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NON-DESTRUCTIVE EVALUATION OF SINTERED SILICON CARBIDE ON ZIRCONIUM ALLOY USING IMMERSION ULTRASOUND TECHNIQUE

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НЕРАЗРУШАЮЩАЯ ОЦЕНКА СПЕЧЕННОГО КАРБИДА КРЕМНИЯ НА ЦИРКОНИЕВОМ СПЛАВЕ МЕТОДОМ ИММЕРСИОННОГО УЛЬТРАЗВУКА

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Аннотация. *Критическое значение высокотемпературных керамических покрытий заключается в их структурной целостности. На целостность, очевидно, влияет наличие дефектов, некоторые из которых могут быть нанесены как покрытия в результате технологических аберраций, тогда как другие развиваются в процессе эксплуатации. Покрытие на основе циркония является перспективным методом получения аварийно-стойкой топливной оболочки для легководных реакторов. Это исследование было мотивировано тем, чтобы оценить изготовленное покрытие с помощью легкодоступного, экономичного и быстрого подхода к неразрушающему контролю. В данном исследовании распыленный слой SiC был нанесен на подложку из сплава Zr-1Nb методом селективного лазерного спекания, а условия поверхности покрытия измерены с помощью метода иммерсионного ультразвукового контроля. Согласно полученным результатам, ультразвуковая иммерсионная методика может быть использована для контроля SiC-покрытия.*

Introduction. Zirconium alloys have gained a long-term application in the nuclear industry [1] due to some unique characteristics including low thermal neutron absorption cross section, high corrosion resistance and appropriate mechanical strength [2]. Ongoing researches on advanced cladding materials such as *SiC* [3], liquid metal bonded hydride fuel [4], high conductivity metallic fuel, and composite fuels towards the development of future generation cladding components of light water reactors [5]. According to Jin D. et. al, 2016 [6], depositing *SiC* coats on *Zr*-alloys demonstrates a promising method to improve corrosion. It is also evident that *SiC* coatings help to establish good oxidation resistance even at high temperatures, and demonstrate a high level of hardness.

Ceramic coatings may exhibit defects such as discontinuity in the deposition, miss-orientation of columnar structures, porosity, inclusions and infiltration by foreign materials. Whereas stringent quality control may eliminate the majority of these defects as-processed coatings. The others need to be identified by routine destructive and nondestructive testing (NDT) techniques. There are several NDT techniques with their intrinsic advantages and disadvantages.

The ultrasound testing method with C-scan image provides a valuable way to investigate the bulk of a material with sintered silicon carbide coatings [7]. Moreover, the ultrasound testing techniques possess some advantages over the rest in terms of accessibility, sensitivity to planar defects, cost and time effectiveness, higher productivity with no radiation risks. Hence, this paper is aimed to describe the performance of ultrasound testing technique on *SiC* coating**.**

Research methods. *Zr-1%Nb* alloys of dimensions (60 mm × 30 mm × 2 mm) were used as substrates for the coating. Before the deposition process, the substrate surfaces were polished to an average roughness of 0.3 µm using the Hommel Tester T1000 and surfaces rinsed with acetone. Ytterbium fiber laser (IPG Photonics, Moscow, Russia) of 1070 nm output wavelength and Laser power of 125 W was engaged in the fabrication process. Table 1 states the sintering parameters involved in this study. Fig. 1 represents the SLS deposition scheme and the immersion ultrasonic testing system.

Table 1

SLS deposition parameters

Laser power (W)	Scanning time (µs)	Laser speed (mm/s)	Deposition thickness (µm)	SLS Atmosphere
125	600	25	200	Air/Ar

