Material: Ferritic Steel: F82H
Property: Stress & Elongation vs. Temperature
Condition: T-HIP, T-Matrix
Data: Experimental

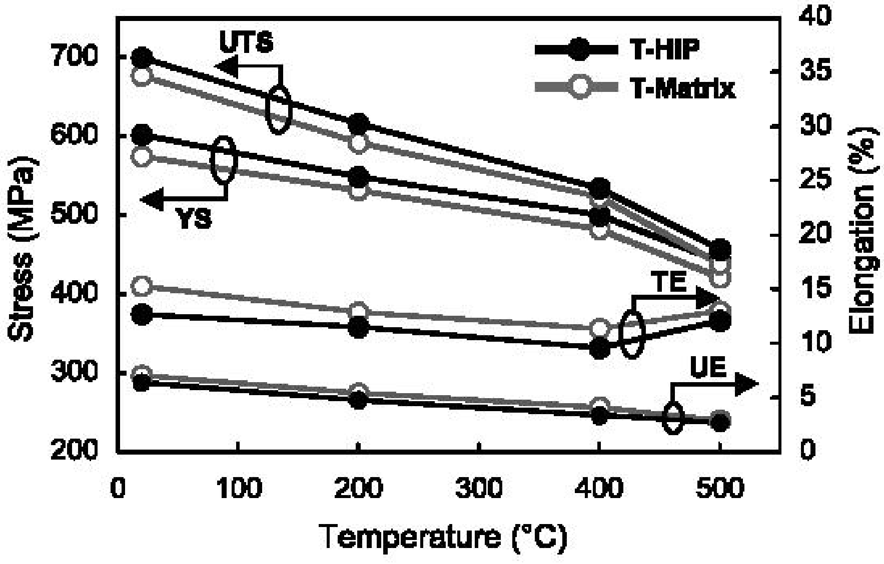

Fig. 2. Result of tensile test up to 500 °C. Tensile properties are nearly equal in HIP boundary (T-HIP) and matrix (T-Matrix).

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Tensile and Impact Properties of F82H Steel Applied to HIP-bond Fusion Blanket Structures

Author of paper or graph:
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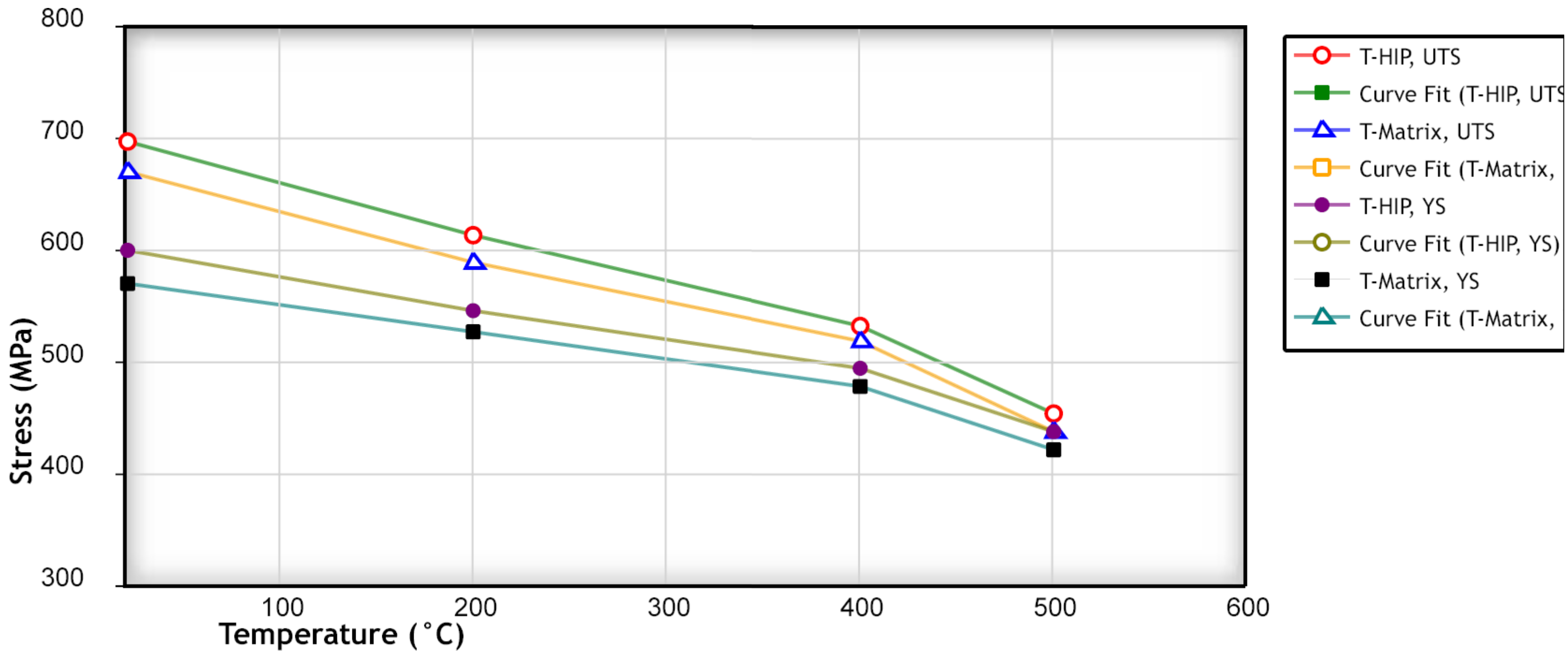

