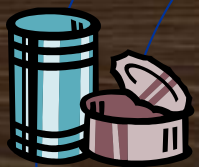
WELDING OF ALUMINUM



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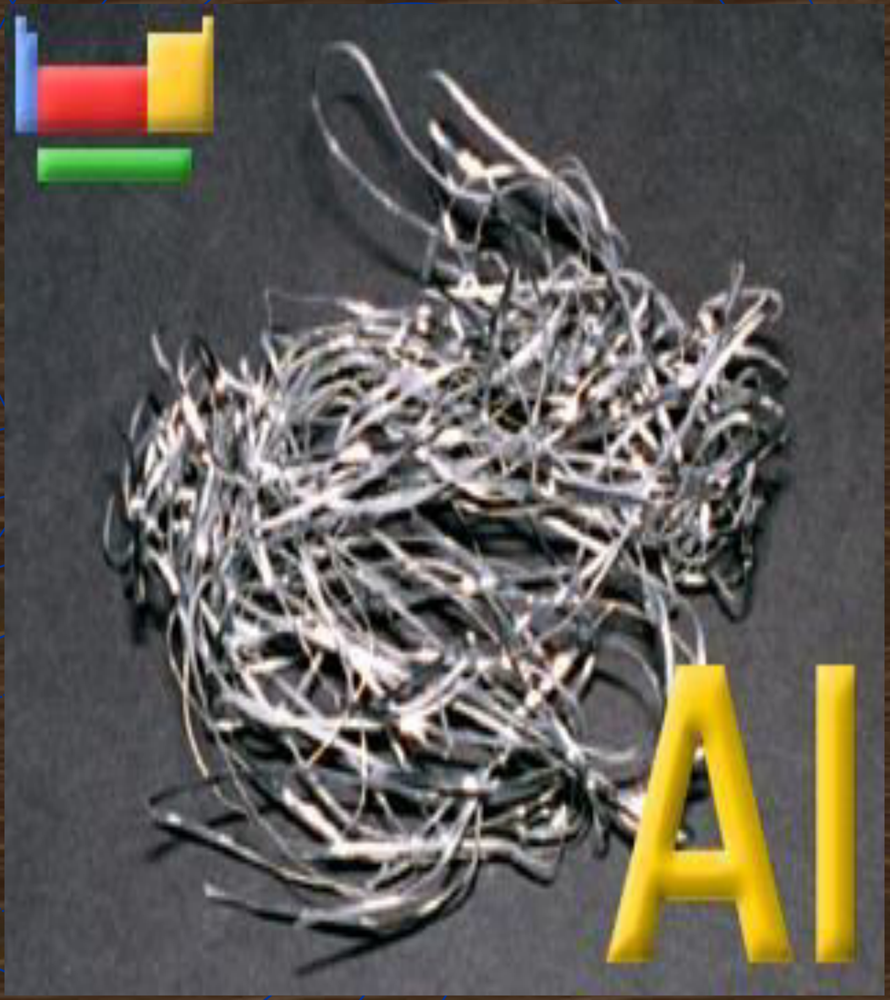
Basic Facts of Aluminum

- Symbol: Al
- Atomic number: 13
- Discovered: Hans Christian Oersted
- Discovered at: Denmark
- Discovered when: 1825
- Discovered how: Hans reacted aluminum chloride (AlCl3) with potassium amalgam (an alloy of potassium and mercury). Heating the resulting aluminum amalgam under reduced pressure caused the mercury to boil away leaving aluminum metal.



Uses of Aluminum

Aluminum is used for many different purposes. Here are a list of some everyday uses of aluminum:

- kitchen utensils
- All kinds of cans and foil
- Aluminum alloys are of vital importance in the construction of modern aircraft and rockets
- Industrial applications where a strong, light, easily constructed material is needed
- Although it's electrical conductivity is only 60% that of copper, it is still used in electrical transmission lines because of its lightness and price.