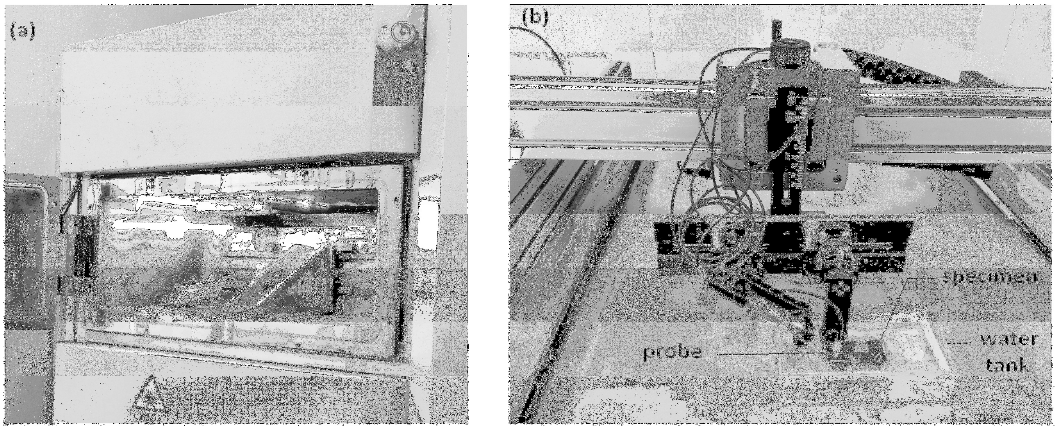

Fig. 1. The setup for SLS fabrication (a) and the immersion ultrasonic testing system (b)

Results. The obtained images associated with this study show the ultrasonic amplitude c-scan of the uncoated *Zr-1Nb* substrate (top and bottom sides) and the coated samples (top and reverse sides) which have been sintered in an air/argon environment by the SLS technique. The length and the width of the specimens are represented by X and Y axes respectively and the amplitude of the reflected ultrasonic signal is represented by Z axis. The amplitude does not give quantitative measurements on the thickness, however, it shows changes in surface conditions. For the images in (b, e) and (c, f), the area with a maximum amplitude of about 3×10^4 corresponds to uniform surface conditions and the area with irregular surface conditions is characterized by lower values of amplitude. The scanned results of the uncoated *Zr-1Nb* substrate (a) and (d) show uniform distribution of the surface. The scanned results of the reverse side (e) and (f) show a single region with high uniformity resulting from the interface layer between the coating and the substrate surface. However, the scanned results of the coated surfaces of the samples (b) and (c) show the uneven distribution of deposits due to the increase of the average roughness from 0.3 to 6-8 µm of the uncoated to coated *Zr-1Nb* substrate respectively.

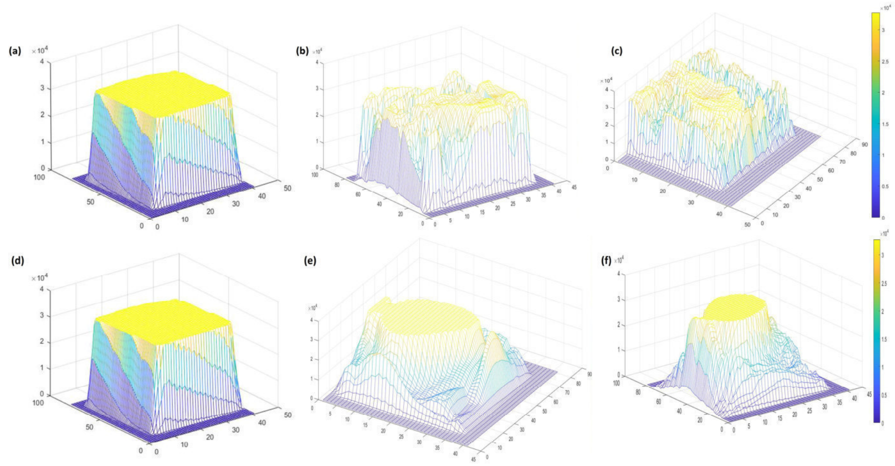

Fig. 2. C-scan ultrasonic immersion tests

Conclusion. This paper has described the use of amplitude C-scan measurement with a single transducer. Results were shown for *SiC* coated *Zr-1Nb* alloy substrate using the immersion ultrasonic testing technique. It was shown that amplitude C-scan is capable of visualizing the surface profile of the specimens. Ultrasonic immersion techniques have the potential to be used for in-service inspection of *SiC* coatings on *Zr* alloy tubes to ensure the structural integrity in this particular design of cladding tubes. Due to the surface conditions of *SiC* coating, surface finishing is required to provide a smooth coating surface in order not to mask indications from the surface defects. Further work will be done to develop a methodology to detect the sub-surface defects, in particular the boundary layer between the *SiC* and the substrate which is important to determine the integrity of the sintering process.

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