Directional Solidification -

There are some applications for which a small equiaxed grain structure in the casting is not desired. castings used for blades and vanes in turbine engines are an example (fig 20). These castings are often made of cobalt or nickel superalloys by investment casting. are airfoils that provide for a smooth flow of the gases

In ~~conventially~~ conventionally cast parts, an equiaxed grain structure is produced. However, blades and vanes for turbine & jet engines fail along transverse grain boundaries.

Better creep and fracture resistance are obtained using the directionally solidified (DS) technique.

In the DS process, the mold is heated from one end and cooled from the other, producing a columnar microstructure with all of the grain boundaries running in the longitudinal direction of the part. No grain boundaries are present in the transverse direction (fig 20b).

Still better properties are obtained by using a single crystal (SC) technique.

Solidification of columnar grains again begins at a cold surface; however, due to the helical connections, only one columnar grain is able to grow to the main body of the casting (fig 20c).

The single crystal casting has no grain boundaries at all and has its crystallographic planes and directions in an optimum orientation; in fig 21, best resistance to fatigue in a nickel alloy is obtained for the [100] orientation.

Solidification of single crystals is also necessary in producing silicon semiconductor wafers, from which electronic devices such as integrated circuits are built.

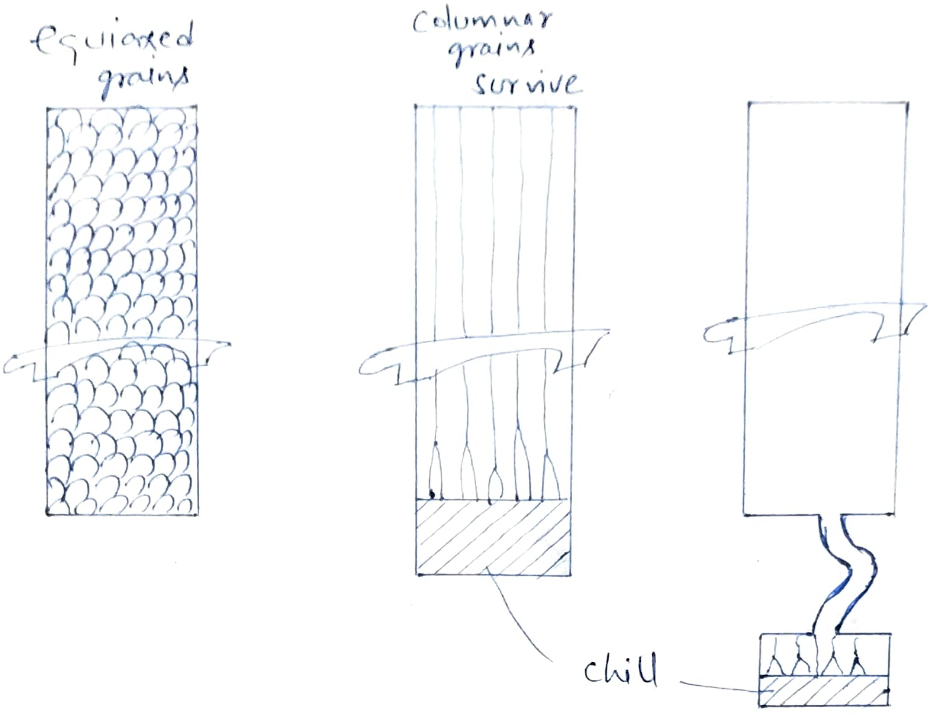

Fig 20: Controlling grain structure in turbine blades.
(a) conventional equiaxed grains
(b) directionally solidified grains, and
(c) single crystal

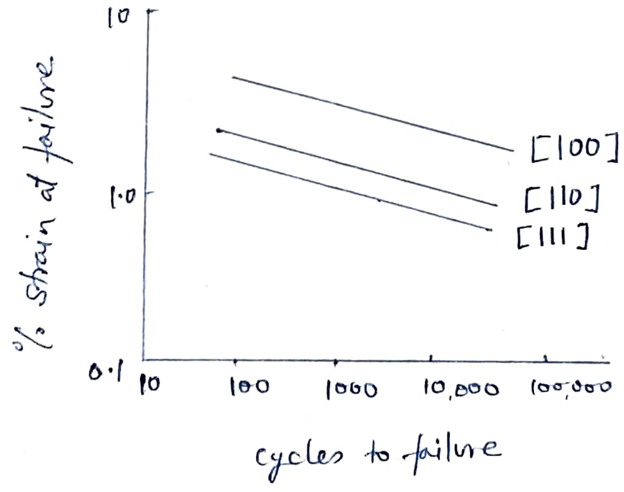

Fig 21: Effect of single crystal orientation on the fatigue properties of a nickel alloy. The percent strain is proportional to the applied stress.

During solidification, the complete casting parts do not cool at the same rate. Due to varying sections & different rates of heat transfer to mould walls, some parts tend to solidify more quickly than others. This sort of uneven solidification causes voids & cavities due to shrinkage. Thus, for the castings to be sound, free from voids & shrinkage defects, the solidification should be such that it starts at the thinner section, continues progressively to the thick sections, simultaneously feeding the shrinkage & towards the riser, the portion to be solidified last. This type of solidification is known as Directional Solidification.

Directional solidification is a result of casting design, location of gates/risers and the use of chills & other methods of controlling the cooling process. Hence, we can design a casting to control the cooling & achieve directional solidification.

Advantage of Directional Solidification:

(i) Solidification of the metal will be uniform, thus the cooling stresses induced are minimum.
(ii) It produces a sound casting, free from voids & shrinkage defects.
(iii) Since in directional solidification riser is the last part to solidify all the impurities given out by the first solidifying metal will be collected in the riser.
(iv) Even complex shaped casting can be cast sound if the casting design facilitates directional solidification.
(v) It produces uniform (homogeneous) microstructure. Thus giving desirable properties.

Methods of Achieving Directional Solidification:

(i) Proper design of gating & risering system.
(ii) Use of chills
(iii) Use of insulating & exothermic materials
(iv) Use of favourable pouring rates & temperature.