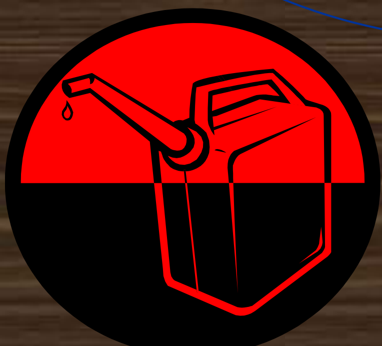
Structural Applications

- Scaffolding and ladders
- Transportation
  - Aerospace, road (trucks, buses, trailers), railway
- Machinery and industrial equipment
  - Non-sparking tools, roofs to tanks, chemical process vessels, jigs, patterns, instruments
- Consumer durables
  - Structure of appliances: refrigerators, furniture, cooking utensils

Recycling Aluminum

- Recycling one aluminum can saves enough energy to keep a 100-watt bulb burning for almost four hours or run your television for three hours.

- Tossing away an aluminum can wastes as much energy as pouring out half of that can's volume of gasoline.



- Aluminum has a high market value and continues to provide an economic incentive to recycle.

Aluminum is the most abundant metal on earth!!!

FEATURES

- Large growth in use since 1950 (6 times)
- Abundant metal - 8% of earth's crust
- Light weight
- Moderate to high strength (depending on alloy)
- Conductivity high (pure metal & low alloys)
- Corrosion resistant
- Reflectivity high
- Non-magnetic

FABRICATION

- Machineability better than steel.
- Cold and hot workability excellent.
- Joined by fusion and non-fusion welding, brazing, soldering and mechanical methods.

Joining Processes

- GTAW and GMAW are the most common processes.
- OFW and MMAW.
- Resistance and pressure welding processes can be used for many alloys.

Alloy Types and Properties

- Strain hardened alloys (plus solid solution hardening)
- Precipitation (age) hardened alloys
- Strength increases at low temperature

Strain Hardened Alloy Tempers

Code	Description
-O	Annealed
-F	As fabricated (no mechanical property limits)
-H1x	Strain hardened
-H2x	Strain hardened and partially annealed
-H3x	Strain hardened and stabilised

Age Hardening Alloy Tempers

- -O and -F tempers as above
- -W: solution treated, but naturally aged
- -T1 to -T10: indicates a combination of hot work, cold work, solution treatment, and aging

Temper Designations

T1	Hot work, then naturally age
T2	Hot work, cold work, then naturally age
T3	Solution treat, cold work, then naturally age
T4	Solution treat, then naturally age
T5	Hot work, then artificially age

Temper Designations

T6	Solution treat and artificially age
T7	Solution treat and stabilise (over age)
T8	Solution treat, cold work, then artificially age
T9	Solution treat, artificially age, then cold work
T10	Hot work, cold work, then artificially age

Aluminum and Welding Processes

- Laser welding doesn't work because Al reflects light.
- Electron beam welding works well.
- Resistance welding is theoretically possible but copper tips used in welding get destroyed too fast.
  - 2000 welds are made on steel before tip is destroyed, only 80 on aluminum.

Major Problem with Welding of Al Alloys

- **Problem**
  - Due to great affinity for oxygen Al Combines with oxygen in air to form a high melting point oxide on metal surface.
- **Remedy**
  - Oxide must be cleaned from metal surface before start of welding.
    - Use of large gas nozzles
    - Use of trailing shields to shield face of weld pool
    - When using GTAW, thoriated tungsten electrode to be used
    - Welding must be done with direct current electrode positive with matching filler wire.

