11.5 Casting Techniques for Single-crystal Components

This section describes the techniques used to cast single-crystal components, such as gas turbine blades which generally are made of nickel-based superalloys, and used in the hot stages of the engine.

Conventional Casting of Turbine Blades. In the *conventional-casting process*, the molten metal is poured into a ceramic mold, and begins to solidify at the mold walls. The grain structure developed is polycrystalline, similar to that shown in

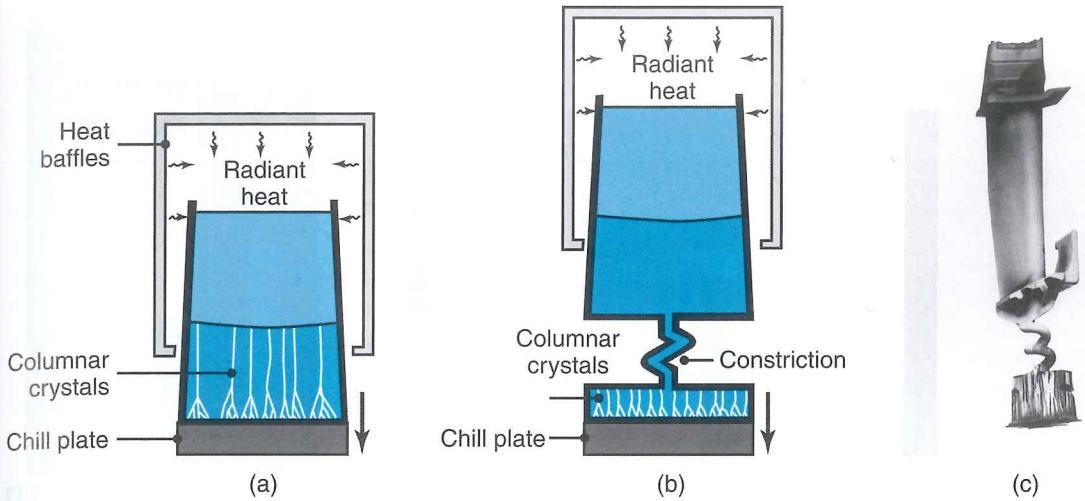

FIGURE 11.27 Methods of casting turbine blades: (a) directional solidification; (b) method to produce a single-crystal blade; and (c) a single-crystal blade with the constriction portion still attached. (See also Fig. 1.1) *Source:* (a) and (b) After B.H. Kear, (c) Courtesy of ASM International.

Fig. 10.2c. However, the presence of grain boundaries makes this structure susceptible to creep and cracking along the boundaries, under the centrifugal forces and elevated temperatures commonly encountered in an operating gas turbine.

Directionally Solidified Blades. The *directional-solidification process* (Fig. 11.27a) was first developed in 1960. The ceramic mold, supported by a water-cooled chill plate, is preheated by radiant heating; after the metal is poured into the mold, the chill-plate assembly is lowered slowly. Crystals begin to grow at the chill-plate surface and on upward, like the *columnar grains* shown in Fig. 10.3. The blade is solidified directionally, with longitudinal but no transverse grain boundaries. The blade is thus stronger in the direction of centrifugal forces developed in the gas turbine.

Single-crystal Blades. In *crystal growing*, developed in 1967, the mold has a constriction in the shape of a corkscrew or helix (Figs. 11.27b and c), with a cross-section so small that it allows only one crystal to fit through. The mechanism of crystal growth is such that only the most favorably oriented crystals are able to grow through the helix (a situation similar to that shown in Fig. 10.3), because all others are intercepted by the walls of the helical passage.

As the assembly is slowly lowered, a single crystal grows upward through the constriction and begins to grow in the mold; strict control of the rate of movement is essential. Although single-crystal blades are more expensive than other types, the absence of grain boundaries makes them resistant to creep and thermal shock, hence they have a longer and more reliable service life.