TALAT Lecture 4400

Friction, Explosive and Ultrasonic Welding Processes of Aluminium

11 pages, 11 figures

Basic Level

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Objectives:

– to give a brief introduction to friction, explosive and ultrasonic welding techniques of aluminium
– to describe the possibilities and results of joining aluminium to different metals, e.g. stainless steel

Prerequisites:

– General mechanical engineering background
– Basic knowledge in aluminium metallurgy

Date of Issue: 1994

4400 Friction, Explosive, and Ultrasonic Welding Processes of Aluminium

Table of Contents

4400.01 Friction Welding

- ♦ Principle of friction welding
- ♦ Feasibility of friction welding aluminium with other materials
- ♦ Tensile strength of friction welded aluminium-steel joints
- ♦ Hardness curves in the joint region
- ♦ Preparation and conduction of friction welding for an Al-Cr-Ni-steel joint
- ♦ Friction welding parameters

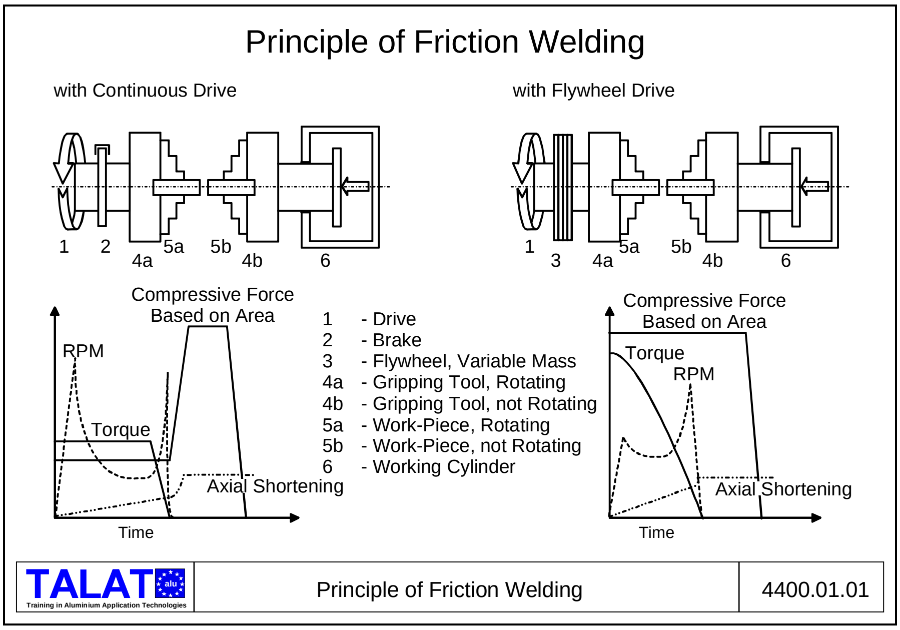
Principle of Friction Welding

Friction welding is a process in which mainly rotationally symmetrical parts are rotated while being pressed together, thereby generating heat of friction which causes the parts to weld.

There are two main variations of this process:

- friction welding with a continuously applied drive
- friction welding using a flywheel drive