Welding of Aluminium Alloys

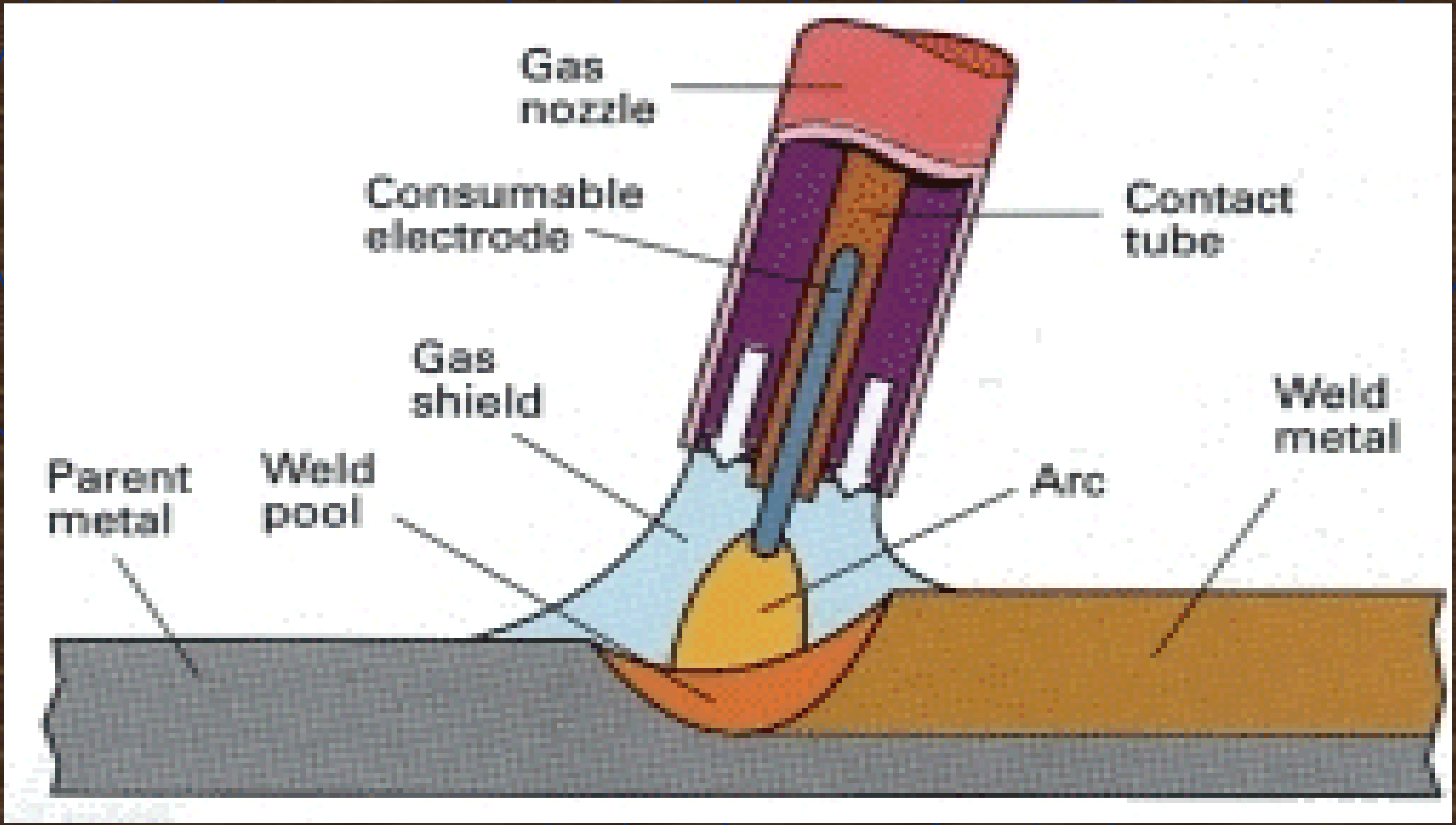
- Most widely used welding process
  - Inert gas-shielded welding
- For thin sheet
  - Gas tungsten-arc welding (GTAW)
- For thicker sections
  - Gas metal-arc welding (GMAW)

- GMAW preferred over GTAW due to
  - High efficiency of heat utilization
  - Deeper penetration
  - High welding speed
  - Narrower HAZ
  - Less distortion

MIG Welding (GMAW)

- Shielding gas is 100% Argon
- Faster than regular steel MIG welding, due to the higher thermal conductivity
- Material must be very clean for effective weld
- Good for long runs and heavy material

