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Basic study on weldability and machinability of structural materials for ITER toroidal field coils

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The toroidal field (TF) coils for ITER are very large components. The main structural component of the coil is the coil case, which requires a massive complex geometry with high fabrication accuracy to attain the required magnetic performance for plasma operations. To provide high mechanical strength and toughness at cryogenic temperature, the structural components employ high-strength austenite stainless steels that have been specially developed for ITER. However, one of the main drawbacks of using those materials is the difficulty of manufacturing capabilities.

A manufacturing study has been conducted to examine welding and machining capabilities for JJ1 and ST-SS316LN, to be employed for TF coil structural components. Both materials include a high nitrogen content up to around 0.2%, which makes welding and machining difficult compared with conventional stainless steels.

Electron beam welding conditions were studied for the JJ1 material. The applicable welding condition was found for a bead length of up to about 300 mm in the case of 40mm thick plates. No optimal condition was found for plates thicker than 40 mm. An additional experimental study was also conducted to explore suitable welding conditions for different welding positions and directions. It was found that the appearance of defects depends on the welding positions and directions. A wider range of welding conditions was found for cases in the vertical upward direction, as opposed to those in the vertical downward and horizontal directions. Based on those results, a verification test up to 900 mm in length was conducted. The test results showed that vertical upward EB welding should be used for the coil case wherever possible. With respect to TIG welding, an average deposition rate as high as 26 g/min (i.e. the filler wire supplying speed of 3,000 mm/min) was achieved.

A series of tests have been conducted to examine machinability of JJ1 and ST-SS316LN. Various types of milling tools, including face milling, shoulder cutter, ball end-mill, and T/A end mill, were examined. In the milling tests, without considering tool durability, high-speed cutting at a rate of more than 100 m/min was possible. However, in practical application, cutting speed is to be lowered to extend tool life. At a cutting speed of 40 m/min, a tool life of more than 2 hours (in a traveling distance up to 9 m) was attained. The amount of cutter wear after 30 minutes of operation, at a cutting speed of 40 m/min, was found to be around 0.1 mm, which is still within an acceptable range.