Improvement of the Welding Joints and Components by Shot Peeing for IIW

I. HUTHER[1], E. DANIEL[2]

1 CETIM, Senlis, France
2 METAL IMPROVEMENT COMPANY, Amilly, France

Abstract
The commission XIII of the International Institute of Welding published in 2007 a document call "recommendations for fatigue design of welded joints and components". It presents various processes to improve fatigue life after welding. Shot peening is well known to improve fatigue life of metallic materials, including welded joints and components, but it has never been properly qualified for the IIW recommendation. In order to include the benefits of shot peening in this paper, METAL IMPROVEMENT COMPANY together with CETIM Senlis, achieved fatigue test to qualify it. The samples are longitudinal non-load-carrying fillet welds, done in DOMEX 700, a hot rolled high strength steel from SSAB Tunnplat, 8 millimeters thick. 12 samples have been peened by METAL IMPROVEMENT COMPANY and 3 not. They have been fatigue tested at CETIM SENLIS with 3 load levels up to 2 000 000 cycles at R=-1 and R=0.1 to quantify the benefits of shot peening. Shot peening is introducing compressive residual stress and also improving the geometry of the weld toe. It is the projection of hard shots made in steel, stainless steel, ceramic or glass of various sizes (diameters from 50 µm to 3 mm). There is also the control of the intensity and of the coverage rate (minimum 100%) of the treatment in order to get a uniform compressed layer. It can be apply manually till fully automatic controlled machines. It is used for more than 60 years to treat fatigue, fretting, pitting (contact fatigue), stress corrosion cracking, intergranular corrosion or thermal fatigue. It is applied for single as well as serial parts in all industrial fields: aerospace, automotive, energy, power generation, medical or general industry. Fatigue test have been done with 3 loads levels up to 2 000 000 cycles at R=0.1 and R=-1 in order to quantify the effect of compressive load on the fatigue life. The results are good. At 2 X 10^6 cycles, the average stress level is 126 MPa for the as-welded samples and 221 MPa for the shot peened samples. It is an improvement of 75% of the fatigue life. The residual stress level has also been measured at the surface of the part close to the welded area and gives also good results of -500 to -650 MPa.

Keywords Shot peening, welding, IIW.

Introduction
The commission XIII of the International Institute of Welding published in 2007 a document called "recommendations for fatigue design of welded joints and components". It presents various processes to improve fatigue life after welding. Whilst shot peening is well known to improve fatigue life of metallic components, including welded joints and components, it has never been properly qualified in the IIW recommendations [1] [2]. In order to include the benefits of shot peening in the future IIW recommendations, Metal Improvement Company together with Cetim, started a procedure to qualify it.

Samples design
The samples are longitudinal non-load-carrying fillet welds (see Figure 1), done in DOMEX 700, a hot rolled high strength steel from SSAB Tunnplat, 8 mm thick.

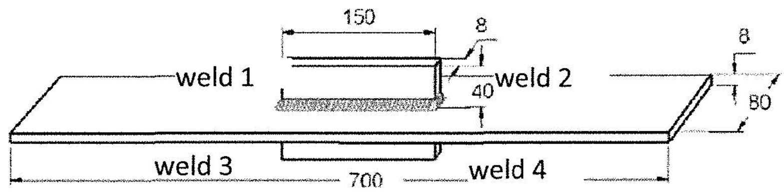

Figure 1 Sample design

Twelve samples have been peened and three not.
To characterize the weld beads, the toe radii of the welds were measured (Figure 2). The values are given on Table 1 (as-welded) and
Table 2 (shot peened).

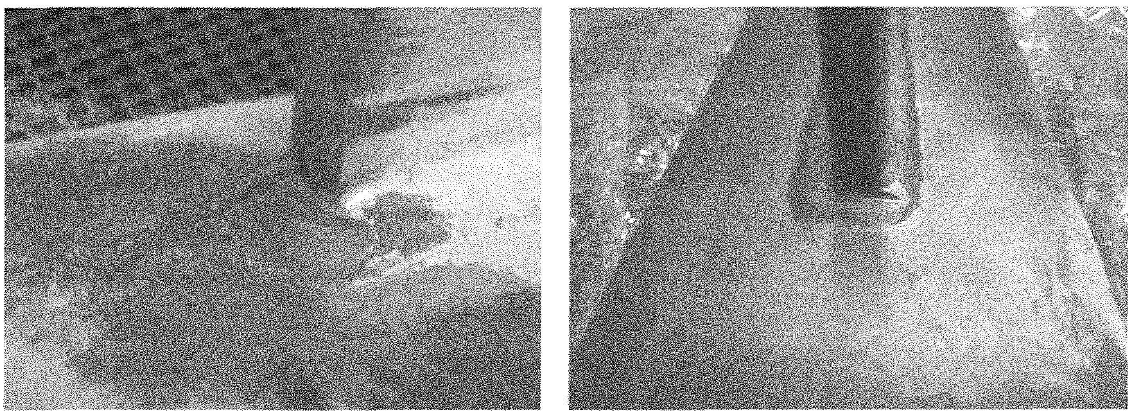
Figure 2 Weld shapes, as-welded and shot peened

