# Controlled Shot Peening Can Help Prevent Stress Corrosion Cracking

Bob Gillespie
Metal Improvement Company
Paramus, New Jersey USA

## Introduction

It is now a well known fact that controlled shot peening (CSP) is an effective means to retard or prevent stress corrosion cracking (SCC). In order for SCC to occur, static tensile stress must be present at the surface of the susceptible material (Fig. 1). SCC cannot occur in an area of compressive stress. The compressive stresses induced by shot peening have proven to be successful in the retardation and prevention of stress corrosion cracking. During the Second International Conference on Shot Peening (I.C.S.P.2), Mr. Paul Feld reported five case histories where shot peening was successfully used to combat SCC (Ref. 1). The author will discuss the status, three years later, of two of those applications. In addition, the author will discuss two additional applications.

**Conditions Required for Stress Corrosion Cracking to Occur**

- Static Tensile Stress at Surface
- Susceptible Material
- Corrosive Environment
- Sufficient Time

Fig. 1:

## Case History I - Digesters

Problem: Catastrophic failure due to SCC in a continuous digester led to the discovery of similar cracking in over 40% of units in use of this type and manufacture. Continuous digesters are approximately 60 meters high and 9 meters in diameter (Fig. 2). They are made of A212B steel plate which is about 4.5cm thick. Welds with and without stress relief showed cracking when inspected with the wet fluorescent magnetic particle method (WFMP). The environment is strong caustic solutions containing aggressive compounds (sulphides and sulphites are felt to be particularly detrimental) with temperatures exceeding 90 degrees Celsius and pressures in excess of 750MPa. Extensive investigations of potential solutions to digester SCC have been conducted. Controlled shot peening has been one of the possible solutions investigated.

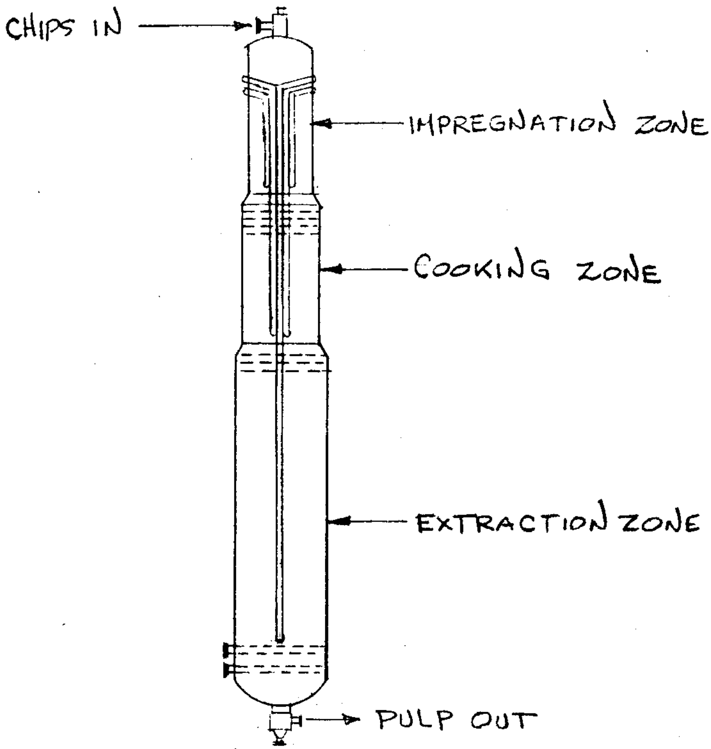


Fig. 2: Continuous Digester

Treatment: Shot peening with 230 shot to an intensity of 17A to 20A. Coverage, 100%. Depth of compression is estimated to be .5cm.

Results: A great deal of time and monies have been expended in the development of a test method which could be used to evaluate potential solutions to the digester problem. A successful test method was developed by the Pulp and Paper Research Institute of Canada (Ref. 2). Once the test method was available, investigations were conducted regarding possible solutions to digester stress corrosion cracking. These possible solutions included: shot peening, overlay welding, plasma spray coating and anodic protection. The results of testing done on shot peened specimens was excellent. No SCC was found to initiate in any shot peened surface. In fact the only SCC found in any of the shot peened specimens initiated in an area adjacent to and propagated into the shot peened zone. These results indicate shot peening should be an excellent solution to the digester problem.

During the years the above mentioned SCC test was developed and testing was being performed, many digester owners began to shot peen their digesters as peening was the most economical of the potential solutions. Shot peened digesters were inspected for evidence of subsequent cracking at intervals of 3 to 12 months. These inspections showed stress corrosion cracking in shot peened surfaces. However, the number of cracks and their depth were normally reduced. But SCC had occurred in surfaces that were previously shot peened - very disturbing news! How could these cracks have occurred?