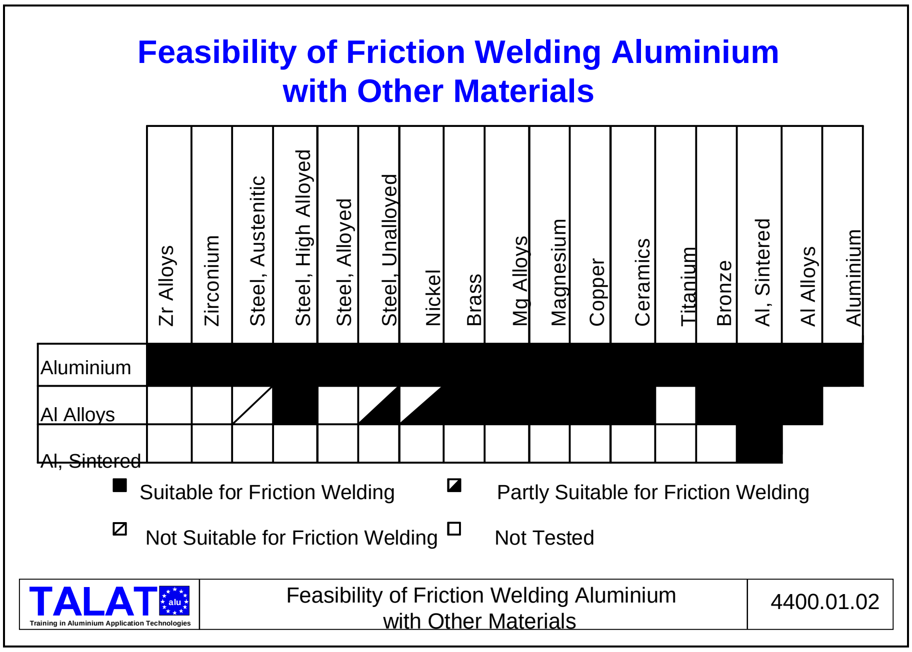
Characteristic for the continuous drive is an externally applied brake. The flywheel drive, on the other hand, delivers its stored energy to the process thereby slowing down itself. Consequently, this leads to differences in behaviour of the two methods regarding torque and the compressive force being brought to bear (**Figure 4400.01.01**).



Feasibility of Friction Welding Aluminium with other Materials

The material data alone are not sufficient to indicate whether friction welding can be successfully employed. Consequently, a number of alloys which cannot be welded by other welding processes, can be welded effectively using friction welding. Parts to be joined by the friction welding process, must have a sufficiently high strength to be able to transmit the axial pressure and frictional moment as well as a sufficient hot forming capacity.

Pure aluminium is ideally suited for friction welding. Out of the large number of aluminium alloys and powder metallurgical materials available, there are still some whose suitability for welding has still to be tested (**Figure 4400.01.02**).



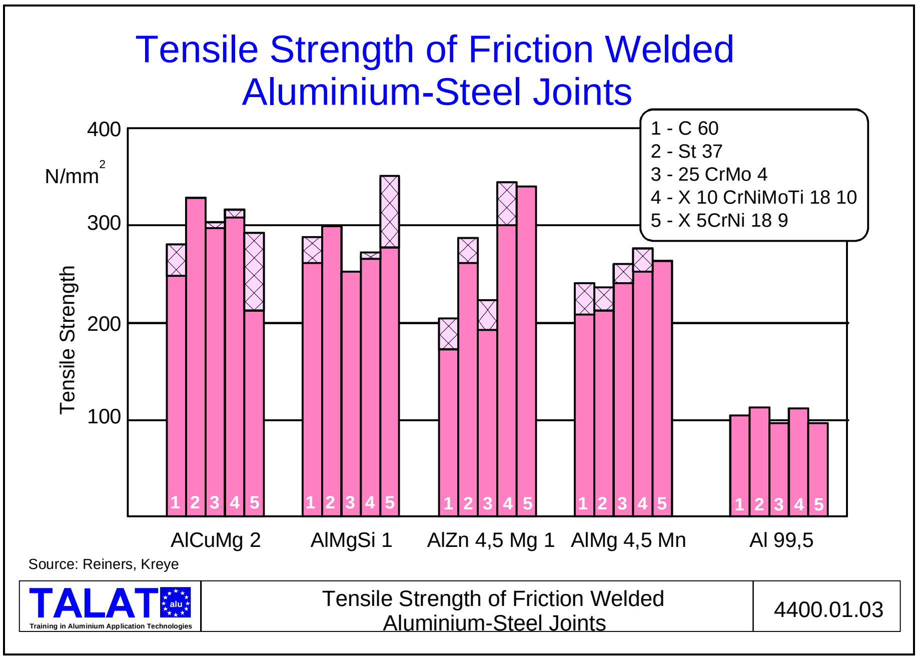
The following disadvantages limit the applicability of friction welding :

- The creation of low-melting phases or brittle intermetallic compounds.
- The softening of aged alloys.
- The amount and distribution of non-metallic inclusions.
- Hardening effects of the material combinations.