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Plot Format:

Y-Scale: ◉ linear ○ log ○ ln

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Tensile and impact properties of F82H steel applied to HIP-bond fusion blanket structures

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Abstract

In a fusion reactor, a blanket made of a low activation material like F82H steel is fabricated by HIP (hot isostatic pressing) bonding method. In a previous study, grain coarsening has been found in specific HIP-bond region of a mock-up of blanket structures. To verify an effect of the coarsening on mechanical properties of the HIP-bond region, tensile and impact tests were done. In result of the tensile test, there was no significant influence of the coarsening on the tensile properties of the HIP-bond region up to 500 °C. In the impact test (RT ~ -50 °C), temperature at which the absorbed energy of the HIP-bond region changed markedly (-35 °C) was almost same to DBTT of the matrix region (-30 °C), but the absorbed energy at room temperature (RT) decreased by about 40% in comparison with that of the matrix region. The major factors were: (1) large inclusions in the HIP interface; and (2) brittle fracture in a part of the HIP-bond region due to grain coarsening. It is important to eliminate a contamination caused by the inclusions from the HIP bonding surfaces, and also it is necessary to suppress and/or refine the grain coarsening.

Keywords: F82H steel; Blanket; HIP; Grain coarsening; Mechanical properties

1. Introduction

Reduced-activation ferritic/martensitic steels (RAF/Ms) are primary candidate structural materials for breeding blanket. In JAERI, development of the fabrication technology is in progress for International Thermonuclear Experimental Reactor (ITER) test blanket used by F82H steel which is one of RAF/Ms. The blanket structures, especially the first wall suffers high thermal stress ($\sim$ 430 MPa for Tresca stress) and huge electro magnetic force ($\sim$6.8 MN for pulling force) [2]. Solid hot isostatic pressing (HIP) bonding method is expected to provide the most promising fabrication method for the blanket structures which can stand in the severe condition.

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In the previous studies, a partial mock-up of the blanket structures made from F82H steel was fabricated with applying the HIP bonding method [3]. Through metallurgical observation of the mock-up, condition of the bonding was sufficient although coarsened prior-austenite grains were found in the specific HIP-bond regions where two rectangular cooling channels and plates are bonded [4]. Since the grain coarsening is expected to change mechanical properties, it is necessary to study the tensile and impact properties which give important mechanical properties. In this paper, these characteristics in the coarsened HIP-bond region will be discussed.