There were a few possible explanations: 1) not all cracks were discovered and removed during the inspection and rework operations preceding shot peening, 2) the shot peening was not done correctly, 3) the entire area needed to be protected was not completely shot peened, 4) the residual stress induced by shot peening was somehow removed.

In other investigations, it was learned that almost all of the digesters involved are chemically cleaned during operation, at least two times, and as many as five or six times per year. This cleaning operation is normally done with 10% to 15% hydrochloric acid at 50 to 75 degree Celsius. Testing done under these conditions indicate that as much as 0.35cm could be removed from the surface of the A212B material during such an acid cleaning operation. Also learned was the general corrosion rate of the material in the digester environment could be as high as 0.5cm per year. The depth of the compressive layer induced by shot peening is typically 0.5cm.

It is fairly obvious the loss of material in both chemical cleaning operation and general corrosion during operating conditions could remove the compressive stress in only a few months. Despite the fact that laboratory testing indicates that shot peening should be an excellent solution to the digester problem, the actual service conditions involved negate some of the beneficial effect of shot peening. Under the service conditions described above, shot peening is considered a temporary solution to the stress corrosion problem plaguing these digesters.

Case History No. II - Stripping Columns

Problem: Stainless steel (type 304 or type 316) stripping columns have failed in service due to SCC. A stripping column can be from 12 to 20 meters in height by approximately 1 meter in diameter (Fig. 3). SCC failure is caused by the action of a chloride environment in the inside of the column and tensile stresses found in the heat affected zone (HAZ) of welds and in formed areas in the heads of the columns. Typically, SCC can be observed after two to three years of service.

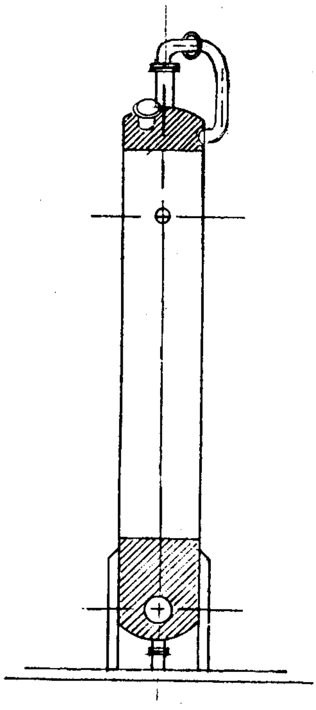

Fig. 3: Stripping Column

Treatment: Shot peen all interior surfaces in top and bottom heads as well as partially up and down the sides (see cross hatched areas of figure 3) using cast steel 170 shot to an intensity of 12A to 14A, followed by glass bead peening for decontamination. Coverage is 200%. Note: In recent years the shot peening callout has been modified by many users to: stainless steel cut wire 23 shot to an intensity of 12A to 16A, 100% coverage verified by Peenscan process.

Results: No failures have been reported after over five years of service in the stripper column reported by Mr. Feld (Ref. 1). In addition, no failures have been reported in approximately 15 stripper columns shot peened since 1982.

Case History III- Ammonia Spheres:

Problem: SCC has been discovered in Met grade (99.9% pure) ammonia spheres. These spheres are approximately 18 meters in diameter made of A286 steel plate (Fig. 4). Stress corrosion cracks occur in the HAZ of welds in the interior of the sphere. It has been reported that this SCC is not as severe in three adjacent spheres due to the lower purity ammonia (higher $H_2O$) environment of the adjacent spheres.