Tensile Strength of Friction Welded Aluminium-Steel Joints

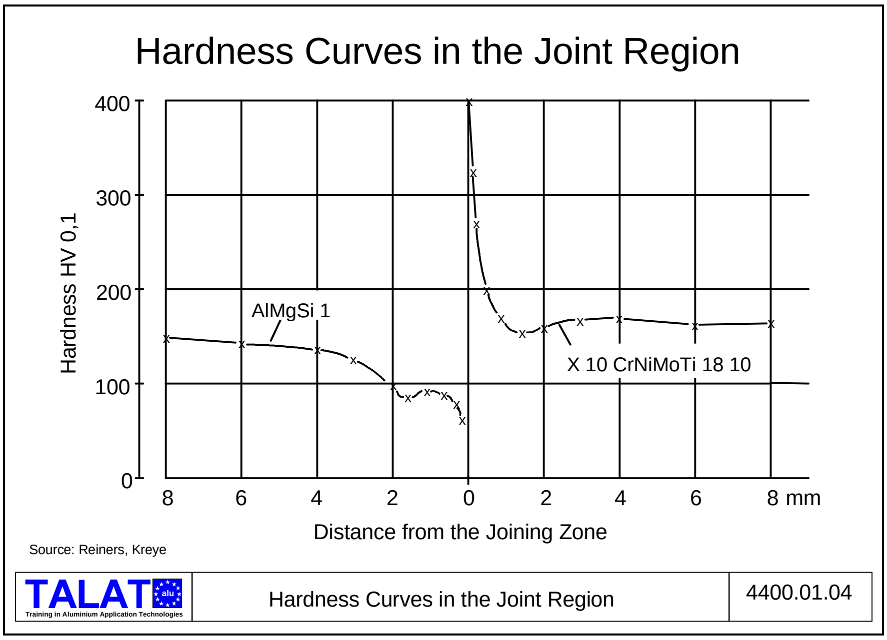
Experiments with friction welding on different aluminium and steel alloys (for parameters see **Figure 4400.01.06**) have shown that strengths exceeding the yield stress of aluminium and steel can be attained. There is no straightforward correlation between strength of alloys and strength of friction welded joints (**Figure 4400.01.03**)

Consequently, one can assume that other factors play an important role here. Such composite joints exhibit brittle fractures with little plastic strain at the joining plane. This is a result of the different mechanical properties of steel and aluminium. The resulting inhibition of plastic deformation at the contact surface which occurs under the influence of multi-axial state of stresses leads to the preferential building of cracks at these sites.



