Prevention of Stress Corrosion Cracking of Weldment by Wet Shot Peening

M. Takemoto

College of Science and Engineering, Aoyama Gakuin University
6-16-1, Chitosedai, Setagaya-ku, Tokyo, 157 Japan

ABSTRACT

In order to prevent Stress Corrosion Cracking (SCC) of austenitic stainless steel equipment, a Wet Shot Peening method which was able to convert tensile residual stresses to compressive stresses during and/or after welding was developed.
In the Wet Shot Peening (WSP), glass beads were injected to member surface with water jet pressurized by high speed centrifugal slurry pump. WSP made it possible to peen the tower and vessel in chemical plant continuously without meeting the problems which were experienced in adopting conventional air-blast type shot peening.
Effect of WSP on residual stresses, surface roughness, metallurgical changes, removability of scale and deposits were investigated in our laboratory.
Two examples of application of this method to chemical process equipment are discussed.

KEY WORDS

Wet Shot Peening; Stress Corrosion Cracking; Shot Peening; Heat Sink Welding; Weld Scale; Austenitic Stainless Steel.

INTRODUCTION

The establishing of an economical countermeasure to SCC is an important dem. for plant maintenance. Stress improvement will be the most effective and economical countermeasure to SCC.
It was confirmed that conventional shot peening was an effective countermeas to SCC (Takemoto(1981)). However, welded and shot peened specimens which wer under applied stress underwent SCC initiated from toe, undercut, weld slag, inbedded bimetallic shot and transformed martensite. In addition to these problems, there seems to be some problems in applying this method to the tower and vessel in a plant, these are the difficulties of recovering blasted shots, the deafening noise and the clouds of dust.

Recently, some new methods for residual stress improvement were developed for nuclear power plants. The so-called Heat Sink Welding(HSW)(Kirihara(1979)) and Last Pass Heat Sink Welding (LPHSW)(Rybicki(1979)) are the methods which were able to convert tensile stresses at any point to compressive stresses during welding by utilizing thermal stress. They could not, however, remove weld slag or scale.

For the complete prevention of SCC of weldment, the following conditions should be satisfied.

1) Residual stresses at irregular or discontinuous parts like the toe, undercut, overlap or poor penetration should be compressive.

2) Weld slag and scale which become suitable sites for pitting corrosion and SCC should be removed and leaving only clean surface.

3) Metallurgical changes like sensitization and martensitic transformation should be avoided.

The authors developed a new method of shot peening, named " Wet Shot Peening" which made it possible to peen tower and vessel contineously without above problems. In the present paper, the effect of WSP on residual stresses of butt welded pipes were introduced in detail. Two examples of applications of WSP to chemical equipment were also introduced.

METHOD OF WET SHOT PEENING

Wet Shot Peening is an improved method of conventional hydro-blasting or liquid honing. In WSP, glass beads of 0.4 mm diameter were injected to the member surface with jet water pressurized by a high speed centrifugal slurry pump (20 HP(15000W), 2900 rpm). The slurry pump was specially designed and manufactured for this purpose. Its impeller and casing were made from stainless steel casting of ASTM CA15. The maximum jet velocity reached about 30 m/sec. which was sufficient speed to peen stainless steel equipment.

Fig. 1 is one method used for residual stress improvement during welding, the detail of which will be discussed later. Glass beads were blasted to the inner surface of welding parts. Blasted shots were easily recovered with water by preparing a simple gutter, so that long-time continuous operation without clouds of dust and deafening noise becomes possible. The mixture ratio of glass shots to water was controlled by adjusting the orifice diameter of two suction tubes.

In Heat Sink Welding (HSW) which was taken up in order to compare its effect with that of WSP, water was sprayed to the inner surface utilizing the same pump. The injection velocity of water was contolled to be the 7 m/sec.. Conditions for air-blast type shot peening were the same as those reported by the authors (Takemoto(1981)).

