Mechanical treatment of welded and brazed joints

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Abstract
The study deals with the mechanical treatment of joints of different materials on steel and aluminium. The treatment is a high frequency peening process, which should improve the fatigue strength by implementation of residual compressive stresses and by reducing the notch effects in the region of the fusion line. The studies on welded thin sheets of a self-hardening hard and a precipitation hardening aluminium alloy, as well as welded joints madeof cold rolled fine grain steels with large thickness differences will be reported. Furthermore, the effects on the properties of brazed sheet metal joints will be presented. It will be shown that mechanical treatment-processes have the capability, depending on the joining mechanisms, to extend the life-cycle of joints.

Keywords High frequency peening, fine grain steels, brazed aluminium

Introduction
In the field of lightweight structures, the viability of welded joints under cyclic load is a critical area in construction and operation. The Institute of Welding and Machining (ISAF) executed various studies to increase the cyclic load-bearing capacity. The fatigue performance of cyclically loaded components can be improved by various post-treatments of the thermal fusing line and the heat affected zone (HAZ) [1], [2], [3], such as shot-peening. A high frequency impact treatment based on pneumatic techniques was chosen to perform all testings. The post-treatment process by high frequency impact treatment includes two different approaches to improve the mechanical properties (cf. [4]):

1. Improvement of weld geometry to reduce stress concentrations
2. Change in the seam stress profile by introducing residual stresses

The mechanical-treatment methods (f.e.: Ultrasonic Impact Treatment (UIT); Pneumatic Impact Treatment (PITEC)) which are used for technical purposes are shown in [5]. Subsequently a selection of studies performed by ISAF is presented. A general overview is given by three completely different areas of the executed studies. First, the influence on fatigue strength of welded aluminium alloys is presented followed by the description of influences on fatigue strength of brazed steel joints, concluded with an overview of investigations on joints with sheet thickness variations of ultra high strength fine grained structural steels. All mechanical treatments presented were performed with a high frequency impact treatment tool based on pneumatic excitation (PITEC). Otherwise, it is stated separately.

Experimental Methods
Welded Aluminium Joints
Aluminium sheets (see [4]) of AlMg3 and AlMgSi1 welded with a MIG pulsed arc process with AlMg5-filler (1.2 mm wire diameter, shielding gas 30 % helium 70 % argon) were used for testing procedures. A two-stage mechanical treatment in the weld seam region has been performed. Step 1 intended a treatment of the seam transition operated by hand. A mechanized mechanical treatment was omitted due to the irregular seam shaping. Step 2 intended the treatment of the heat affected zone (0.5 mm, feed 1 m/min track offset) by an automated process. A variation of two process parameters, the processing pressure and the working frequency were realized. In addition to hardness measurements fatigue-specimen (SEP1240;

LCF shape, Low Cycle Fatigue) were taken to perform cyclic tests (stress ratio: R = 0.1). A method of consecutive load steps for the different treatment conditions was used.
Investigated treatment conditions:

- Base material
- Welded
- Treated only in the seam area
- In addition, treated next to the seam

The fatigue limit was set at two million load cycles. The chosen failure criterion was the complete specimen fracture.

Brazed Steel

The studies [6] of brazed steel sheets were carried out on the grades HCT780XD and HCT780XD + Z. The used base materials were dual-phased steels processed in the automotive industry. These were joined with various solder-material and brazing-processes (CuSi3Mn1; CuSn6P; CuAl7). The sheets of 0.8 mm and 0.9 mm thicknesses were joined by a regulated short arc process (Fronius CMT®) as well as with a plasma hybrid process. Again, the corresponding SEP1240 (LCF shape, Low Cycle Fatigue) samples were taken from the seam area and tested in untreated and treated conditions. The post-treatment conditions were set to a working frequency of 90 Hz and a working pressure of 4 bar. In order to perform the comparison with another post-treatment method shot-peened (SCCW (spherical conditioned cut wire); grain size 350µm; 3 bar) specimens were examined. Flanged seams were used for brazing with the plasma-hybrid-process. In contrast, double-sided soldered joints have been created with a regulated short arc process. A method of consecutive load steps was used to perform the cyclic tests.