Table 1 As-welded joints

	radius (mm)		
	B1	B2	B3
weld 1	3.6	1.4	1.8
weld 2	6.0	5.4	4.3
weld 3	7.2	4.3	3.5
weld 4	7.9	3.2	3.4

Table 2 Shot peened welded joints

	Radius (mm)									
	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Weld 1	6.2	3.3	0.8	5.0	5.1	6.2	5.4	7.0	7.9	5.4
Weld 2	9.3	4.7	7.4	5.7	3.1	10.8	5.1	8.3	4.4	5.4
Weld 3	1.1	4.2	6.4	3.2	4.4	3.5	3.9	5.1	7.4	4.0
Weld 4	2.7	2.6	5.0	3.9	6.7	1.9	1.8	6.1	4.3	4.5

Shot peening parameters
Shot size : MI 170 H
Almen intensity: F 35-40 A
Controlled by PEENSCAN
Automatic machine

Test conditions
The fatigue tests were performed in tension and in tension-compression on a vibrophore with a maximum capacity of 450 kN.

The test frequency is equal to 120 Hz.
The stop criterion is the specimen failure or 5 millions of cycles.
The tests of as-welded joints and some shot peened joints were performed with a stress ratio of R = 0.1 in order to compare with those of IIW "round-robin" on fatigue improvement [4] [5]. The other shot peened joints were tested at R = -1 to study the influence of a compressive load on fatigue behavior. The specimens were tested on two stress levels.

Fatigue test results

The fatigue test results are given on Fgiure 3 with as-welded joints (AW), shot peened R = 0.1, shot peened R = -1.
The crack initiations are localized at the weld toe for as-welded joints (Figure 4) and at the weld root for shot peened joints at R = 0.1 (Figure 5). As the depth of compressive stress introduced by shot peening is less than 1 mm, it is normal that the crack initiates at the weld root.

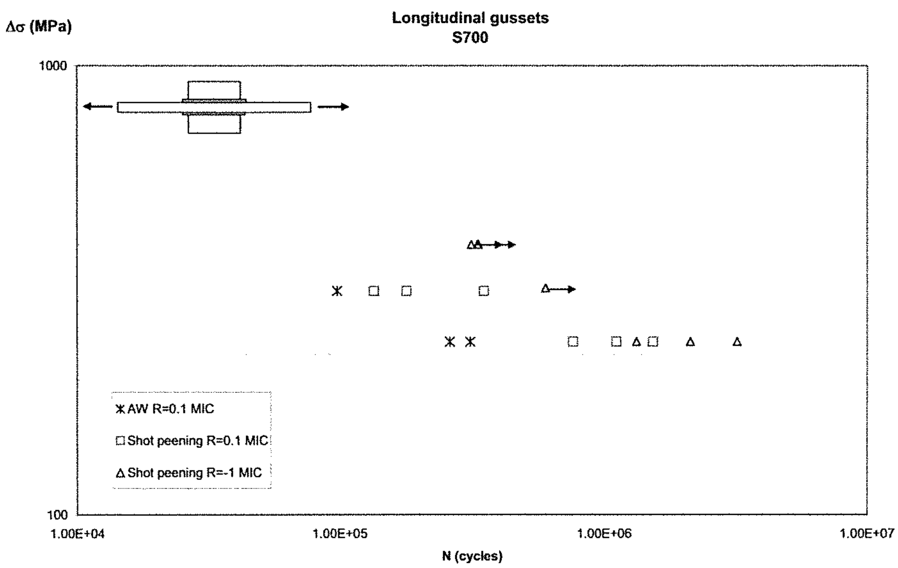

Figure 3. Fatigue test results

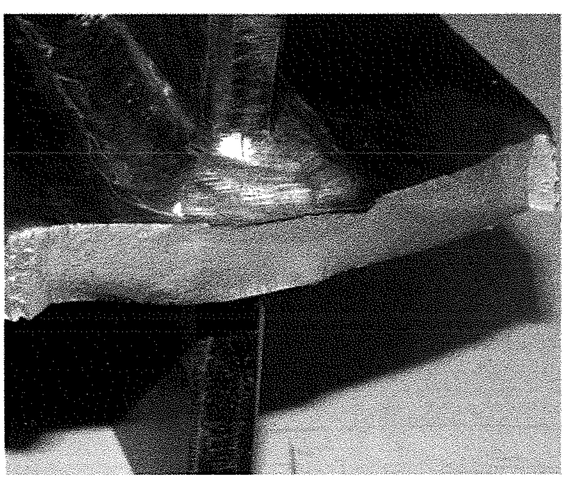

Figure 4. Crack initiation on as-welded joint (weld toe)

