WHAT IS CLAIMED IS:

1. A casting ingot furnace for directional solidification growth of crystalline silicon, comprising:

a furnace body comprising an upper furnace body and a lower furnace body engaged with the upper furnace body, wherein the lower furnace body defines a shaft hole at a bottom of the lower furnace body;

a supporter comprising a rotating shaft and a heat exchanger fixed to an end of the rotating shaft, wherein the heat exchanger is provided with a crucible, the other end of the rotating shaft extends through the shaft hole to be coupled with a driving device disposed outside the lower furnace body, wherein the driving device is configured to drive the rotating shaft to rotate, whereby enabling the crucible to rotate, and wherein the rotating shaft defines a coolant circulating passage for introducing and circulating coolant to achieve circulating cooling of the rotating shaft;

a protective plate disposed on an outer side wall of the crucible;

a thermal insulation cage comprising a top thermal insulation plate, a side thermal insulation plate, and a bottom thermal insulation plate, wherein the rotating shaft rotatably extends through the bottom thermal insulation plate; and

a heater disposed in the thermal insulation cage.

2. The casting ingot furnace of claim 1, wherein a coolant supply system is further disposed outside the lower furnace body, and the coolant supply system is in communication with the coolant circulating passage.

3. The casting ingot furnace of claim 1, further comprising a sealing device for sealing a gap between the rotating shaft and an inner wall of the shaft hole.

4. The casting ingot furnace of claim 3, wherein the sealing device comprises a magnetic fluid sealing device, the magnetic fluid sealing device is sleeved on the rotating shaft and fixed to the bottom of the lower furnace body.

5. The casting ingot furnace of claim 1, wherein the protective plate comprises a side protective plate and a bottom protective plate, wherein the bottom protective plate is sandwiched between a bottom of the crucible and the heat exchanger, and the bottom protective plate is provided with non-slip texture on a surface of the bottom protective plate.

6. The casting ingot furnace of claim 1, further comprising a plurality of heat dissipation blocks, wherein the plurality of heat dissipation blocks are disposed adjacent to the heat exchanger, and each of the plurality of heat dissipation blocks is fixed to the bottom of the lower furnace body via a support rod.

7. The casting ingot furnace of claim 1, wherein the rotating shaft is provided with a connecting plate at the end close to the heat exchanger, the connecting plate is provided with a plurality of connecting rods, and the plurality of connecting rods are fixedly connected with the heat exchanger.

8. The casting ingot furnace of any of claims 1 to 7, wherein the heater comprises a top heater and a side heater, wherein the top heater is disposed above the crucible, the side heater is disposed outside the outer side wall of the crucible, and the side heater is free of contact with the crucible during a rotation of the crucible, and wherein the side heater has a cross section in a shape of circular, square, or polygonal.

9. The casting ingot furnace of any of claims 1 to 7, wherein the top thermal insulation plate, the side thermal insulation plate, and the bottom thermal insulation plate corporate to define a sealed chamber, and wherein at least one of the top thermal insulation plate, the side thermal insulation plate, or the bottom thermal insulation plate comprises at least one thermal insulation layer.

10. An application of the casting ingot furnace of any of claims 1 to 9 in preparing single crystal silicon, polycrystalline silicon, or similar single crystal silicon.