The Effect of Heat Treatment on Mechanical Properties and Microstructures of Alloy 690

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1. Introduction

Because of good corrosion resistance and mechanical property, Alloy 690 is used as one of the key structural materials in nuclear power plants. To optimize the corrosion resistance, workability and mechanical property, grain size and grain boundary carbides need to be controlled through heat treatment. In present study, microstructure variations by heat treatment were investigated by SEM observation. And the relation between microstructure and mechanical properties were investigated.

2. Materials and Experiments

2.1 Test materials and heat treatment

Alloy 690 used in this study is a ASME SB 166 round bar type and supplied by VDM Co.. It contains 0.02% of C and 28.36% Cr. It was solution annealed for 3.42 hrs at 1045°C and then heat treated for 10 hrs at 720°C.

Heat treatment conditions in this study were chosen considering the manufacturing procedure of VDM Co. and material purchase specification (MPS) of Doosan Heavy Inc.. Figure 1 shows the history of heat treatment used in this study. The Heat treatment conditions are summarized in Table 1. After heat treatments, the microstructures of alloy 690 were observed through SEM. Mechanical properties were investigated using miniature tensile tests and micro-hardness tests.

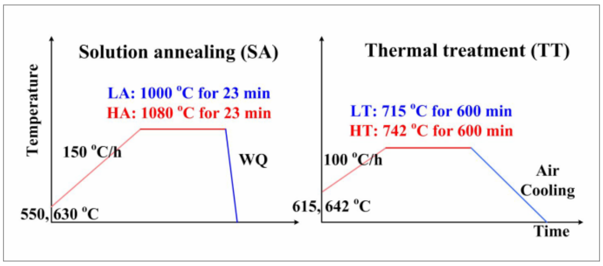


Fig. 1. Thermal treatment processing

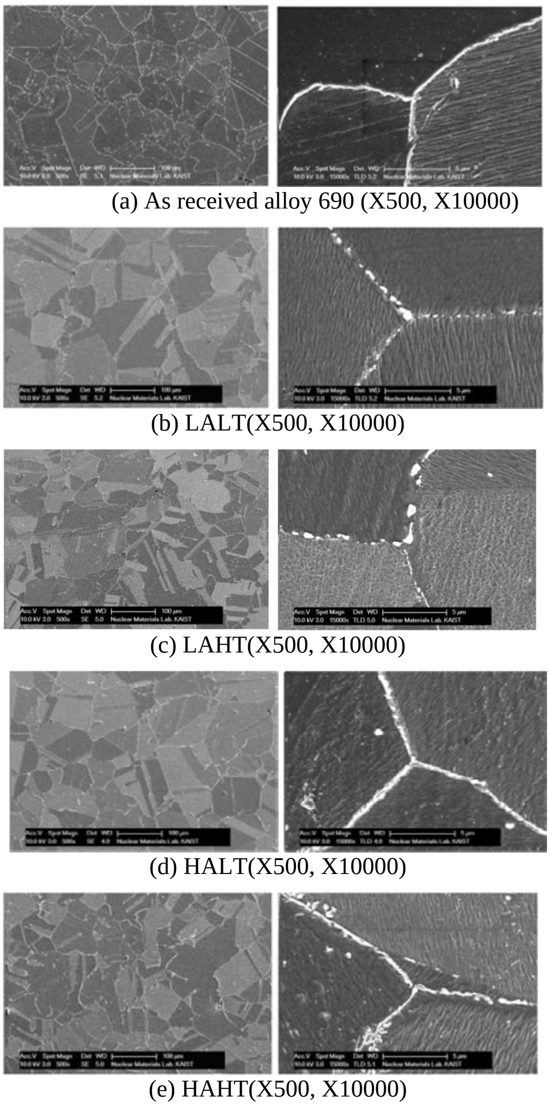
Table 1. The designation of heat treatment conditions

HT Condition	Solution annealing temperature and time	Thermal treatment temperature and time
LALT	1000°C for 23min	715°C for 10h
LAHT	1000°C for 23min	742°C for 10h
HALT	1080°C for 23min	715°C for 10h
HAHT	1080°C for 23min	742°C for 10h

3. Results and Discussion

3.1 Microstructure Observation

Figure 2 shows microstructures and grain boundary carbides of the as-received specimen and the heat treated specimens. As shown in the figure, the morphologies of grain boundary carbides depend on solution annealing condition. Also, grain boundary carbides of heat treated specimens after 1000°C SA are more discontinuous than those after 1080 °C SA. It is thought that grain boundary carbides are not dissolved sufficiently during 1000°C SA process. It has been known that the undissolved carbides in grain boundaries disturb uniform formation of carbides through thermal treatment process [3]. Also, the dependence of 715°C and 745°C of TT temperature on grain boundary carbides was not observed.