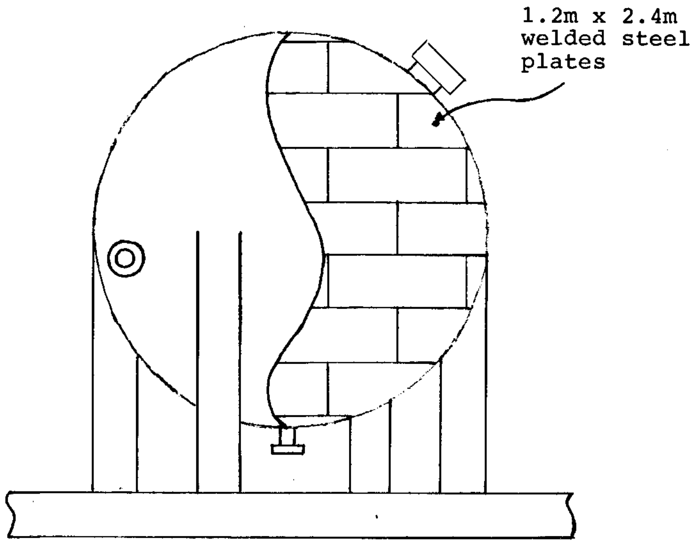


Fig. 4: Ammonia Sphere

Treatment: Shot peen an area 5cm either side all welds in the interior of the sphere using 550 cast steel shot to an intensity of 3C to 6C with 100% coverage. The total repair sequence of the subject spheres is; 1) steam clean, 2) magnetic particle inspect (MPI), 3) grind out existing cracks, 4) MPI, 5) weld in new material, 6) MPI, 7) shot peen.

Results: SCC is significantly reduced (by a factor of at least 50%), if not eliminated in this application. Explanation of why SCC was not totally eliminated is that not all of the original cracks or corrosion pits are removed during rework. Since the depth of the compressive stress induced by shot peening using these parameters is approximately one millimeter, any corrosion pit or previous crack which is deeper than one millimeter will act as sites for additional stress corrosion cracking.

Case History IV - Steam Generator Tubing

Problem: Nuclear power plants are concerned with SCC in roll expanded portions of Inconel 600 steam generator (SG) tubing. In order to stay in position inside the SG, Inconel 600 tubing is expanded into their tube sheet (Fig. 5). Residual tensile stresses are created in the inside surface (roll transition area) of the SG tubing during tube expansion operation. Contaminates in the primary side (ID) water which flows through the tube acting with the tensile stress induced could be sufficient to allow SCC to occur.

Treatment: Shot peen the roll transition region of the ID of the SG tubing using computer controlled and monitored shot peen equipment built specifically for this application. Also used is special corrosion resistant alloy shot developed for this operation.

Results: An accelerated sodium tetrathionate test and a standard sodium hydroxide test were conducted on shot peened and non-shot peened tubing roll expanded under identical conditions as in service (2 to 6% wall thinning). An important consideration in the evaluation of this application was that there be no detrimental effect in SCC resistance of the secondary side (OD) surfaces of the SG tubes. There was no SCC observed in any 2 to 6% roll expanded shot peened tube in either test (Ref. 3). In addition, there was no observed reduction in SCC resistance on secondary side surfaces. Computer controlled shot peening is in use today as an acceptable method to help retard SCC of Inconel 600 steam generator tubing.

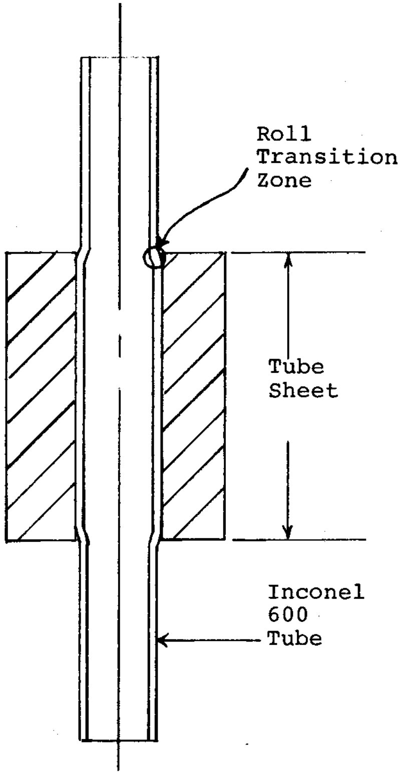


Fig. 5: Steam Generator Tubing

In summary, these case histories clearly show shot peening cannot only retard SCC but can prevent it in many cases. As long as nothing is done to remove the surface compressive stress induced, shot peening is effective in eliminating SCC. In all cases, one should look at the entire application in order to be aware of any conditions which may remove or relieve the compressive stresses and thereby reduce the potential effectiveness of shot peening in combating SCC.

References

(1) P. G. Feld, R. D. Gillespie: "Controlled Shot Peening Reduces or Eliminates Stress Corrosion Cracking", I.C.S.P.2 (1984) pages 121-125.

(2) D. L. Singbeil, O. A. Garner: "Stress Corrosion Testing of Full-Thickness Digester Weldments", Pulp and Paper Research Institute of Canada.

(3) F. P. Vaccaro, B. P. Miglin, J. V. Monten, G. J. Theus, J. N. Helmey, A. L. Jenkins: "Effect of Shot Peening on Transition Stress Corrosion Cracking of Alloy 600 Steam Generator Tubing", Corrosion 87 Paper #87.