Welded fine grain steel with sheet thickness differences

The last study deals with the thermal joining of ultra high strength fine grained structural steels of large plate thickness differences. The joining of the steel S700MC with a standard fine grain steel filler (14341-A G 50 7 M21 4Mo) was examined. T-shaped specimens were chosen to evaluate the weldment in order to obtain a realistic loadcase. The specimen geometry is shown in Figure 1. All welding was performed with the same energy input at the lower end of the process window. The treatment parameters used are: feed 0.006 m/s (approx. 9 hits/mm²) and 0.018 m/s (approx. 27 hits/mm²), working pressure 6.0 bar, and an operating frequency of 120 Hz. Planar and linear treatments were studied. All transitions between the weldment and ground metal were treated. Two different treatment strategies have been executed. The area treatment contained the weldment and the heat affected zone. As opposed to the area post-treated specimen the line post-treatment strategy contained only the transition area between filler and base metal.

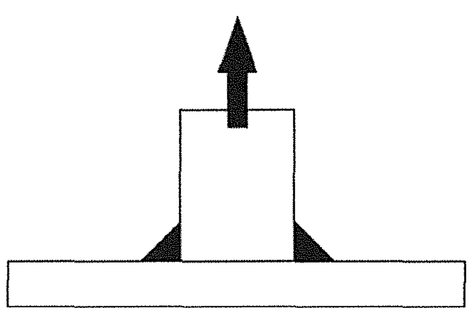

Figure 1: T-shaped specimen geometry (schematic)

The fatigue limit was also set to two million load cycles. The chosen failure criterion was the complete specimen fracture. A method of consecutive load steps was used to perform the cyclic tests.

Experimental Results

Welded Aluminium Joints

The results of fatigue tests on welded aluminium sheets suggest that an improvement in fatigue strength can be achieved by a treatment with high frequency impact treatment methods. 2a-b clearly indicate significant increases in fatigue life for the low cycle fatigue and for the fatigue limit. However, the deviations within the measurement series increase by treated specimen compared to the untreated.