2. Experimental procedure

Fig. 1 shows a schematic of first wall cross section of the mock-up. Roughness of the HIP bonding surfaces was prepared within 6.3 μm in

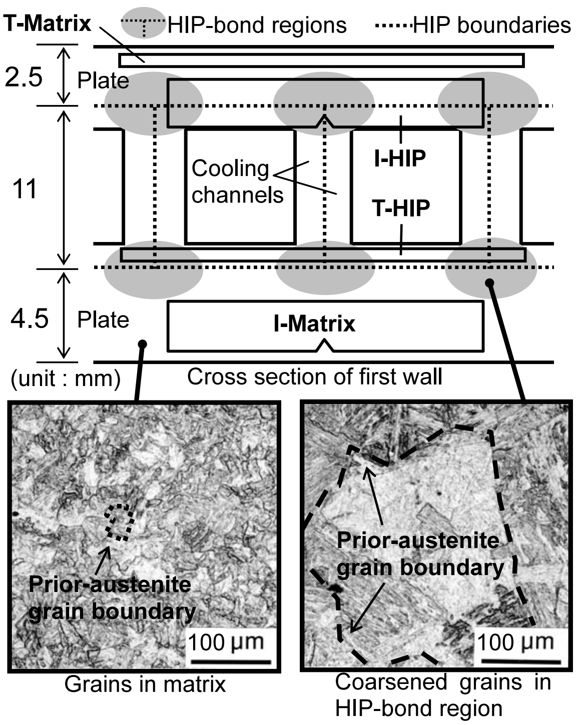

Fig. 1. Schematic of location where tensile and impact specimens were sampled. Coarsened grains are seen at HIP-bond regions.

Rmax. The mock-up was HIPed in the condition, i.e. temperature, 1040 °C; holding time, 2 h; pressure, 150 Mpa; and after that, followed by tempering at 740 °C for 2 h. Fig. 1 also shows sampling locations for tensile specimen (Type SS-3) and impact specimen (Type 1/3-CVN) [1]. Tensile specimen indicated ‘T-HIP’ was sampled so as to locate HIP boundary at the center of the specimen. The T-HIP specimen is composed of two cooling channels. Impact specimen indicated ‘I-HIP’ was sampled so as to locate HIP-bond region at the center. The I-HIP specimen is composed of two cooling channels and a plate. V-notch (0.51-mm-deep) for the I-HIP specimen is located along with the HIP boundary composed of two cooling channels. Tensile (T-Matrix) and impact (I-Matrix) specimens were sampled from a matrix region of the mock-up for reference. The specimens have no coarsened grains. The tensile test was performed in a temperature range from a room temperature (RT) to 500 °C with a strain rate of 5×10^{-4}/s. The ruptured region was observed by an optical microscope. The impact specimens were tested in a temperature range from -50 °C to RT. The fractures were observed by a scanning electron microscope (SEM) with 15 kV.

3. Results and discussion

3.1. Tensile property

Result of tensile test for HIP boundary (T-HIP specimen) and matrix (T-Matrix specimen) are shown in Fig. 2. Ultimate tensile stress (UTS) and 0.2%-offset yield stress (YS) of the HIP boundary increased by $\sim$5%, and the total elongation (TE) and uniform elongation (UE) decreased by $\sim$3 and $\sim$0.5%, respectively, at all of the test temperature regions in comparison with that of the matrix. The result means that the HIP boundary is harder somewhat than the matrix, but these changes are small, and are not significant. Therefore, the grain coarsening has no any serious influences on the tensile property. Fig. 3 shows typical shapes at ruptured regions of the HIP boundary (a, b) and the matrix (c, d), at RT and 400 °C. Although reduction-of-area (RA) of the

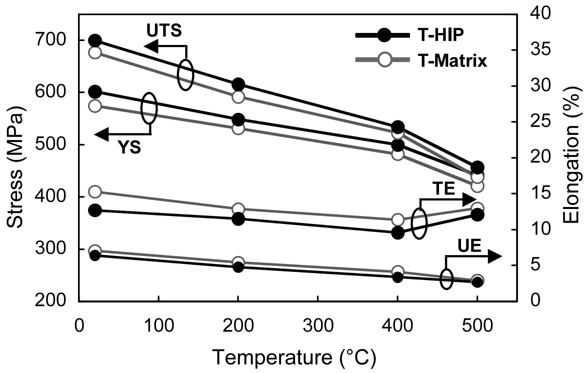

Fig. 2. Result of tensile test up to 500 °C. Tensile properties are nearly equal in HIP boundary (T-HIP) and matrix (T-Matrix).

