The Feasibility study of laser peening effects on the Nuclear power plants Using Shot peening treatment with operating temperature

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1. Introduction

Recently, the nuclear power plants industry was faced with material aging problems. One of them is Primary water stress corrosion cracking (PWSCC)[1]. Even if Alloy 600, which is a nickel based superalloy, has been used in some parts of nuclear power plants, it is widely used in the manufacturing of commercial and military components. The Alloy 600 is a standard structural engineering material which requires the resistance to corrosion and thermal effects. However, some parts of BMI nozzle have PWSCC problem. Several methods have been used to prevent PWSSC. Typically, peening process is used extensively in the industry to improve life time and to mitigate stress corrosion cracking (SCC)[2]. Laser peening (LP) is one of the best ways to achieve the above reasons. This technology was already applied to nuclear power plants by developed countries. Nowadays Korea nuclear power plants industry is highly ranked in the world market. Thus, the demands of laser peening technology will increase. However, it is very difficult to characterize the material properties after peening treatment on the parts of nuclear power plants. Therefore, we accomplished a precedent study of experiments to investigate the effects of peening process on the Alloy 600, and the threshold temperature for stress relief and the effect of LP through the Shop peening(SP). LP and SP process have equal mechanism but just different peening media.

In this paper, to determine the effects of laser peening process on the nuclear power plants manufacture Alloy 600 using the shot peening treatment with operating temperatures.

2. Experimental Procedure

2.1 Test specimen preparation

The material used in this study was the rolled Alloy 600 for nuclear power plants in Fig. 1. Table Ⅰ shows the chemical composition and mechanical properties. Table Ⅱ shows the heat treatment condition of material. The material was given the standard heat treatment, solution treatment at 1100℃ for 30 minutes in the furnace cooling and then holding at 705℃ for times up to 12 hours[3]. The microstructures of the surface layers of the shot peened specimens that were received four different ageing treatments, annealed at 316℃, 538℃, 760℃ and 927℃ for one hour each.

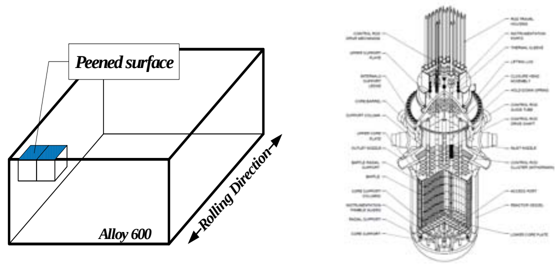

Fig. 1. Position of the specimen the rolling material (left) and Cutaway View of water Reactor Vessel (right) by USNRC.

Table Ⅰ: Chemical composition of Alloy 600(wt%)

C	Mn	P	S	Si	Ni	Cr
0.044	0.23	0.01	0.0002	0.2	74.34	16.09
Co	**Cu**	**Fe**	**Cb**	**Ta**	**Al**	**Ti**
0.03	0.02	8.59	0.02	0.003	0.18	0.18

Table Ⅱ: Heat treatment condition

Heat treatment(Alloy 600)			
	Annealing treatment	Solution treatment	Ageing treatment
Temperature, time	1100℃/30min, 705℃/1hr	700~730℃	316℃/1hr 538℃/1hr 760℃/1hr 927℃/1hr

2.2 Shot peening treatment

The process of the Shot peening(SP) treatment is shown in Fig 2. It was performed according to optimize peening intensity which was controlled coverage calibrations, velocity and specimen masking. The SP using conditioned cut wire shot ball of 0.8mm mean diameter and specific peening conditions is accomplished with 0.45mmA[4], specimens were rotated in two fixture impeller type nozzles for a constant angle, distance, and pressure with flow rate.

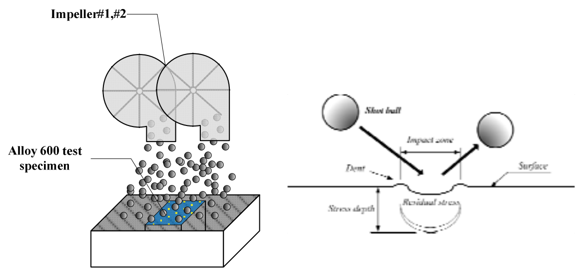

Fig. 2. Process of the Shot peening treatment.