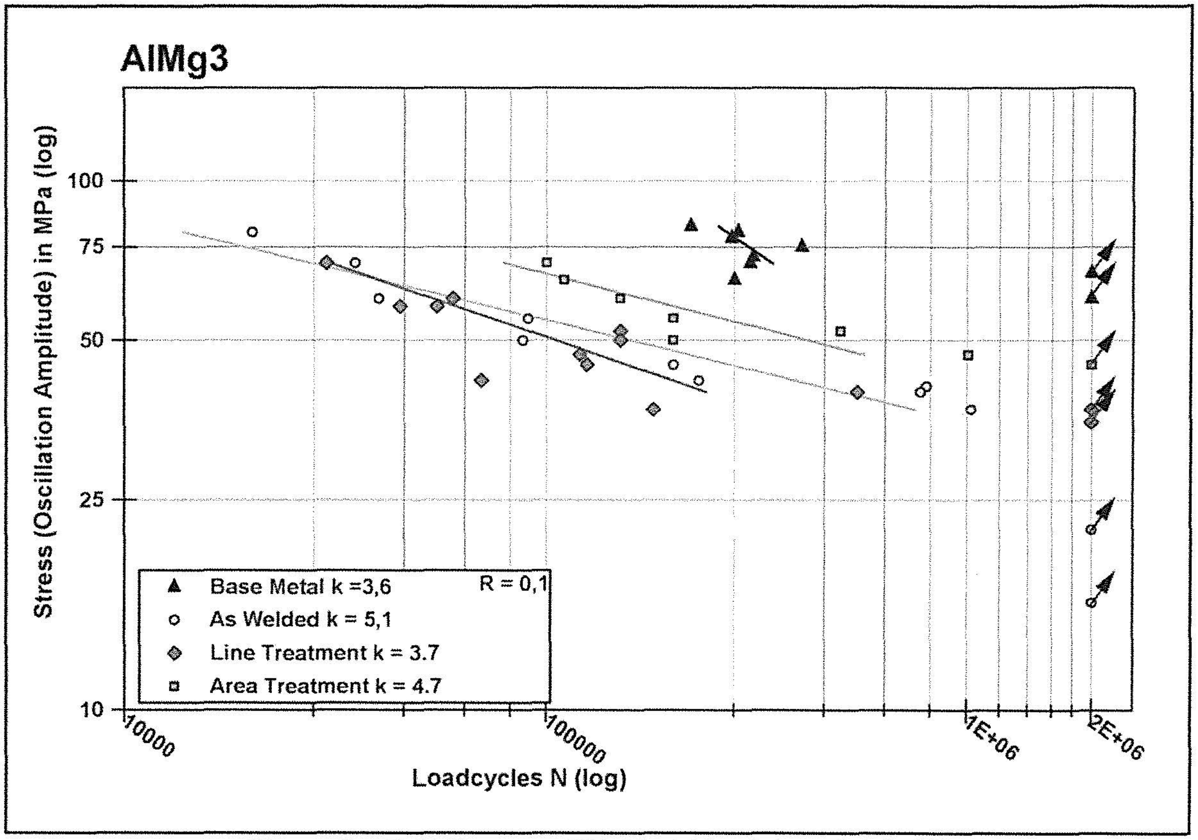

Figure 2a: S-N Curves of Welded Aluminium Joints [4]

Brazed Steel

A significant increase of fatigue strength in brazed joints of high strength steel sheets could not be detected for double-sided brazed joints (Figure 3). As stated in [6], a significant increase of fatigue strength could be detected for flanged seams in combination with the plasma-hybrid-process.

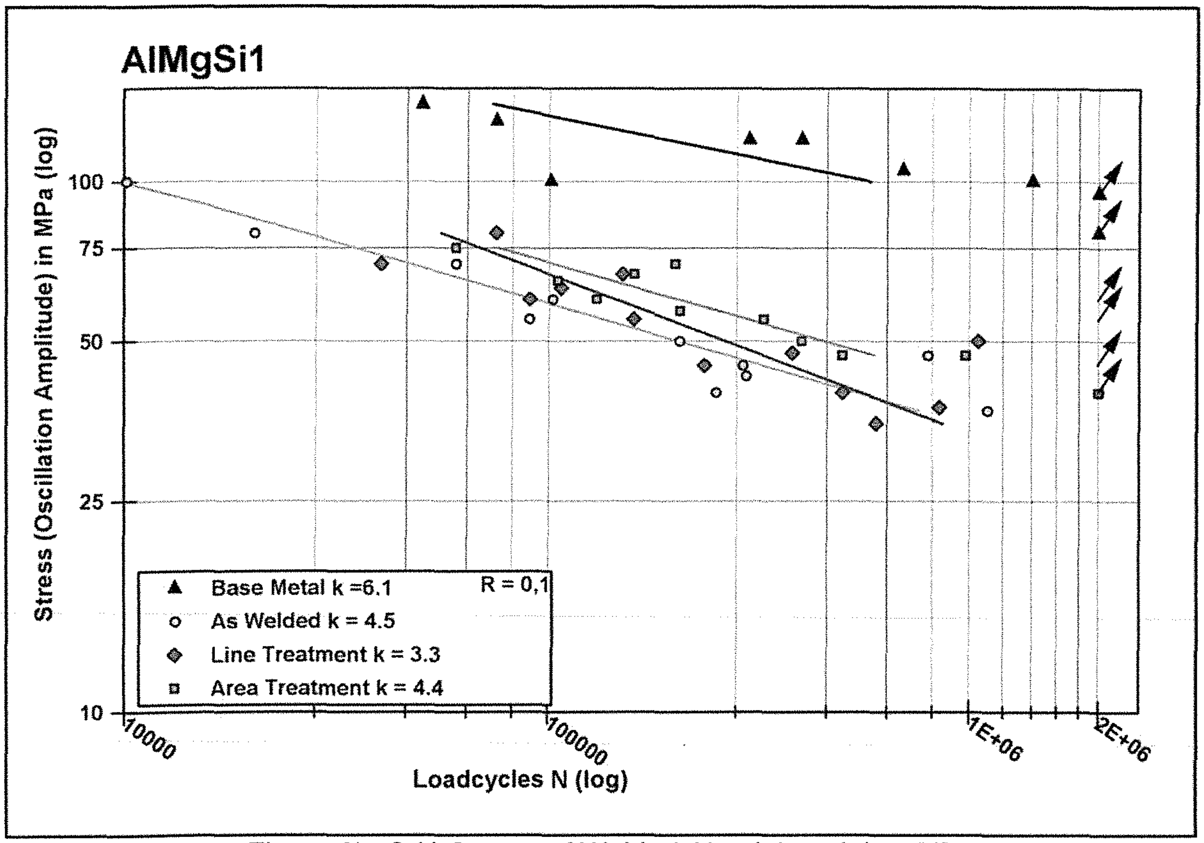

Figure 2b: S-N Curves of Welded Aluminium Joints [4]

