STRUCTURE OF COMPOSITES

Structure of a composite material determines its properties to a significant extent.

Structure factors affecting properties of composites are as follows:

- **Bonding strength** on the interface between the dispersed phase and matrix;
- **Shape of the dispersed phase inclusions** (particles, flakes, fibers, laminates);
- **Orientation of the dispersed phase inclusions** (random or preferred).

Interfacial bonding

Good bonding (adhesion) between matrix phase and dispersed phase provides transfer of load, applied to the material to the dispersed phase via the interface. Adhesion is necessary for achieving high level of mechanical properties of the composite.

There are three forms of interface between the two phases:

1. Direct bonding with no intermediate layer. In this case adhesion (”wetting”) is provided by either covalent bonding or van der Waals force.
2. Intermediate layer in form of solid solution of the matrix and dispersed phases constituents.
3. Intermediate layer (interphase) in form of a third bonding phase (adhesive).

Shape and orientation of dispersed phase

Importance of these structure parameters is confirmed by the fact, that one of the systems of Classification of composites is based on them.

- **Particulate Composites**
- **Fibrous Composites**
- **Laminate Composites**

Particulate Composites

Particulate Composites consist of a matrix reinforced with a dispersed phase in form of particles.
Effect of the dispersed particles on the composite properties depends on the particles dimensions.

Very small particles (less than 0.25 micron in diameter) finely distributed in the matrix impede movement of dislocations and deformation of the material. Suchstrengthening effect is similar to the precipitation hardening. In contrast to the precipitation hardening, which disappears at elevated temperatures when the precipitated particles dissolve in the matrix, dispersed phase of particulate composites (ceramic particles) is usually stable at high temperatures, so the strengthening effect is retained. Many of composite materials are designed to work in high temperature applications.
Large dispersed phase particles have low strengthening effect but they are capable to share load applied to the material, resulting in increase of stiffness and decrease of ductility.
Hard particles dispersed in a softer matrix increase wear and abrasion resistance.

Soft dispersed particles in a harder matrix improve machinability (lead particles in steel or copper matrix) and reduce coefficient of friction (tin in aluminum matrix or lead in copper matrix).

Composites with high electrical conductivity matrices (copper, silver) and with refractory dispersed phase (tungsten, molybdenum) work in high temperature electrical applications.

When dispersed phase of these materials consists of two-dimensional flat platelets (flakes) which are laid parallel to each other, material exhibits **anisotropy** (dependence of the properties on the axis or plane along which they were measured). In the case of flakes oriented parallel to a particular plane, material demonstrates equal properties in all directions parallel to the plane and different properties in the direction normal to the plane.

Fibrous Composites

Dispersed phase in form of fibers (Fibrous Composites) improves strength, stiffness and Fracture Toughness of the material, impeding crack growth in the directions normal to the fiber.
Effect of the strength increase becomes much more significant when the fibers are arranged in a particular direction (preferred orientation) and a stress is applied along the same direction.

The strengthening effect is higher in long-fiber (continuous-fiber) reinforced composites than in short-fiber (discontinuous-fiber) reinforced composites.
Short-fiber reinforced composites, consisting of a matrix reinforced with a dispersed phase in form discontinuous fibers (length < 100*diameter), has a limited ability to share load.

Load, applied to a long-fiber reinforced composite, is carried mostly by the dispersed phase - fibers. Matrix in such materials serves only as a binder of the fibers keeping them in a desired shape and protecting them from mechanical or chemical damages.

Laminate Composites

Laminate composites consist of layers with different anisotropic orientations or of a matrix reinforced with a dispersed phase in form of sheets.
When a fiber reinforced composite consists of several layers with different fiber orientations, it is called multilayer (angle-ply) composite.

Laminate composites provide increased mechanical strength in two directions and only in one direction, perpendicular to the preferred orientations of the fibers or sheet, mechanical properties of the material are low.

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