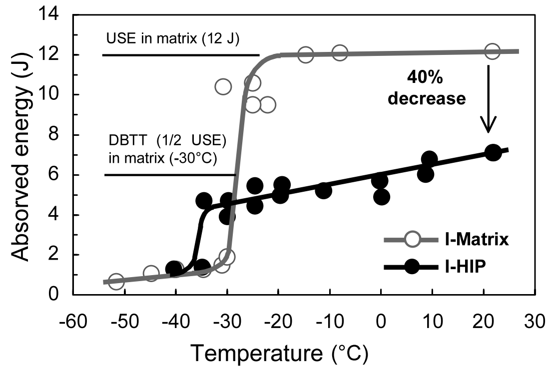

Fig. 4. Result of charpy impact test at various temperatures (RT ~ -50 °C). Absorbed energy at RT decreased by about 40% in the HIP-bond (I-HIP).

HIP boundary is wider somewhat than that of the matrix, sufficient RA is seen. The result means that behavior like brittle fracture does not occur in the HIP boundary.

3.2. Impact property

Impact test results of HIP-bond region (I-HIP specimen) and matrix (I-Matrix specimen) are shown in Fig. 4. Ductile-brittle transition temperature (DBTT) and upper shelf energy (USE) of the matrix are -30 °C and 12 J, respectively. Since the HIP-bond region includes HIP interface, the DBTT is indefinable. Absorbed energy of the HIP-bond region changes markedly at -35 °C, which is almost same to DBTT of the matrix. While the absorbed energy of the HIP-bond region increases gradually with rise in the test temperature, the energy at RT decreases by about 40% (5 J) in comparison with that of the matrix. Fig. 5 shows SEM images at fracture of the HIP-bond region, at -40 °C and RT. These temperatures correspond to brittle and ductile temperatures of the matrix. Images (a, c) in the figure show

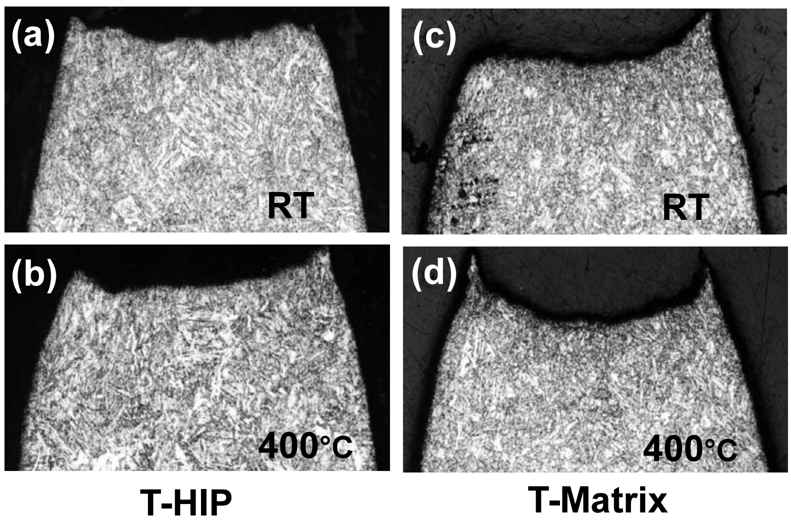

Fig. 3. Photographs of the fracture regions of HIP boundary (T-HIP) and matrix (T-Matrix). Sufficient reduction-of-area is seen in HIP boundary.