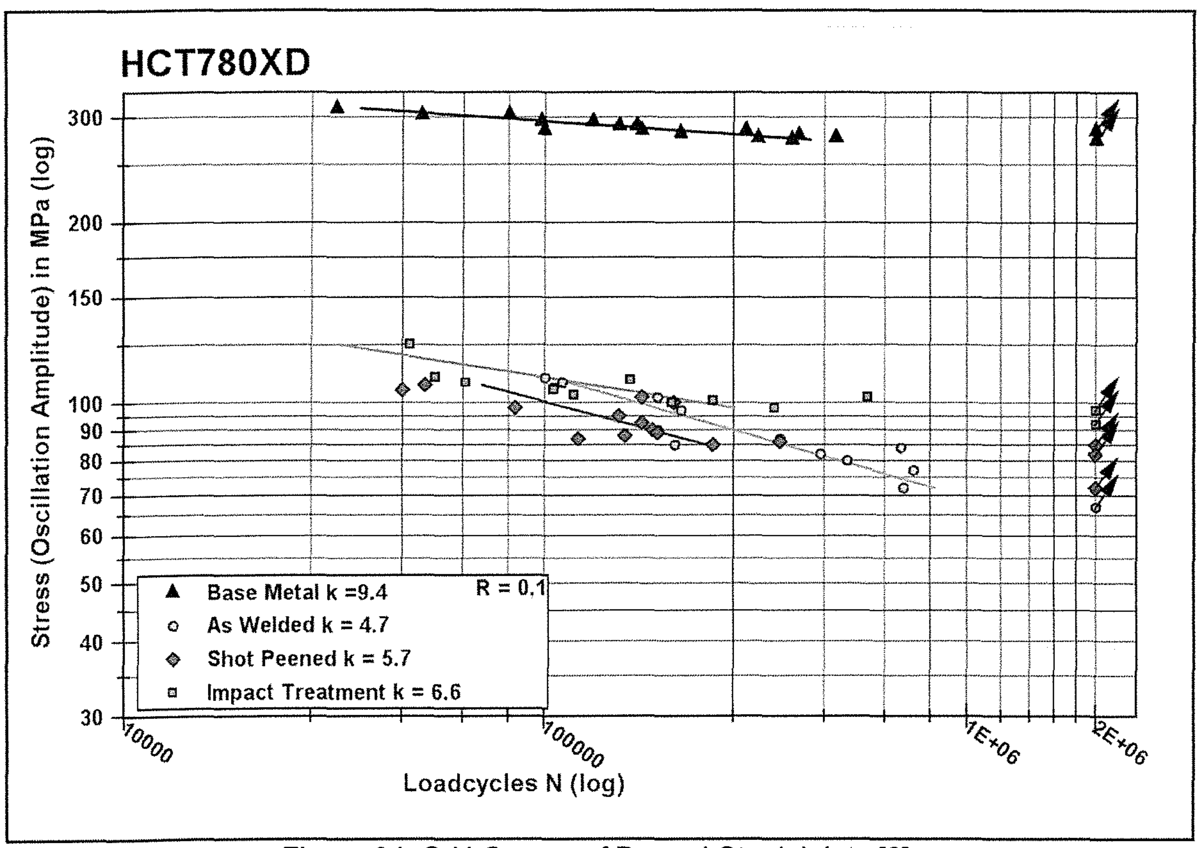

Figure 34: S-N Curves of Brazed Steel Joints [6]

Welded fine grain steel with sheet thickness differences

The fatigue behavior of welded fine grain steel before and after an impact treatment is significantly different. The fatigue limit had been increased by approximately 55 % compared to the welded state for area treated specimen (Figure 4). The fatigue strength overall has been expanded over the level of the base metal by more than 40 %. A significant variation between 9 and 27 hits/mm² was detected for area treated specimen. The 27 hits/mm² test series showed a smaller increase in fatigue limit and fatigue strengths compared to the 9 hits/mm² series. Compared to the welded state, a fatigue strengths improvement of 28 % was reached for the 9 hits/mm² series. As shown in Figure 4 significant increase of the fatigue life overall or the fatigue limit in particular for the line treated specimen could be obtained. The increase of the fatigue limit is not as high as the increase for the 9 hits/mm² area treated test series.