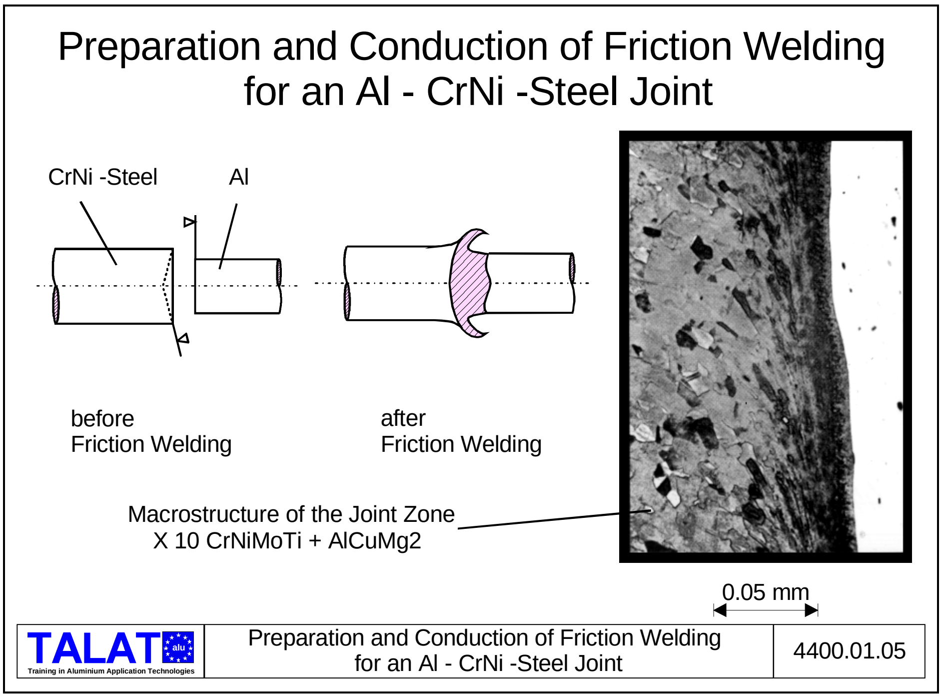
Hardness Curves in the Joint Region

The short welding times lead to correspondingly high hardness values. For aluminium joints this is less of a problem than for composite joints of aluminium with steel. The very narrow bonding plane, characteristic for the process, shows hardness peaks only in a region of 100 to 200 µm (**Figure 4400.01.04**). Austenitic steels have a higher strain hardening coefficient than ferritic steel and therefore reach higher hardness values. In heat-treatable alloys the precipitates can go into solution, causing a softening of the alloy. In heat-treatable alloys which respond to natural ageing, a precipitation of the hardening particles occurs at room temperature, causing the hardness to rise again.



Preparation and Conduction of Friction Welding for an Al-Cr-Ni-Steel Joint

The different thermal properties of the materials have to be taken into account while preparing the welds. The surface area of materials with a low thermal conductivity should be increased, in order to deliver a joining zone with good properties. In this region, the grains are highly deformed (**Figure 4400.01.05**).



Friction Welding Parameters

Friction welding of aluminium with itself and its alloys as well as with steel is characterised by extremely short welding times and high frictional and compressive forces. As a result, the joining plane is kept extremely narrow, so that intermetallic compounds and phases cannot be built. The diffusion zone characteristic for this region is thus kept very small (< 1µm).

Friction Welding Parameters

Material	Diameter (Massive) mm	Area-based Frictional Force N/mm^2	Area-based Compressive Force N/mm^2	Friction Time sec	Compression Time sec	Circumferential Speed m/sec
Al 99,5 + Al 99,5	20	10 ... 30	30 ... 80	0,1 ... 4	2 ... 5	2,0 ... 4,0
AlMgSi0,5 + AlMgSi0,5	20	30 ... 80	50 .. 150	0,1 ... 6	2 ... 5	0,5 ... 2,0
Al 99,5 / AlMg4,5Mn / AlMgSi1 / AlZn4,5Mg / AlCuMg2 + St 37 / C 60 / 25 CrMo4 / X5CrNi18 9 / X10CrNiMoTi18 10	20	40 .. 70	65 .. 250	0,1 .. 1,1	3 ... 4	1,2 ... 2,3

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Short friction times for aluminium are only relevant in connection with a rapidly increasing force the friction and compressive phases (**Figure 4400.01.06**).

