APPLICATION OF SHOT PEENING TO STRESS CORROSION CRACKING OF CHEMICAL PROCESSING EQUIPMENT

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ABSTRACT

While austenitic stainless steel is widely used for chemical plants, stress corrosion cracking (SCC) is the most frequent cause of all failures of chemical processing equipment. Method of application of shot peening to prevent SCC and its effect after longtime operations are described.

KEY WORDS

Shot peening; stress corrosion cracking; austenitic stainless steel; chemical processing equipment; residual stress; shot.

INTRODUCTION

Austenitic stainless steel is characterized by its extreme ductility and toughness and has dominated the market in the chemical industry. Its weak point, however, is that it is susceptible to stress corrosion cracking (SCC) mainly in chloride environment.

SCC initiates at the surface of chemical equipment due to combined effect of tensile stress and corrosion. The mechanism of preventing SCC is accordingly the same as that of preventing fatigue failures.

We at Showa Denko have been practicing shot peening since 1982 and found that it has an excellent effect in preventing SCC. Our method to apply shot peening to chemical processing equipment and its performance after longtime operations are described in the following.

CASES OF SHOT PEENING APPLICATION

We have applied shot peening to more than 20 cases in the past eight years. This presentation covers three of them.

Reactor

SCC occurred along the weld line of a reactor made of austenitic stainless steel (SUS 304). The SCC was located at the upper side of the reactor--in the vapor zone, to be specific.

The type of this SCC was intergranular one. Since sensitization of stainless steel can cause intergranular SCC, we measured the degree of sensitization at the cracked part by the electrochemical reactivation method and found that the portion was highly sensitized. The sensitization had been caused by heat effect of welding. Pitting or crevice corrosions were not found.

Fortunately SCC was discovered before the crack grew to an extent to allow the vapor leak out. By that time, the crack depth was one-third of the thickness of the reactor wall. So we could repair it by welding.

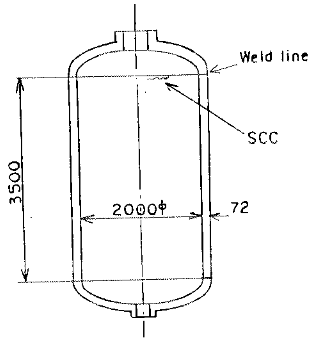


Fig. 1 Reactor

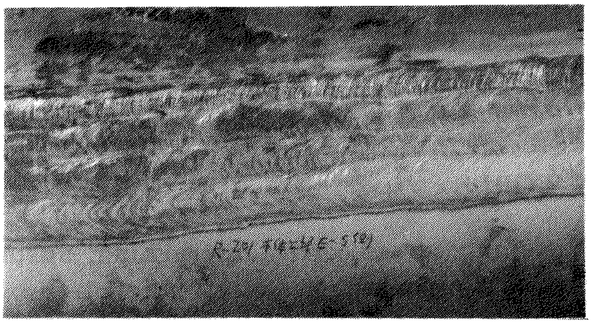


Fig. 2 SCC along weld line

After the repair, we applied shot peening to the vapor zone of the reactor to change tensile stress at the surface caused by welding to compressive stress. The head of the reactor, made of low carbon stainless steel (SUS 304L), was not sensitized and did not require shot peening. We used stainless steel (SUS 304) shots that measured 0.5mm in diameter.

In July 1990 or after seven years of operation, we inspected the reactor and found no SCC. We measured residual stress at peened surface by X-ray technique. The measurement was $-15 \sim -50 \times 10^7$ N/m^2 and the value was estimated to be enough to prevent SCC.

Absorber Column

After ten years of operation, an extensive SCC was found at the bottom head of the column along the weld line. The SCC was of intergranular type, and was attributed to sensitization at the heat-affected zone of welding. The sensitization was enhanced by plastic deformation of head material caused during production of the head. In this case too, pitting or crevice corrosions were not found.

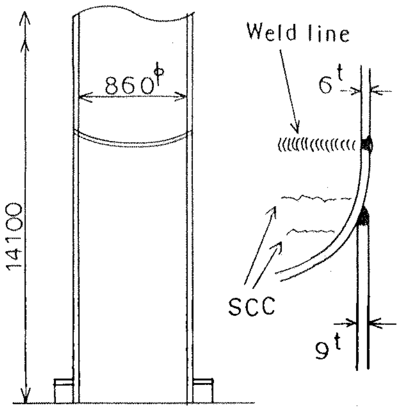


Fig. 3 Absorber column

The cracked part was removed by gouging and then filled by welding. To prevent SCC, the repaired part was shot peened. In this case too, stainless steel shots were used. Since this action was taken, the column has been operating successfully for eight years.