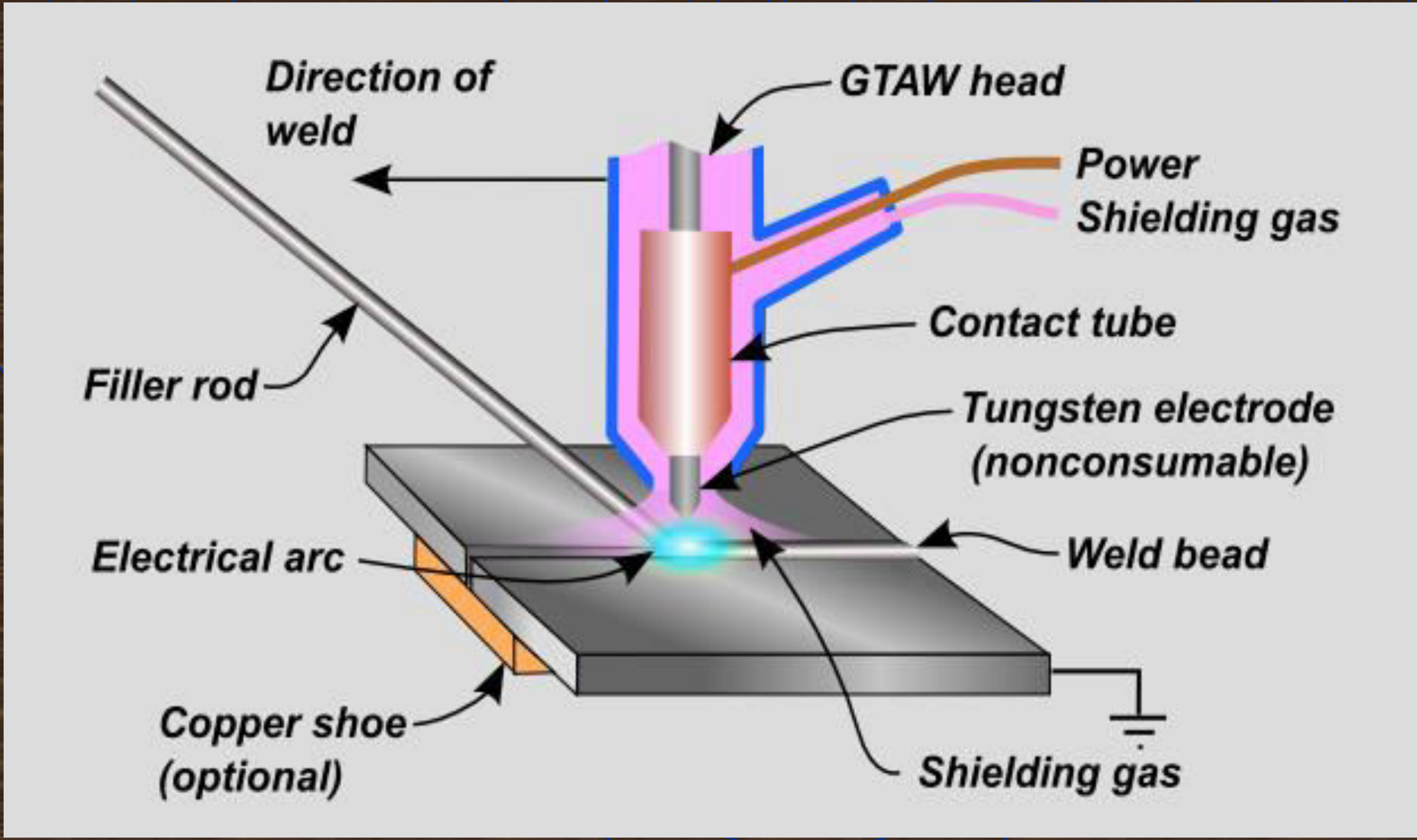
MIG Welding


Gas nozzle
Consumable electrode
Contact tube
Gas shield
Weld metal
Parent metal
Weld pool
Arc

TIG Welding (GTAW)

- Shielding Gas usually Argon
- Tungsten Electrode is used
- Cleans surface while welding, less prep than MIG
- Slower than MIG
- Good for thin metal, seals better than MIG

TIG-Welding Process



Recent Work on Alluminium Welding

Author & year	Research
V. Balasubramanian, (2007)	**Purpose:** This paper reports the influences of pulsed current welding and post weld aging treatment on fatigue crack growth behavior of AA7075 aluminium alloy (Al–Zn–Mg–Cu alloy). **Design/methodology/approach:** Four different welding techniques have been used. Fatigue crack growth behaviour of the welded joints has been evaluated by using servo hydraulic controlled fatigue testing machine. (i) continuous current GTAW (CCGTAW), (ii) pulsed current GTAW (PCGTAW), (iii) continuous current GMAW (CCGMAW) and (iv) pulsed current GMAW (PCGMAW) processes. Argon (99.99% pure) used as the shielding gas. **Findings:** • Pulsed current welding is beneficial to enhance the fatigue crack growth resistance. • Pulsed current gas tungsten arc welded (PCGTAW) joints offered greater resistance for the growing fatigue cracks.