4400.02 Explosive Welding

- Principle of explosive welding
- Macrostructure of explosive welded joints

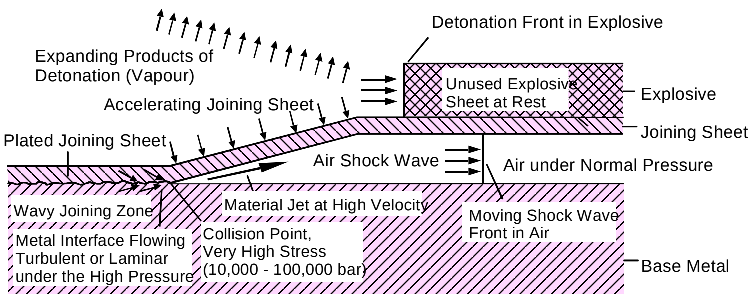
Principle of Explosive Welding

Shock waves (3,000 to 9,000 m/s) can produce pressures of up to 6 x 10^6 N/cm^2. This energy is utilised for explosive welding, especially for plates with large areas.

The shock waves spread out and create a "material wave" at the joining plane. At the collision point a thin jet of material is heated to a high temperature, causing melting and mechanical mixing at the interface (**Figure 4400.02.01**).

Aluminium can be effectively welded with itself and also with steel and copper giving composite joints.

Principle of Explosive Welding



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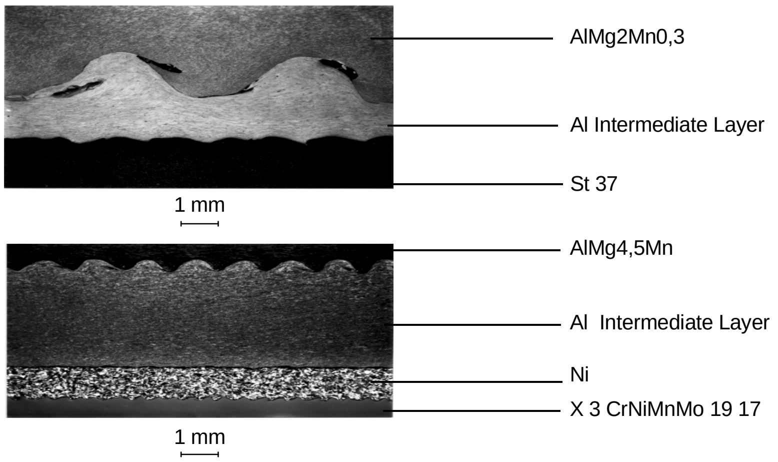
Macrostructure of Explosive Welded Joints

The detonation force waves can be clearly seen as waves in a microsection. "Multiple explosive welding" can be used to join a number of materials of different thicknesses (**Figure 4400.02.02**). Even here it is possible to join materials which cannot be joined by other processes.

Macrostructure of Explosive Welded Joints



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4400.03 Ultrasonic welding

- ♦ Principle of ultrasonic welding
- ♦ Joint forms with ultrasonic welding
- ♦ Material combinations for ultrasonic welding

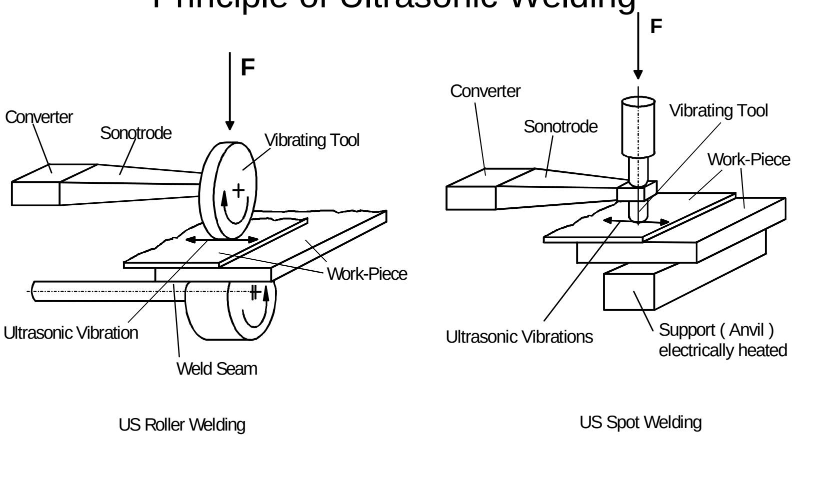
Principle of Ultrasonic Welding

In ultrasonic welding, frictional heat produced by the ultrasonic waves and force is used for the joining process. Ultrasonic waves (15 to 60 kHz) are transferred to the material under pressure with a sonometer. Welding times are lower than 3 s. The welding can proceed with or without the application of external heat (**Figure 4400.03.01**).