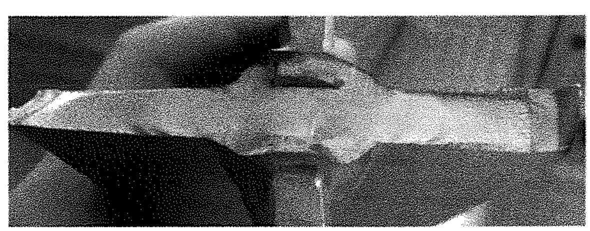

Figure 5 Crack initiation on shot peened joints (weld root)

Discussion

Residual stress level on surface

The residual stress estimation was performed near the weld toe in longitudinal direction as shown on Figure 6 by X-ray diffraction.

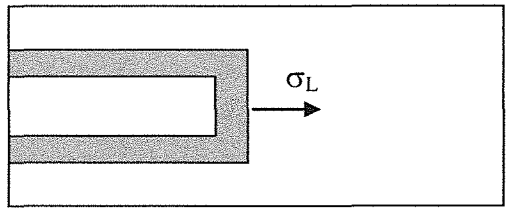

Figure 6. Residual stress measurement direction

On shot peened welded joint (G3), the results of the estimation on surface are:
- near the weld toe (weld 1) : $\sigma_L = -507 \pm 8$ MPa
- near the weld toe (weld 3) : $\sigma_L = -651 \pm 10$ MPa

It is important to note that the maximum compressive level is in depth with shot peening.
Comparison with IIW round robin as-welded results
The test results were compared with the as-welded results of IIW "round robin" (see Figure 7 and Figure 8.
Figure 7 shows that the as-welded joint results are better than those of IIW "round robin". It may be noted that the weld toe radii are of the order of 2 mm whereas those of IIW "round robin" were of the order of 0.7 mm.

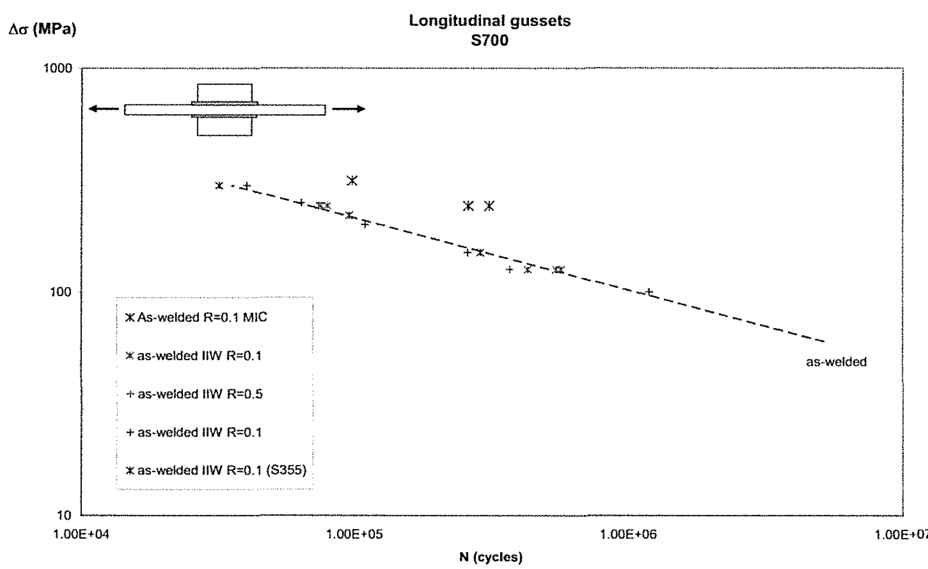

Figure 7. Comparison of tests with as-welded results of IIW round robin

Figure 8 illustrates the mean S-N curves for "round robin" as-welded joints, for as-welded joints and shot peened joints (R = 0.1).
Comparing the results at 2.10^6 cycles, the "mean" stress range is equal to:
- for round robin as-welded joints: *82 MPa*
- for present study as-welded joints: *126 MPa* (gap of 50% with round robin),
- for shot peened joints: *221 MPa* (75% of improvement with regard to as-welded).

