

6. MATRICES

6.1 Function of Matrix

- A. Bind the fibers together to become a fiber tow.
- B. Separate the individual fibers to promote the wetting capability.
- C. Protect the fibers from rubbing one another and being damaged through contact and friction.
- D. Ductile matrix can help to slow down the damage process of the brittle fibers.
- E. Matrices serve as a load transferring medium among fibers.

6.2 Ideal Matrix

The ideal material for which a matrix is derived should be, initially, a low-viscosity liquid that can be converted readily to a tough, durable solid, adequately bonded to the reinforcing fibers.

6.3 Polymer Matrices

A. Polymers have low density, poor mechanical properties, low thermal stability, moderate resistance to environmental degradation and good chemical resistance. They can be easily fabricated and joined.

B. Polymer materials can be classified into two categories: amorphous type and partially crystalline type. The amorphous polymer can be either linear (molecular entanglement) or cross-linked, while partially crystalline polymers have high degrees of molecular order and alignment. The inability of attain a full crystallinity (depending on the type of polymer, molecular weight, and crystallization temperature) in a polymer is mainly due to the long chain structure of polymer. Some twisted and entangled segments of chain that get trapped between crystalline regions never undergo the conformational reorganization necessary to achieve a crystalline state.

C. Depending on their responses to elevated temperature, amorphous polymers can be divided into thermosetting and thermoplastic types. Thermosetting polymers such as epoxy, polyester, BMI, phenolic, polyurethane and polyimide are formed of many monomers. The process of joining monomers together to become a three-dimensional cross-linking network is called polymerization, cross-linking or curing. This process makes sliding of molecules past one another difficult and results in higher strength and higher rigidity polymers as opposed to monomers.

D. The processing for thermosetting polymers can be of multiple-stage to achieve ideal properties and processing efficiency. An important treatment, so-called post-curing process is often given to minimize any further cure and change in properties during service and to increase operating temperature.

E. Once thermosetting polymers are formed, they don't soften or melt on heating. Around the glass transition temperature T_g , the molecular order of amorphous polymers will vanish. By further increasing the temperature, thermosetting polymers can be decomposed or pyrolyzed.

F. Some commonly used thermosetting polymers can be either low-grade polyester or advanced-grade epoxy. An example of the former is polyester which is made of polyester resin, MEKP initiator (0.5%-3% weight), and accelerator/catalyst such as cobalt

nephthenate (0.05%-0.5% weight). Advanced-grade thermosetting polymers such as epoxy consist of epoxy resin and curing agent with a fixed ratio (e.g. 2:1 in weight).

G. Once resin and initiator/curing agent are blended together, polymerization starts to take place. The time the mixture (i.e. the matrix) remains liquid enough for mixing with fibers is called the pot life. Once the matrix and fibers are mixed together to become a composite, the polymerization still continues. In order to slow down the polymerization process, the composite should be kept refrigerated. The period of time it can be stored without changing too much the viscosity is called the shelf life.

H. Thermosetting polymers are of low toughness and sensitive to both moisture and UV light attacks. Their properties degrade as temperature increases. In addition, they undergo thermal contraction (i.e. decreases of thermal vibration and free space) and form thermal residual stress after curing.

I. In addition to cross-linking, amorphous polymers can be of linear type. Linear polymers such as polyethylene, polystyrene, PMMA, nylon, polypropylene and polycarbonate are called thermoplastics since they can be softened and melt on heating. The process from liquid to solid is instead called consolidation and the melting temperature T_m , instead of T_g , plays an important role in thermoplastic properties. As a consequence, only single-stage process is required in processing and thermoplastics can be recycled.

J. Since thermoplastic polymers are solid materials in room temperature, they can be stored anywhere. And it takes higher temperature and pressure in fabrication than the thermosetting counterpart. In order to improve the wettability between solid fibers and solid thermoplastic matrix, the latter is usually fabricated into fibers to be entangled with reinforcing fibers or into thin sheets to be layered with fabrics. A more advanced but costly process is to coat the reinforcing fibers with thermoplastic powder.

K. Examples of thermoplastic polymers are low-grade ones such as polysulphones, polyamide, polypropylene, polycarbonate and nylon and advanced-grade ones like PEEK and PPS. Generally speaking, thermoplastic polymers are tougher than thermosetting polymers though they also suffer inadequate mechanical properties at elevated temperature. Although they are susceptible to solvent, they are almost non-water-absorbing materials.

6.4 **Metal** Matrices

A. Metals have medium to high density, useful mechanical properties, high toughness and good thermal stability. They are usually ductile and experience large plastic deformation due to dislocation. They can be made corrosion resistance by alloying and can be shaped and joined.

B. Metals are crystalline except metallic glasses.

C. There are three major types of defect in metals: line defect such as dislocation, surface defect on grain boundaries and volume defect such as inclusion. Strain hardening can impede dislocation movement in the metals and result in high yield stress,

6.5 **Ceramic** Matrices

A. Ceramics have low density and are very rigid, strong and extremely brittle. They resist to most ordinary forms of environmental attack but are difficult to be formed and shaped.

B. Ceramics are metallic oxides. Except glass, they are crystalline materials. They are brittle and have low fracture toughness. However, they have high modulus, high temperature and corrosion resistances.

C. Examples of ceramic matrices are SiC, Si₃N₄, TiB₂ and oxide ceramics such as Al₂O₃ and ZrO₂. Other examples are glass, oxy-nitride glass and glass-ceramics (95-98% crystalline and 2-5% glass such as Corning ware).