Gas Separator

In a rectangular box-type vessel used to separate methylene chloride from steam, SCC was found after six months of operation. There were a number of cracks--about 30-50mm in length--which crossed the weld line and had grown to leak the vapor through the 4mm-thick tank walls. The SCC was of transgranular type attributable to the influence of chloride.

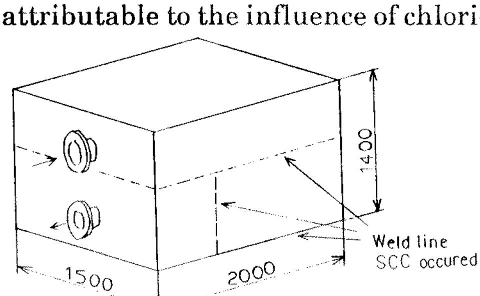


Fig. 4 Gas separator

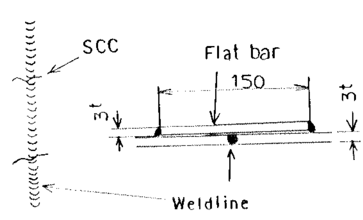


Fig. 5 Repair method

In this case, there were too many cracks for us to repair one by one. We therefore covered all inner weld lines by welding flat bars. To prevent SCC due to tensile stress caused by welding, the welded zone was shot peened.

In May 1988 or six years after the repair, we inspected the equipment and found that it had operated successfully. Meanwhile, internals which had not been peened were found severely cracked.

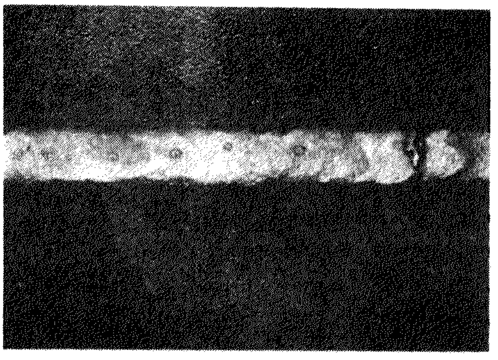


Fig. 6 Shot peened (No SCC)

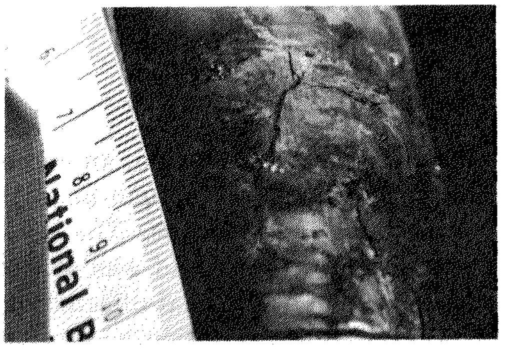


Fig. 7 Internals not peened (SCC)

PROCESS OF SHOT PEENING

Equipment and shot

(a)Peening equipment

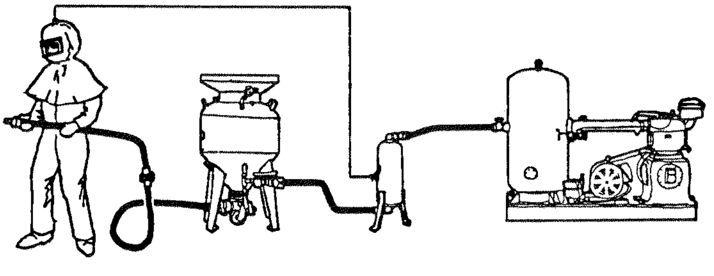
The equipment must be portable for applications at plant sites. So we employed common blast machines which are used for surface preparation for painting steel structures.

(b)Compressor

Unless compressed air was available at the site by pipeline, we used portable air compressors. The capacity of compressor is related mainly to the size of nozzle. For example, when the nozzle is 8mm and 10mm in diameter, the compressor capacity should be 15kW and 22kW, respectively. Outlet air pressure is about 7×10^5 Pa.

Fig. 8

Peening equipment



(c) Specifications of shots

Austenitic stainless steel shots were selected. We did not use common carbon steel shots because we were afraid that fragments of carbon steel shots adhered to the surface of material might cause corrosion. Stainless steel shots were made by cutting wire and accordingly their shapes were cylindrical.

