforced thermoplastics. Most use is in the area where great stiffness is required, coupled with low weight, especially where rapid acceleration and deceleration is essential, e.g. in textile weaving equipment.

A potential major volume development is in the field of robot construction where again high specific stiffness is a frequent requirement. Here, as in many other cases, the use of carbon in a honeycomb sandwich to improve this property still further is a very important consideration.

The majority of these non aerospace applications are accomplished by manufacturing from resin/fibre prepreg in both unidirectional or woven fabric form. The principal exceptions to this being the filament wound tubes and the injection mouldings. Very little wet resin hand lay-up impregnation is used because it is time consuming, less accurate in fibre/resin ratio and is generally less satisfactory from the operator's viewpoint.

For the majority of non aerospace uses the main requirements for prepreg systems are:-

a) cure at 120°C
b) long out-life at ambient temperature
c) easy handling in use
d) good mechanical properties up to 100°C maximum
e) excellent toughness
f) processable by press, vac-bag, autoclave, oven/ shrink-wrap tape

Woven prepregs are available in a variety of weave styles for different handling and draping properties in widths up to approximately 1.25 metres.

Unidirectional prepreg is produced as a standard of 300mm width although wider and narrower versions are available. Indeed, very narrow tapes or even individual prepregged tows are becoming increasingly popular for winding applications where they replace liquid resin.

Amongst the many applications in Europe the following are important. either in terms of volume or interest.

SLIDES (1), (2) <u>FISHING RODS</u>

A great variety of types are manufactured from all-carbon or carbon/glass hybrids. The principal advantage is reduction in weight for equivalent stiffness.

SLIDE (3) <u>TABLE TENNIS BATS</u>

Small volume application. The use of carbon fibre skins on a foam core gives rise to great stiffness at low weight resulting in less arm fatigue during long matches and rallies. The rubber faces still control the ball contact properties.

SLIDE (4) <u>GOLF SHAFTS</u>

Still a significant user of carbon prepreg. More recent developments include the manufacture of carbon reinforced heads as well.

SLIDE (5) <u>GUITARS</u>

Carbon fibre faced guitars giving very high quality sound at relatively low cost. Musical instrument manufacture still needs design optimisation to fully utilise carbon, but the prospects look good in some areas.

SLIDE (6) VIOLIN BOWS

Use of carbon prepreg has resulted in substantial reduction in weight for the same stiffness and still yields excellent bowing characteristics. Significant amounts of prepreg have been used already.

SLIDE (7) BICYCLE FRAMES

Lightweight racing cycle with carbon fibre main frame tubes weighing only 8.5kg. The carbon tubes are bonded into the aluminium alloy castings. These bicycles are outstanding for racing and are now becoming available to the general public. It is expected that as the price reduces carbon fibre will be used in general touring cycles as well because the weight saving is about the same as the current touring loads carried.

SLIDES (8), (9) SKI POLES

Low weight and correct stiffness make the ski pole an ideal and very successful application for carbon. Many tons of fibre have been sold for this application. Fabrication here is usually by wet winding.

SLIDE (10) DOWNHILL SKIS

A number of ski manufacturers have used carbon fibre in the production of skis - usually as a laminate on top of the main wood, foam or honeycomb core.

The actual advantage in this application has been questioned but many such skis have been sold.

SLIDE (11) TENNIS RACQUETS

Many types of racquets for tennis, badminton and squash amongst others have been designed and produced using carbon fibre reinforcement.

The techniques used vary very widely from the incorporation of a simple CFRP laminate into standard wood construction to resin injection into carbon fibre braid supported on low melting metal alloy formers.

As an application there are real advantages to be gained in the use of carbon, although care must be taken not to make racquets too stiff, resulting ultimately in elbow or wrist injury to the user.

(12), (13) RACING CARS

The use of composites in racing cars has been very successful. They not only result in lowering the body weight of the cars but they have proved very energy absorbent in many crash situations - particularly when used in the form of honeycomb sandwich. The reinforcements used may be carbon, Kevlar or glass in any combination. The example shown is a carbon/Kevlar hybrid fabric - non metallic honeycomb sandwich, monocoque produced in France.

Most FORMULA 1 cars now have composites as part of their structure and in the typical race shown in the U.K. all of the entrants could be considered as of composite construction.

(14), (15) ENDURANCE CARS

LOLA air intake scoop, main tray, frame and body shell manufactured from glass, Kevlar, carbon and non metallic honeycomb to give very low weight and high stiffness for good aerodynamic flutter resistance.

SLIDE (16) ECONOMY CARS

FORD economy car pictured during a recent competition in the U.K. The car makes extensive use of carbon/Kevlar/Nomex honeycomb sandwich in its construction. On this occasion it recorded a figure of 905 km/litre but further improvements are confidently predicted.

SLIDE (17) SAILPLANES

Whilst this is an aerospace application in its true sense, most sailplanes and gliders are used for sporting purposes. It is common practice to use some carbon fibre selectively to stiffen the otherwise predominantly glass structure. In this case the Slingsby Kestrel has carbon fibre spar caps.

SLIDE (18) MARINE USE

At present the majority of composites used in boat hulls, masts, superstructure, sail boards, surf boards, water skis etc. are manufactured from glass fibre and glass/honeycomb/foam sandwich.

Many specials have been produced incorporating carbon fibre particularly into masts, keels and rudders but have seldom been specially designed for such materials. New attempts with more attention to design are being made but their cost effectiveness is open to question at present.

SLIDE (19) INJECTION MOULDED PARTS

Using thermoplastic compounds containing up to 30-40% short length carbon fibre reinforcement a wide range of parts can be made by injection moulding including those of very complex shape.

Illustrated are a number of parts produced from carbon reinforced nylon including:- fishing rod gear, textile machinery parts, impeller blades, brackets, wheels and even a cigarette filter tip dispenser. The potential list is endless.

SLIDE (20), (21) DRIVE SHAFTS

Carbon fibre and hybrid drive shafts, torque tubes and support struts are often manufactured by wet winding techniques, but also increasingly one of the various types of prepreg tape.

The fibre reinforced plastic tube is not only much lighter than its metal counterpart, but it can be designed to be completely vibration free and usually eliminates the expensive intermediate universal joint used in long metal shafts.

Examples shown illustrate propeller shafts designed for automobiles and power transmission shafts for the Learfan 2100.

Although the number of uses of carbon fibre in sporting goods will increase, it is not expected that growth will be very significant in the future either in Europe or Worldwide. SLIDE (22).

However, the industrial uses of carbon fibre will go through a period of steady growth from a small base during the next 5-10 years before a rapid expansion due to mass production of parts which have been undergoing proving trials. Much of this expansion will be in the transport areas where the cost of energy will become more important again in the 1990's.