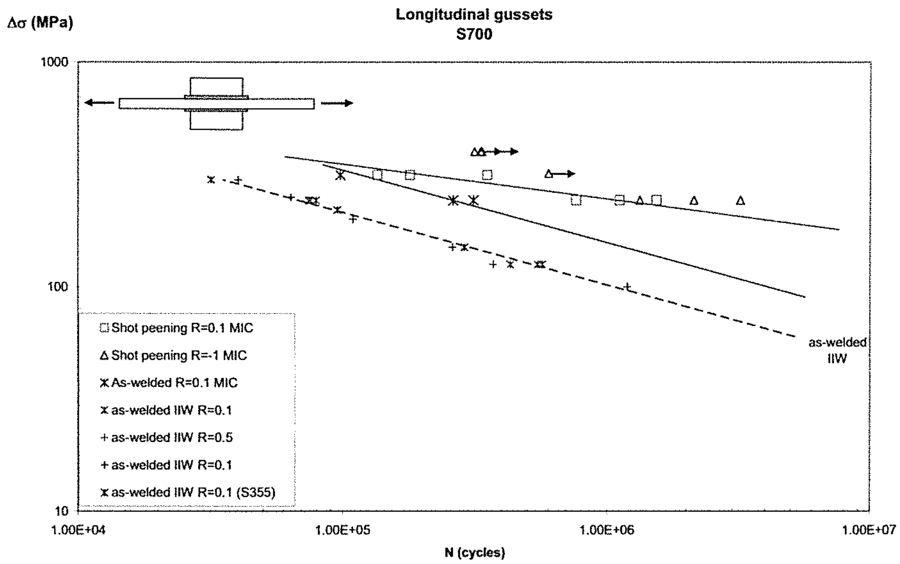

Figure 8. Mean S-N curves of tests (as-welded and shot peened R = 0.1)

Comparison with IIW round robin UIT/UP hammer peened results
The test results were compared with the UIT/UP hammer peening results of IIW "round robin" (see Figure 9).
The shot peening results are better than the UIT/UP hammer peening results [4].
It is important to note that the shot peening improves the fatigue strength by a factor of 1.75 compared to as-welded.
The fatigue strength at 2.10^6 cycles observed for hammer peening is in the range of 180 MPa. It is less than the fatigue strength after shot peening amounting to 221 MPa.

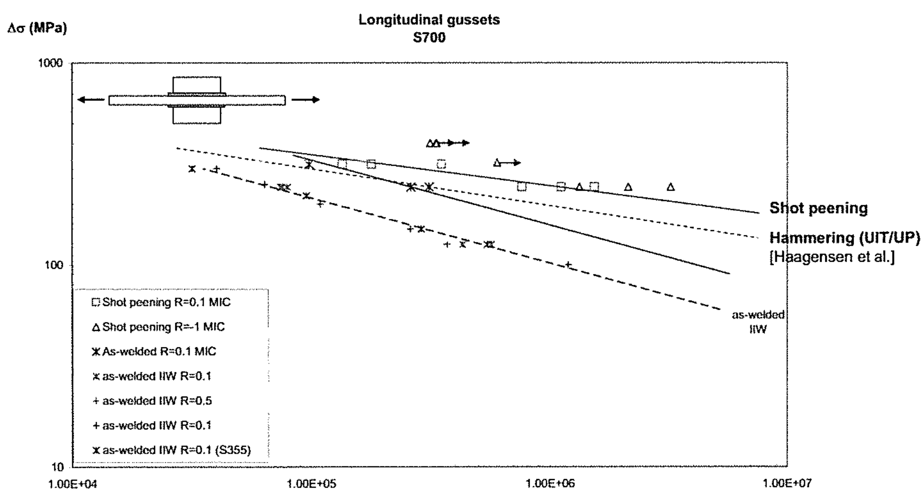

Figure 9. Comparison between shot peening and UIT/UP peening

Conclusion

The aim of this study was to characterize the fatigue behavior of longitudinal non-load-carrying fillet welds being shot peened.
Fatigue tests were performed on as-welded joints to have a reference and on shot peened joints with a stress ratio equal to R = 0.1 to compare with the results to those of IIW "round-robin" on improvement. Other shot peened specimens were tested at R = -1 to study the influence of compressive load on fatigue behavior. The estimation of residual stress levels on a shot peened joint were in the region of -500 to -650 MPa at the surface.

The results of as-welded joints are better than those of IIW "round robin" tests.
The mean stress range at 2.10^6 cycles is equal to:

- for round robin as-welded joints : *82 MPa*
- for as-welded joints of this study : *126 MPa* (gap of 50% with round robin),
- for shot peened joints : *221 MPa* (75% of improvement with regard to as-welded). It is better than *180 MPa* for the round robin hammer peening.

References

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