Joint Forms with Ultrasonic Welding

The principle of the process limits the allowable mass of material on the sonotrode side to a maximum of 10 g. The maximum thickness that can be welded, depends on the self-damping characteristics of the work-piece material. A main advantage while welding aluminium is the fact that the vibrations break the oxide layer and transport it to the boundary regions. As a result, mechanical and chemical surface cleaning is not necessary. Surface coatings (e.g. coated wire) and impurities behave in a similar manner. Consequently, a main application area for ultrasonic welding is the contact joining of wires (**Figure 4400.03.02**).

Principle of Ultrasonic Welding



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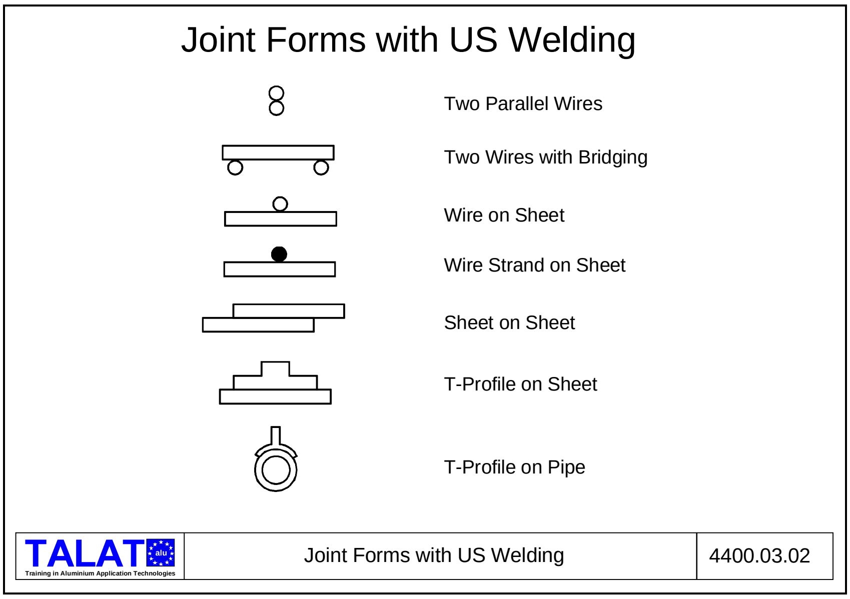

Material Combinations for Ultrasonic Welding

Ultrasonic welding is particularly suitable for joining aluminium and its alloys with each other as well as for producing composite joints with other materials (**Figure 4400.03.03**).

In electrical and electronic applications, the frictional energy creates clean welding zones with low contact resistances.

Hardness influences the weldability of composite joints with steel. Hard alloys are less suitable, since the plastic formability required for the joining is not sufficient. Very often an intermediate layer is used to overcome this deficiency.

Material Combination for US Welding

Al Alloys with	Al Alloys Copper Brass Gold Germanium Steel, Iron Mg Alloys Mo Alloys Ni Alloys Pd Alloys Pt Alloys Si Ag Alloys Ta Alloys Ti Alloys Sn

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4400.04 Literature

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Neumann, A. und Schober, D.: Reibschweißen von Metallen. Fachbuchreihe Schweißtechnik Bd. 107, Deutscher Verlag für Schweißtechnik 1990, Düsseldorf

4400.05 List of Figures