Recently, however, we have adopted costless carbon steel shots to replace stainless steel shots because we have found that carbon steel shots do not corrode targets.

Test of Peening Condition

Essential conditions are:

a) Arc height exceeds certain target values.

b) Coverage is 100%.

The above two conditions must be checked before peening at the site since air pressure, valve size, air hose diameter and other factors differ case by case.

Peening Conditions (example)

Size of blast machine		200ℓ
Air hose diameter		25mm
Nozzle size		8mm
Compressor specification		22kW; 7×10^5 Pa
Shots	stainless steel (SUS 304)	0.5mm
Distance between nozzle and target		300-500mm
Peening time		15 min.~1 hr./m^2
Arc height		0.2mm A scale

Manpower for Peening

When the target area is smaller than $10m^2$, one supervisor and two workers are enough. Workers must be protected from shots and dust by a protective device. Chemical equipment usually has a nozzle at its bottom and shots can be recovered through the nozzle.

Inspection of Peened Surface

After peening, surface of the target should be visually inspected to make sure that its coverage is 100%.

SCC Testing Method

Sometimes we need to convince plant maintenance managers of the effectiveness of shot peening in preventing SCC.

In actual environment, it usually takes a long time to initiate SCC. By performing a laboratory test with a 42% magnesium chloride solution, however, we can demonstrate the effectiveness in a short time.

We use relatively large welded specimens for the ease of peening. Austenitic stainless steel (SUS 304) plates are welded to produce a specimen measuring 100mm×150mm×6mm.

As residual tensile stress of welding is generally larger than 0.2% proof stress, unpeened specimens crack in a few hours in the 42% magnesium chloride solution. Meanwhile, peened specimens do not crack in one or two weeks' time.

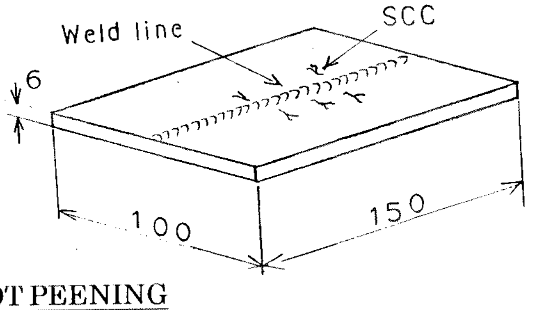


Fig. 2 SCC test specimen

MERITS AND DEMERITS OF SHOT PEENING

Merits

The greatest merit of shot peening is that its cost is low. It takes only 15 min.~1 hr. to peen 1 m^2 of target area. Equipment for peening is simple and shots can be recycled.

Since shot peening can be accomplished in a short time, it is suitable for repairing equipment during a tight-scheduled plant maintenance.

Demerits

The thickness of a subsurface zone where residual stress is compressive is about 0.2~0.3mm. Accordingly we cannot apply shot peening when pitting or crevice corrosions have occurred and the corrosion has become greater than the subsurface zone in depth.

However, we have experienced many cases in which only SCC occurred (with no corrosion) and therefore shot peening was applicable.

Shot peening is not applicable to inner surface of tubes, crevices and other parts where workers cannot apply nozzles.

OTHER MEASURES TO PREVENT SCC

Alloy change

This means use of ferritic or dual phase stainless steels which are less susceptible to SCC. To prevent intergranular SCC, low carbon austenitic stainless steel is useful.

This measure, however, is costly. So long as shot peening is applicable, use of austenitic stainless steel is recommended because it is economical. We have that experience regarding equipment used in a cooling water environment.

Cathodic protection

We have many experiences in applying cathodic protection to hot water reservoirs. In the case of equipment with a complicated shape, heat exchangers for example, application of this measure is rather limited because of the difficulty in obtaining uniform current distribution.

Heat treatment for stress relieving

Stress relieving is commonly applied to ferritic steels such as carbon steel or low alloy steel. Austenitic stainless steel has high strength at high temperatures. It is accordingly difficult to apply the stress relieving method to austenitic stainless steel and actual applications are quite few.

CONCLUDING REMARKS

It has been known since 1961 that peening can prevent SCC. However, shot peening is not yet the prevailing way for the prevention of SCC.

Main reasons for that are:

1) Its effectiveness is not properly recognized.
2) Concrete ways of application is not widely known.

In addition, there are several problems to be solved including the question of how to develop peening method for inner surface of tubes or crevice.

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