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Notes from a Meeting with Dunlop to discuss the capability of Carbon-Carbon Composites as Control Rods in a Very High Temperature Reactor

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Notes from a Meeting with Dunlop to discuss the capability of Carbon-Carbon Composites as Control Rods in a Very High Temperature Reactor

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Summary

This report presents the results of a meeting with Dunlop Aerospace, a specified carbon-carbon (C/C) manufacturer. The objective of the meeting was to discuss the possibility of Dunlop Aerospace acting as a potential supplier of C/C composites for components of High Temperature Reactor (HTR) control rods. The results of the discussions are presented within this document.

The meeting took place as part of the HTR-M and HTR-M1 projects on “European Project for the development of HTR Technology – Materials for the HTR” funded under the 5th Framework Programme.

1 Introduction

This report presents the results of a meeting with Dunlop Aerospace, a specified carbon-carbon (C/C) manufacturer. The objective of the meeting was to discuss the possibility of Dunlop Aerospace acting as a potential supplier of C/C composites for components of Very High Temperature Reactor (VHTR) control rods.

This report will be complemented by reports from other HTR-M partners regarding discussions with other C/C composite suppliers.

1.1 Background

Increasing the operating temperatures of fission reactors is of major interest, especially for the VHTR.

For the control rods, metals such as Alloy 800H are at or near their operational limit and a new material is needed to be able to withstand the higher temperatures and irradiation environment.

Increasing the operating temperatures of fission reactors is of major interest. With the use of C/C composites there could also be a possibility of increasing the thermal resistance, however this would be at the expense of degradation of material properties due to oxidation and irradiation damage.

Meetings are being held with potential suppliers to assess and list possible materials for the VHTR control rod.

The concept proposed by JAERI for the High Temperature Test Reactor (HTTR) has been used as a guideline for the dimensions of the rods to be manufactured. The rods will consist of two tubes, an inner tube of external diameter 75mm, thickness 7.5mm and length 290mm, and an outer tube of external diameter 113mm, thickness 4mm and length 297.2mm [1]. Each pair of inner and outer tubes would be classed as one unit. In total there would be ten units connected in series using bolts also made of the same material. Between the inner and outer tubes for each unit will be compacted B_4C (boron carbide) which will act as a neutron absorber.

1.2 Requirements

During the discussions, several design requests were made to Dunlop Aerospace.

- The ability to withstand a maximum temperature of 1600^oC, which would be accident conditions, during normal operating conditions, the temperature would be in the region of 1100^oC.
- Ability to withstand a tensile stress of 30 MPa.
- Ability to withstand a shear stress of 10 MPa.

There were several other design requests relating to mechanical properties including limits for thermal conductivity, fracture toughness etc., however only the above main requests were mentioned at the meeting.

2 Identification of Contacted Persons

The contacted person at Dunlop Aerospace with whom to initiate discussions was;

Dr. Toby Hutton
Manager of Carbon Technology
Dunlop Aeorspace
Holbrook Lane
Coventry
CV6 4AA
England
toby.hutton@dunlop-aerospace.co.uk
tel : +44 (0)24 7666 6655 ext. 2627

3 Proposal

The main market for Dunlop Aerospace is the fabrication of materials for aircraft brake discs.

The specifications were discussed and requirements put forward. However, Dunlop were of the opinion that at present cannot they offer a suitable grade for VHTR purposes.

It was noted that placing an order would require a lead time of approximately 5.5 months for a standard grade and 6.5 – 7 months for a non-standard grade of composite. They also said that if an order were to be placed, they could manufacture up to approximately 20 tubes in the lab although for larger amounts a business case would have to be discussed.

Toby Hutton stated that at the moment he would rather not give the properties of the materials manufactured by Dunlop Aerospace.

4 Discussion

Despite the inability of Dunlop Aerospace to offer a suitable grade, the meeting was very useful and much advice and information was received.

The biggest problem when working with C/C composites at high temperatures is oxidation both in the fibres themselves and the matrix. During oxidation there is a loss of mass, and a 5% loss in the mass would result in a 30% loss of strength. Although 5% is extreme the associated large loss of strength must be noted.

Toby Hutton offered an initial opinion to use pitch fibres with a geodesic wind and the matrix inserted by Chemical Vapour Deposition (CVD) to increase the mechanical properties. Graphitisation would be recommended to increase the thermal resistance. However, when C/C composites are heat-treated the dimensions can change slightly, therefore the tolerances (errors) would be an important factor.

Unirradiated room temperature properties are achieved during the manufacturing process and can be tailored according to the requirements of the customer. Technically, non-standard grades are not straightforward but are achievable.

For future work, Dunlop Aerospace are looking at infusing B_4C into C/C composites with the hope that this may result in a reduction in oxidation. As B_4C is used as the neutron absorber within the control rods, the results of this work could prove to be very interesting to VHTR.

Toby Hutton also said that it may be worth considering Ni based alloys, such as nimonics. These are at present being used in jet engines and operate in areas of high temperatures (in the region of 1000^{o}C), although it is not clear that they may withstand temperatures up to 1600^{o}C. Nimonics also offer a high creep resistance.

For the VHTR requirements, there is a need for a low fracture toughness (3MPa m^{-2}), and the possibility of using engineering ceramics e.g. Monolithic SiC, Silicon Nitride and refractory ceramics e.g alumina (fracture toughness 4.5MPa m^{-2}) was also mentioned, although the tube thicknesses may not be suitable for use.

Other companies that could be approached within the UK were also identified.

- Surface Transforms.
- Ten Mat.
- Carbolite.

5 References

[1] M. Eto et. al., Development of carbon/carbon composite control rod for HTTR – concept, specification and mechanical test of materials. JAERI-Research 98-003