S. Malarvizhi, (2008)	**Purpose:** This paper reports the effect of post weld heat treatment on fatigue behaviour of electron beam welded AA2219 aluminium alloy. **Design/methodology/approach:** An attempt has been made to enhance the fatigue strength of the electron beam welded joints through post weld heat treatment methods such as- • Solution Treatment, • Artificial Aging, • Solution Treatment And Artificial Aging. **Findings:** •The fatigue strength and fatigue life of the AA2219 aluminum alloy have been greatly reduced by electron beam (EB) welding. •The fatigue notch factor and notch sensitivity factor of the AA2219 aluminum alloy have been increased by EB welding.
Hyoung Jin Park, et al. (2009)	**Purpose:** Discussed the characteristics of welds resulting from joining dissimilar alloys, steel SPRC440 and aluminum alloy 6K21. **Design/methodology/approach:** The joint was obtained by means of AC pulse MIG welding, which alternates between direct current electrode positive (DCEP) and direct current electrode negative (DCEN), based on the EN ratio. **Findings:** The arc characteristics in relation with varying EN ratios were analyzed. • As the EN ratio increased, the deposition rate increased. • As the EN ratio increased, the gap bridging ability improved. • As the EN ratio increased, the tensile strength value improved.

A. Kumar (2009)	**Purpose:** Discussed the influence of pulsed welding parameters such as peak current, base current, welding speed, and frequency on mechanical properties such as ultimate tensile strength (UTS), yield strength, percent elongation and hardness of AA 5456 Aluminum alloy weldments. **Design/methodology/approach:** Taguchi method was employed to optimize the pulsed TIG welding process parameters of AA 5456 Aluminum alloy welds for increasing the mechanical properties. **Findings:** It is observed that, there is 10–15% improvement in mechanical properties after planishing. This is due to fact that, internal stresses are relieved or redistributed in the weld.
S. Malarvizhi (2010)	**Purpose:** The effect of three welding processes on fatigue crack growth behaviour of AA2219 aluminium alloy on square butt joints without filler metal is reported in this paper. **Design/methodology/approach:** Samples are welded by - • Gas tungsten arc welding (GTAW), • Electron beam welding (EBW) • Friction stir welding (FSW) **Findings:** • The joints fabricated by FSW process exhibited higher fatigue crack growth resistance compared to GTAW and EBW joints. • The FSW joint showed a crack growth exponent of 3.57 which is 15% lower than GTAW and 6% lower than EBW joints (lower the crack growth exponent, higher the crack growth resistance).

Z. Nikseresht, et al (2010)	**Purpose:** Discussed the corrosion behavior and microstructure of Al6061 alloy welded by GTAW and followed by various heat treatments. **Design/methodology/approach:** The microstructure of both weld metal (WM) and base metal (BM) was studied using - • Scanning electron microscopy (SEM) • Energy dispersive spectroscopy (EDS) **Findings:** Results indicated that - • Fe-rich coarse intermetallic particles behave as cathodic sites. • The WM zone is cathode and shows better corrosion resistance under different conditions compared with the BM area. • Heat treatment shifts the corrosion potential of the BM area towards positive direction, while it has no significant effect on the WM zone.
Fatih Hayat (2010)	**Purpose:** Investigating the joining capability of magnesium AZ31 alloy sheets and aluminium 1350 alloy sheets with the application of resistance spot welding. **Design/methodology/approach:** The studies examined the nugget geometries of joined specimens, recorded the scanning electron microscopy (SEM) images of the welded zone and the fracture surface, and recorded the energy-dispersive spectroscopy (EDS, semi quantitative) analyses. **Findings:** The increase in the weld current and duration resulted - • An increase in the nugget size and the weld strength. • The tensile load bearing capacity (TLBC) increased.