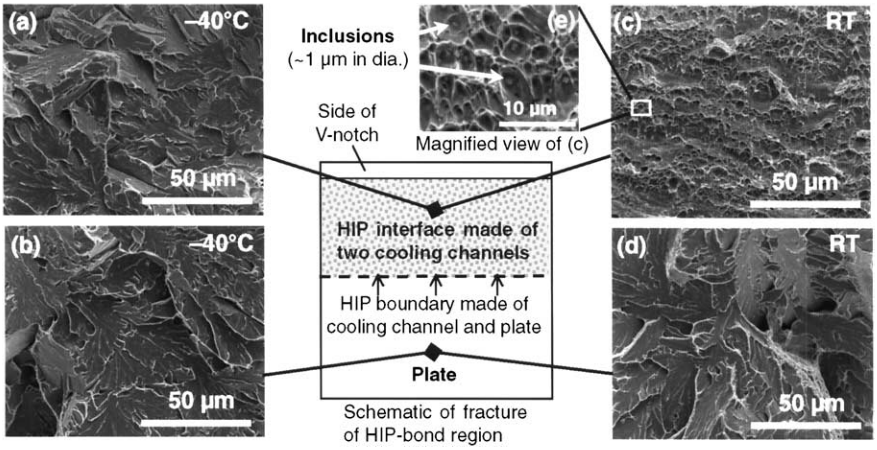

Fig. 5. SEM images at fracture of HIP-bond region. In spite of temperature (RT), ductile fracture (c) and brittle fracture (d) are seen in HIP interface and plate, respectively.

fractures of HIP boundary, that is to say HIP interface made of cooling channels, and (b, d) show fractures of plate. At -40 °C, cleavages are seen in the HIP interface (a) and plate (b). The tendency is same to that of the matrix. At RT, dimples are seen at the HIP interface (c). The (c) also signify there are no traces of void or exfoliation which mean insufficient bonding [5]. This means sufficient diffusion bonding was done in the appropriate HIP condition includes surface roughness. Although the tendency for dimples to appear at RT is same to that of the matrix, the dimples seen in (c) are shallow and flat somewhat, and as shown in (e), large inclusions, ~ 1 µm in diameter, are seen. Fig. 6 shows a mechanism to form the

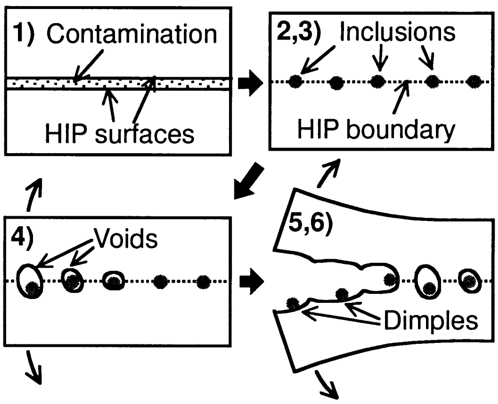

Fig. 6. Mechanism to form shallow and flat dimples.

dimples like these. The explanation of Fig. 6 is as follows: (1) a contamination caused by inclusion adhere to the HIP bonding surfaces before HIP treatment; (2) large inclusions are formed along with the HIP interface during HIP treatment; (3) impact specimen sampled from the HIP-bond region has large inclusions in its HIP interface; (4) voids begin to grow by deforming of the specimen; (5) adjoining voids link before the voids grow sufficiently, due to the large inclusions; (6) in result, shallow and flat dimples are formed. Therefore, the shape of dimples means the rupture occurred before the specimen is deformed adequately, which is identical that the absorbed energy to be used for rupture was small. In addition, since the inclusions exist along with the HIP interface, it is easier to rupture. This is one reason why the absorbed energy of the HIP-bond region decreased. Therefore, it is important to eliminate a contamination caused by the inclusions from the HIP bonding surfaces before HIP treatment. On the other hand, as shown in Fig. 5(d), cleavages are seen in plate of the HIP-bond region. This means that although HIP interface has ductility at RT (c), plate is in its brittleness in spite of RT. This is another reason why the absorbed energy decreased. It seems that the brittle fracture occurred due to grain coarsening. Consequently, it is also necessary to suppress and/or refine the coarsening. The grain coarsening does not affect the HIP interface made of cooling channels. This suggests that toughness of the cooling channels is better than that of plate. Further study needs to reveal the reason.

4. Summary

Tensile and impact tests were carried out for HIP-bond regions and for matrix regions of the blanket structures mock-up made from F82H steel. SEM observation was performed for ruptured regions of impact specimens. In the present study, the following results were obtained:

1) Tensile properties of coarsened HIP-bond region and of matrix region are nearly equal. Consequently the grain coarsening has no great influence on the tensile property.
2) Absorbed energy of coarsened HIP-bond region decreased by about 40% in comparison with that of matrix, at RT. The reasons are: (1) large inclusions in the HIP interface; and (2) brittle fracture in the plate.
3) It is very important to maintain HIP bonding surfaces clean, and also needs to study ways to suppress and/or refine the grain coarsening in order to improve toughness in the HIP-bond regions.

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