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Full scale electrical insulation coating development

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Abstract

A de-mountable mechanical system has been designed by ITER-IT for the attachment and the remote handling of the blanket modules. The modules are attached to the supporting structure by bolting using four flexible radial supports (cartridges) which are electrically insulated from the vacuum vessel to avoid high-value circulating currents. The hydraulic coaxial connectors also electrically connect the blanket to the module and straps are used to provide an electrical path for halo currents. Coating the contact surfaces with alumina provides the required electrical insulation. The objective of this work was to test the performance of the electrical insulation coatings specified for the ITER blanket attachment design. The testing campaign required the manufacture of mock-ups and the application of alumina coating by plasma spray technique. The flexible attachment system was mechanically tested with a 500 kN push/pull load for 1000 cycles. Another assembly was thermally cycled between 150 and 300 °C for 1000 times in inert gas atmosphere and then mechanically cycled. The activity included mechanical testing of two pairs of wedged coated keys under an impact load of 500 kN applied 1000 times. No failures and damages occurred on the alumina coatings, which preserved good insulating and mechanical properties confirming suitability for the ITER blanket system.

Keywords: Blanket modules; Alumina coatings; Plasma spray technique

1. Introduction

The objective of this activity was to test the performance of the electrical insulation coatings specifically for the de-mountable mechanical system for the attachment and the remote handling of the international thermonuclear experimental reactor (ITER) blanket modules. The activity required the manufacture of the mock-ups, the application of alumina coating by atmospheric plasma spray (APS) technique and the following testing campaign consisted in mechanical and thermal testing of the mock-ups for the conditions applicable in ITER.

The activity included also a mechanical test of two pairs wedged keys, to verify the behaviour of the alumina coating under impact load cycling.

2. Mock-ups description

The alumina coatings were applied on the cartridge and on the collar of the flexible attachment system and on the mechanical keys.

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2.1. Alumina coating

The use of plasma spray deposition technique to produce ceramic coatings operating as electrical insulators had already been studied and developed by ENEA in collaboration with the company "Flametal" in a previous contract [1]. The selected coating for the present application was pure alumina (Al_2O_3) with a thickness of 0.3 mm. The coating characteristics and APS system powder parameters are reported in Table 1.

2.2. Flexible attachment system

The assembly consisted in an Inconel stud bolt screwed in an AISI 316L base and closed by a special nut with the interposition of a Ti-alloy cartridge and a Cu-alloy collar (Fig. 1). Two alumina coatings were applied on the lower surfaces of the cartridge and on the lower surface of the collar (Fig. 2).

Four bolts were manufactured with Inconel 718 and then subjected to a solution anneal, followed by a double stage age to provide a good combination of notch rupture strength and ductility with sufficient tensile strength of the material. The Titanium alloy used for the cartridges was the Ti–6Al–4V while the material selected for the collar was CuAl11Fe4Ni5.

The special nut, manufactured by Superbolt, chosen to tighten the assembly and preload the bolt up to 650 kN, has a ring of smaller bolts and a washer. The main thread serves to position the tensioner on the bolt against the hardened washer while tensioning is accomplished by torquing the jack-bolts that encircle the main thread.

Table 1
Alumina coating characteristics and system powder parameters

Alumina coating		
Al_2O_3	99%	
Other oxides	1%	
Grain size	5–25 μm	
Porosity	2–5%	
Bond: NiAl	95%Ni–5%Al	
	NiAl	Al_2O_3
System powder parameters		
Carrier gas	Ar/H_2	Ar/H_2
Spray rate	55 g/min	48 g/min
Spray distance	140 mm	110 mm

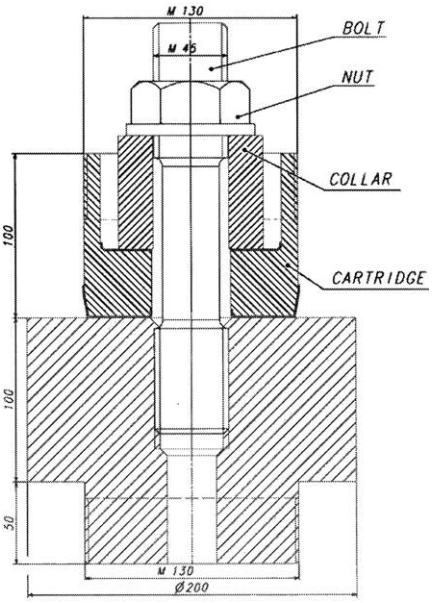

Fig. 1. Flexible attachment system drawing.

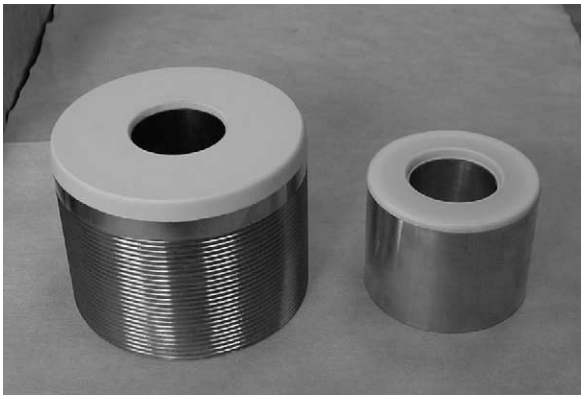

Fig. 2. Insulated cartridge and collar.

2.3. Mechanical keys

The mechanical key assembly consisted in a set of two wedged keys screwed on a base plate, a key profile and a load block. The alumina coating was applied on the key surface interfaced to the base plate while the opposite inclined surface was