M. Temmar, et al (2011)	**Purpose:** Gives the influence of post-weld aging treatment on the microstructure, tensile strength and hardness of weld joints low thickness 7075 T6 aluminium alloy welded by Tungsten Inert Gas (TIG). **Design/methodology/approach:** Hot cracking occurs in aluminium welds when high levels of thermal stress and solidification shrinkage are present while the weld is undergoing various degrees of solidification. This often results in low weld mechanical properties and low resistance to hot cracking. **Findings:-** • Mechanical properties are very sensitive to microstructure of weld metal. • Simple post-weld aging treatment at 140 °C applied to the joints is beneficial to enhance the mechanical properties of the welded joints.
Kalenda Mutombo, et al (2011)	**Purpose:** This investigation studied the corrosion fatigue behaviour of aluminium 6061 in the T651 temper condition, and determined the corrosion damage ratio (ratio of the fatigue life in a NaCl solution to the fatigue life in air). **Design/methodology/approach:** The influence of welding using magnesium-alloyed ER5183 aluminium filler wire and fully automatic pulsed gas metal arc welding (GMAW-P) on the fatigue life in air and in a NaCl solution was also measured in this investigation. **Findings:** • The fatigue life of 6061-T651 aluminium in the welded condition was considerably reduced in air and 3.5% NaCl solution. • On testing in a NaCl solution, the fatigue life was reduced even further, facilitating the rapid fatigue failure of the welded specimens.

Milan Sága, et al (2012)	**Purpose:** The article deals with determining of fatigue lifetime of structural materials during multiaxial cyclic loading. **Design/methodology/approach:** The theoretical part focuses on fatigue and criterions for evaluation of the multiaxial fatigue lifetime. The experimental part deals with modeling of combined bending - torsion loading and determining the number of cycles to fracture in region low-cycle fatigue and also during of the loading with the sinusoidal wave form under in phase ø = 0°. **Findings:** • Fatigue strength of the welded specimens decreased for bending and torsion cyclic loading compared to that of the base material. • The existence of tensile residual stresses in a surface layer accelerates crack initiation reducing fatigue life due to the increase of local mean stress.
R.S Florea, et al (2012)	**Purpose:** The fatigue behavior of resistance spot welding (RSW) in aluminum 6061-T6 alloy was experimentally investigated. **Design/methodology/approach:** Three welding conditions, denoted as "nominal", "low" and "high", were studied to determine the microstructure of the weld nuggets. Different fatigue failure modes were observed at several load ranges and ratios for a constant frequency and three welding currents. **Findings:** •The welding current had a large influence on welding nugget dimensions and lap joint mechanical behavior. • No fatigue initiation sites were observed in the porous area formed from rapid solidification in the center of the welds.

J.T. Tan, et al (2013)	**Purpose:** The growth, interaction and coalescence of two coplanar short cracks of varying lengths in AA7050-T7451 aluminium alloy were studied under low amplitude cyclic loading. **Design/methodology/approach:** A new mathematical model was developed to account for this behaviour. **Findings:** • The way in which the fracture surfaces developed are dependent on the relative sizes of the two short cracks. •The growth and coalescence of two short cracks did not contribute to accelerated crack growth rates, instead experienced an overall fatigue life that is similar to that of a single crack.
Z. Semari, et al (2013)	**Purpose:** Fatigue crack growth from an expanded hole is simulated. Expansion and its degree of influence are studied using a numerical analysis. **Design/methodology/approach:** Stress intensity factors are determined and used to estimate the fatigue life. Residual stress field is evaluated using a nonlinear analysis. **Findings:** • The study of residual stresses field indicate the existence of two zones near the crack tip (ZCRS) compressive residual stresses and (ZDP) plastic deformation zone. • Fatigue life depends essentially on (ZCRS) compressive residual stresses. These stresses diminish the effect of applied stress field and tend to delay crack growth rate.

POSSIBLE FUTURE WORK

- As FSW shows better crack growth resistance so the parameters can be useful to enhance the crack growth resistance in other welding techniques like GTAW,GMAW and EBW etc.
- Effect of welding in different conditions and with different parameters can be examined on crack growth behaviour.
- Prediction of fatigue life of material on the basis of improved mechanical properties.
- Effect of various heat treatments and cold working processes on material properties and fatigue life.

THANK YOU