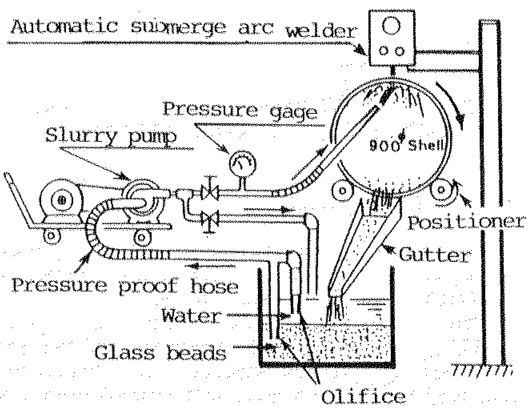

Fig.1 Test apparatus for Wet Shot Peening during welding

LABORATORY TEST OF STRESS IMPROVEMENT OF WELDED PIPES

WSP was applied to butt welding of 100 mm diameter pipes using the equipment shown in Fig. 2. The welding sequence was like this: first pass was made by Gas Tungusten Arc Welding, and the second pass and the subsequents by Shield Metal Arc Welding from outer surface. WSP was applied to the welds from second pass weld. Specimens were rotated utilizing a positioner whose holder was declined 20 degree downward to make the shot recovery easy. A shot nozzle was fixed upward so as to peen the reverse side of welding part. Residual stresses were measured at a point 180° to the starting point of welding using strain gauge and X-ray method. Fig. 3 shows the residual stresses of as-welded, HSW, Shot Peened, and WSP specimens. Either of these methods is able to convert the residual tensile stresses of as-welded pipes to compressive stresses. Compressive stresses induced by WSP is, however, larger than that induced by other methods. This is due to the conjoint effect of thermal stress induced by water cooling and shot peening. Vickers hardness at surface reached 400 which was the highest level obtained by air blast type shot peening. Weld scale and slag were completely removed, and a bright surface was left. Metallurgical examination of WSP specimens showed that WSP could reduce significantly both sensitization and martensitic transformation, which is ascribed to controlling the water temperature. In case where sensitization has pejorative effect on the SCC, surface temperature should be controlled to be as low as possible. On the contrary, in case where the transformed martensite has a pejorative effect, the temperature should be controlled to be about 100°C which is higher than M_d point of austenitic stainless steel. The relation between residual stresses and the weld pass number to which the WSP was applied was also studied. It was found that WSP was effective even if it was applied only to the last pass welding.

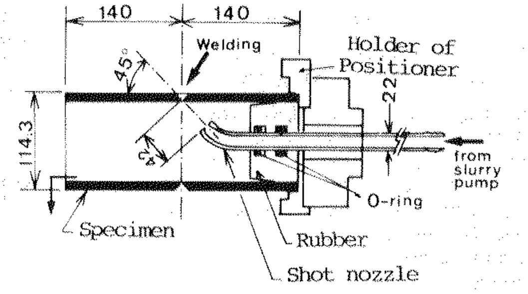

Fig. 2 Equipment for Wet Shot Peening during 100 mm pipe welding

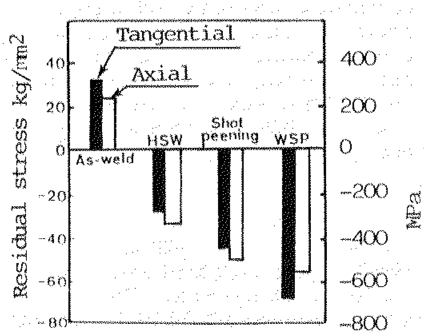

Fig. 3 Effect of treatments on residual stresses of 100 mm butt-welded pipes

APPLICATION OF WET SHOT PEENING TO CHEMICAL PROCESS EQUIPMENT

1. Improvement of Residual Stresses of Shell During Welding

WSP was applied to the last pass submerged arc welding of a 900 mm diameter shell which was used as a storage tank. The method and equipment used were the same as shown in Fig. 1. LPHSW was tried in order to compare its effect with WSP. Residual stresses were nondestructively measured with X-ray by using a portable goniometer. The result is shown in Fig. 4. Residual compressive stresses induced by WSP are much larger than that by LPHSW. The sensitization was not so reduced in this case because WSP was applied only to the last pass welding. The surface was bright and scarcely had transformed martensite.

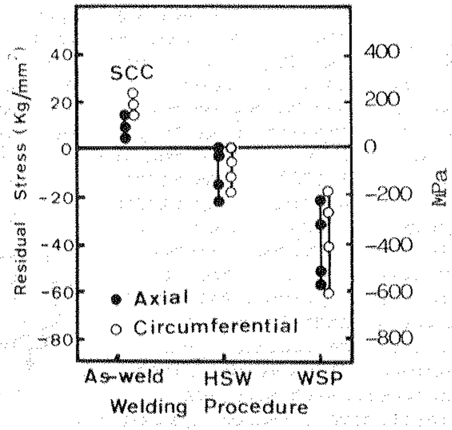

Fig. 4 Effect of treatments on residual stresses of 900 mm$^{\phi}$ welded shell

2. Countermeasure to External Stress Corrosion Cracking (ESCC)

Storage tank of AISI304 insulated with calcium silicate suffered ESCC near the girth weld line of dished plate to shell after 5 years'service. The tank was weld repaired, but it was feared that ESCC may occur on other parts of the tank in further service.
Heat resistant coating was considered to be an effective countermeasure to ESCC, where the surface was much contaminated with chloride-containing deposite and insulator. Cleaning of the surface and proper primer treatment for coating was required(Litzsinger(1983)). Conventional blast cleaning is not entirely adequate for this purpose because it does not completely wash off the deposits. WSP was the most suitable method which could wash the deposits off and induce proper surface condition for coating. WSP was done without difficulty by preparing simple jacketing and gutter of plastics.

CONCLUSION

The usefullness of WSP method was examined and compared with that of HSW and shot peening. The results are summarized in Table 1. WSP was found superior in controlling the residual stresses and metallurgical changes as well as removing the weld slag and scale. WSP also made possible shot peening, as a surface treatment of welded and/or cold worked members, for large towers and vessels in-site without injuring the operators' health.

Table 1 Evaluation of Three Types Treatment for SCC Prevention

	Shot-Peening	HSW	WSP
Mitigation of Residual Stresses	○	○	◎
Mitigation of Sensitization	X	◎	◎
Recovery of Shots	X	—	◎
Prevention of Transformation	X	○	○
Removal of Slag	◎	X	◎

◎ Superior ○ Better X Poor

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