(a) As received alloy 690 (X500, X10000)

(b) LALT(X500, X10000)

(c) LAHT(X500, X10000)

(d) HALT(X500, X10000)

(e) HAHT(X500, X10000)

Fig. 2. Microstructure of alloy 690 : (a) as received alloy 690, (b)LALT, (c)LAHT, (d)HALT, (F)HAHT

3.2 Grain size variation through heat treatment

It is generally known that grain size is closely related with solution annealing time. In this study, grain size of alloy 690 is slightly increased by SA process. But in temperature range of 1000°C~1080°C, as shown in Figure 3, the grain size variation was not significant within the ranges of heat treatment conditions specified by Doosan Heavy Inc..

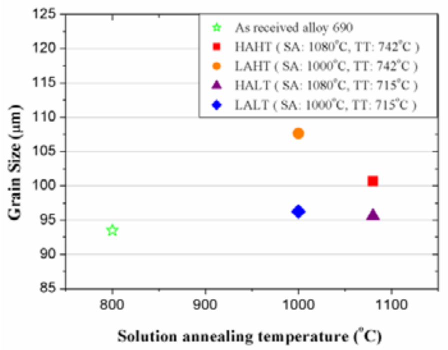


Fig. 3. Relation of between grain size and SA temperature.

3.3 Tensile and hardness properties

In general, the relation between grain size and yield strength can be expressed as Hall-Petch equation shown in below.

$$\sigma_Y = \sigma_i + k_y d^{-1/2}$$

To find the relationship between grain size and mechanical properties, miniature tensile and micro-hardness tests were performed for the as-received and heat treated specimens at room temperature and 310°C air conditions. From the results shown in Figure 4 and 5, no significant change of mechanical properties of alloy 690 was observed among the heat treatment conditions used in this study.

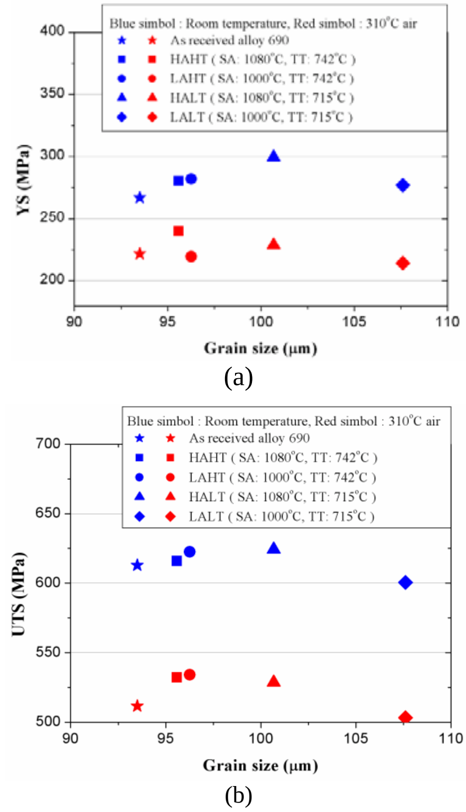


Fig. 4. Relation of between grain size and strength in two temperature conditions

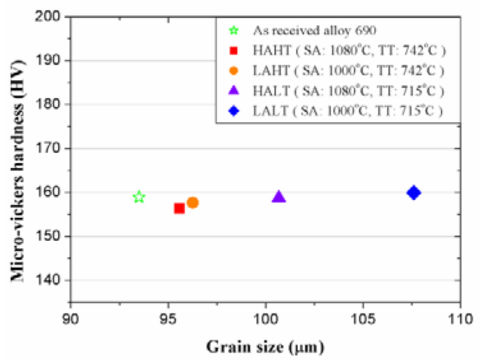


Fig. 5. Relation of between grain size and hardness in room temperature conditions

4. Summary

From the microstructure observation, grain boundary carbides were more continuous at 1080 °C SA than at 1000°C SA. Also, the dependence of 715°C and 745°C of TT temperature on grain boundary carbides was not observed. In the relation between grain size by heat treatment and mechanical property, the change of mechanical properties did not be observed through heat treatment following heat treatment specification. Therefore, it is thought that the current heat treatment specification could produce rather consistent mechanical properties for alloy 690.

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