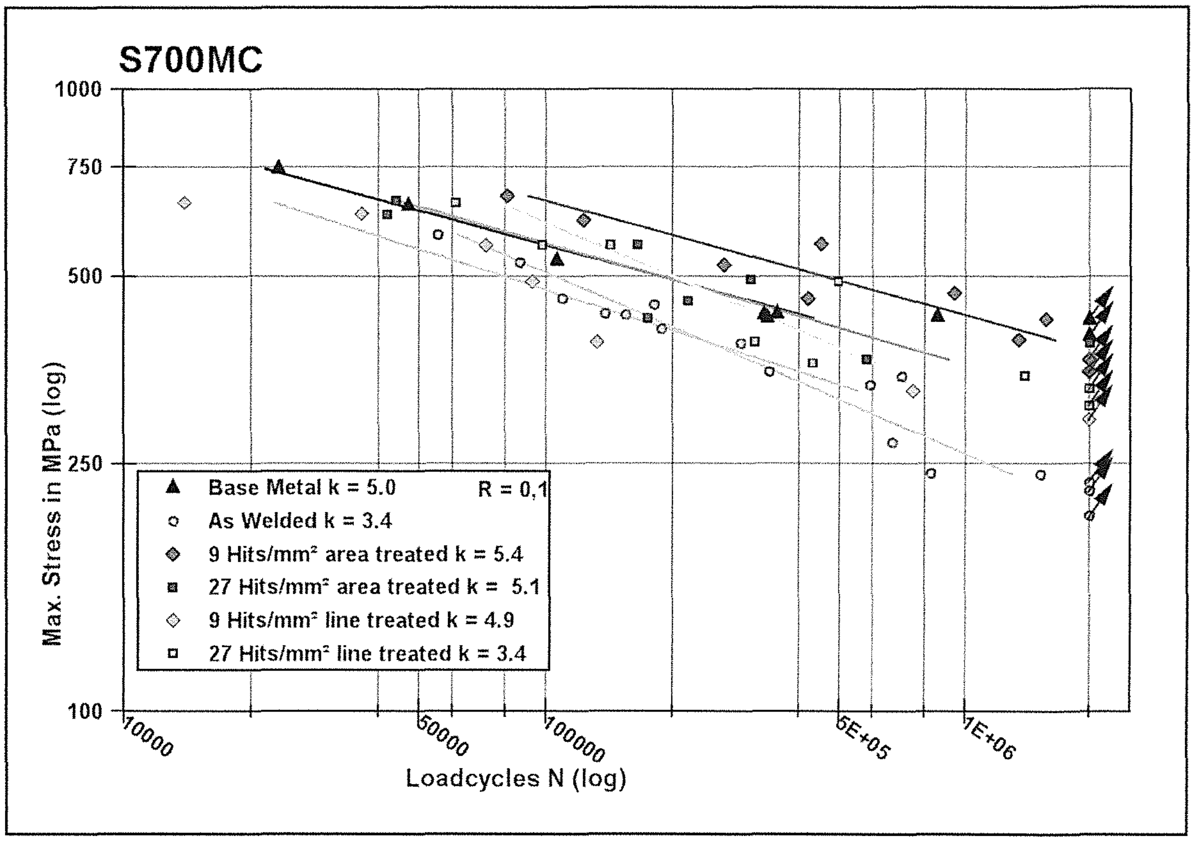

Figure 4: S-N Curves of Welded Fine Grain Steel

Conclusions

The three different joint-types with their post-treatment show clearly different fatigue behavior under cyclic load. The weldments clearly show enhanced fatigue strength up to ca. 55 % for steel and up to ca. 45% for the shown aluminium joints. On the contrary the brazings had not shown a significant improved fatigue behavior. This may be due to the different joining types. The solder-material connects via adhesion between the join parts and the thin solder-material sheet. An implementation of residual comprehensive stresses has only small effects on the adhesive joining. Looking at brazings, the brazing itself is the weakest connection part. However the melted and affected areas in welding processes have their weakest point in the HAZ. The implementation of residual comprehensive stresses has a big effect on the fatigue behavior of the HAZ in welded joints as shown in the results for the welded S700MC fine grain steel. Furthermore, the studies on fine grain steels and aluminium clearly show that those positive effects occur only for area treatments.

High frequency impact treatments have the capability to enhance the fatigue strengths for various applications, especially for high loaded welded joints.

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