3. Experimental Results

3.1 Effect of SP treatment

In order to investigate the effects of the SP on the Vickers hardness distribution at the cross section of the peened specimens are shown Fig 3. In this figure, the hardness value on the normal material were almost around 181Hv, however the value of the SP treated material was expectably increased around 395Hv. In the present study, Fig 4. shows the effects of surface residual stress of SP on the nickel based superalloy[4].

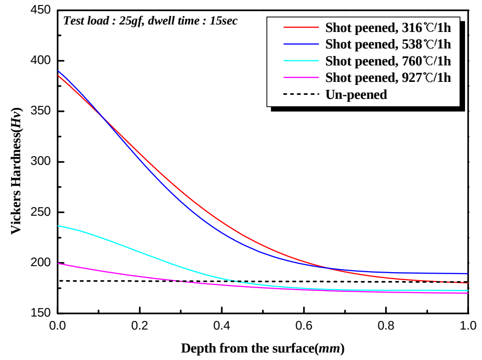

Fig. 3. Vickers hardness distribution of the Un-peened and SP treated material cross section with variety temperatures.

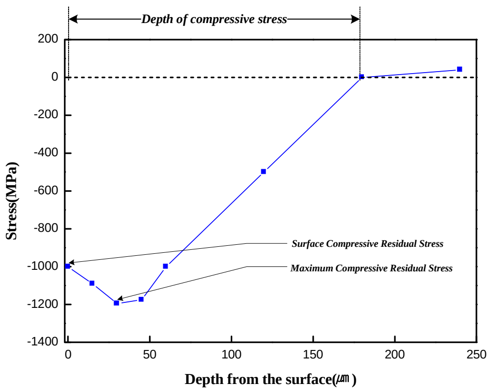

Fig. 4. Compressive Residual stress as a function of depth of nickel based superalloy[4].

3.2 Microstructure

The microstructure of Alloy 600 presented in Fig. 5. It clearly consists of fine grain structure in the cross section. Aging treatment was carried out at 316℃, 538℃, 760℃ and 927℃ for equal time period. For microscopy, the specimens from the heated treatments were cut, mechanical polished and etched with a chemical solution consisting of HCI and HNO_3 of ratio 4:1 distilled water. Fig. 5 shows the grain size, which were heat treated with different temperatures. According to this result, the average grain size decreased starting from 760℃. As like a Vickers hardness distribution result both 760℃ and 927℃ temperatures changed specimen properties dramatically. It may relative with the recrystallization temperature of Alloy 600[3,5].

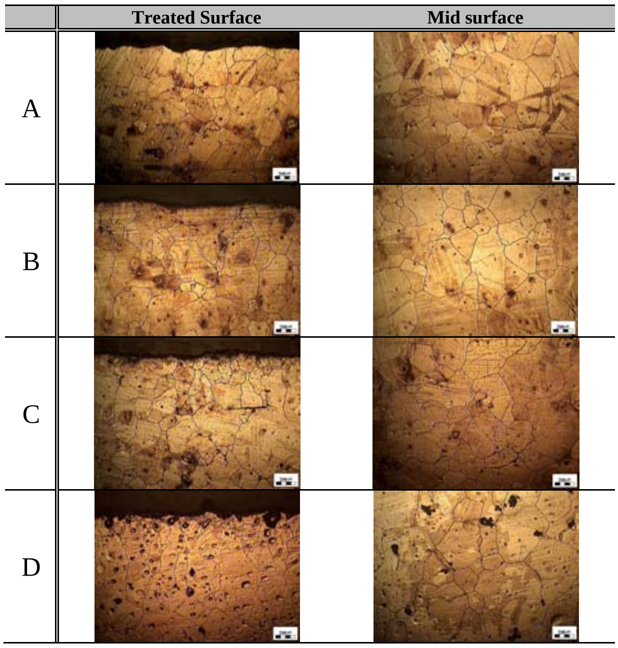

Fig. 5. An optical micrograph showing the grain size in the annealed specimens at different temperatures for 1hour in Alloy 600: (a)316℃, (b)538℃, (c)760℃, (d)927℃.

4. Conclusion

The effects of Vickers hardness and the material characteristics of shot pening for Alloy 600 were evaluated. The Vickers hardness distribution increased almost twice more than normal material. However, the reversion of the Vickers hardness decreased starting from 760℃. It may explain the feasibility of peening treatment under operating temperature in the Korea nuclear power plants. Therefore, further study of LP is follow to the future plans.

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