Experimental Studies of Different thick Steel sheets and variable clearance in MIG Brazing

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Abstract. Current automotive industry trend is developing the new materials and technologies for automobile BIW to enhance the latest stringent requirements like safety, weight and safer body. Main aim is to reduce the weight of body without compromising the targeted quality and safety norms. One of the solutions is different grades of steel sheets and different thickness combination are used combinedly to weld depend on the function of the designed structural component. Reduction of weight is searched most in the recent high strength steels. Target is to reduce dead load and reduce the cost. In this scenario roof outer and inner panel which is having closed ring type assembly. For ring panel assembly different thickness materials and variable clearance joinery is welded by MIG brazing tags. As per benchmark study the strongest joint 930.8 Mpa is achieved when the joint clearance is 0.038mm. When the clearance is narrower than it’s harder for the filler metal to distribute itself adequately throughout the joint and joint strength is weakened. Conversely, if the gap is wider than necessary, the strength of the joint will be reduced almost to that of the filler metal itself. But in ordinary day-to-day brazing, need not this much precise to get a sufficiently strong joint. In this study analyzing the tensile shearing strength of the joinery with respect to the thickness and variable clearance. Also, parameters contributing to the strength variation. MIG brazing welding processes is using CMT machine and CuSi3 of brazing wire.

1. Introduction
Brazing is the processes of joining the metals similar with nonferrous metal mainly bronze alloy as filler material with metal inert gas like CO₂ or helium for shielding. Usually brazing is lower than the melting point of the base ferrous and nonferrous metals being joined. In brazing only filler material melts and joins the joining material.

Where as in MIG welding it works with excessive heat input and base material melting will leads to deformation of a weldment. As the MIG brazing process enables a formation of the weld without melting of base material and is also providing relatively low level of heat input to the material. In the current market scenario Brazing is a highly efficient method for joining process for the industries especially in aerospace and automotive applications [1]. As earlier said that brazing joints must be verified for the strength examinations using nonferrous material joints ex. AA3005 material. In the examinations theoretical and post brazing effects of fatigue and mechanical properties has been verified. In the examination confirmed that additional decrease in fatigue life of the alloy after brazing is due to the surface cracks and recrystallization occurred during the brazing process [2]. for industrial application brazing is one the process used extensively and brazed components has to meet the increased expectation
such as mechanical, thermal, corrosion resistance under specific condition. Experimented with high
temperature brazing with newly developed Co based filler material and it is mainly developed for high
strength and resistance against Corrosion and creep. To Join the dissimilar material like aluminium to
Stain less steel and simile material like steel to steel Induction brazing. Low temperature joining of
copper using Ag nano particles [3]. In the MIG brazing joints wettability, micro hardness and the
hardness of the joints also verified on DP 600 and DC 01 steel sheets are used and CuSi3 material has
been used as a filler material. post measurement of the joints found that there is maximum hardness curve
in the DP 600 steel [4]. Also, various welding process like CMT and GMAW to find the porosity
formation, growth, and escape behaviour, and the mechanical properties of weld joints. Also studied over
a wide range of heat inputs and maximum weld pool temperature which the temperature varies from
1650 to 2700 C. study confirms that low temperature omits the low zinc vapor pressure during the brazing
and the high temperature of the weld pool omit the zinc vapor bubble to grow inner side grow up. Also
study shown that minimum heat input of 200 J/mm is required to achieve penetration of base metal above
10%. conclusion is one is low heat input ranging from 200 to 250 J/mm and another high heat inputs,
starting from 350J/mm and rising to 550 J/mm [5]. When the thin sheets lesser then the 0.8mm brazing,
that is metal inert gas brazing process focused mainly on understand the Zinc vaporization which leads
to rust or corrosion and wettability of brazing joint. Target is to experiment on low temperature and
suitable shielding gas. Also analysed with micro structure for penetration and tensile strength of the joints.
in the experiments identified the various heat, corrosion and wettability variation are identified with
respect to the mixture of shielding gases [6]. Also experimented with various filler materials like
CuSi3MnAl & CuSi3 are used on the stainless-steel grade 304L in Cusi3MnAl found that uniform shape
and less face deformation, less spatter and no surface damage even with high temperature on base
material observed and similarly with CuSi3 brazing melts the base material and big difference in wetting
angle. Now checked with mechanical properties of MIG brazing on TRIP (Transportation induced
plasticity) 800 steel plates and the thickness of 1.5mm using various braze angels found that Ultimate
brazing strengths, in that study of 50 ~90 deg braze angle. Study shows the torch angle of 50° gives the
best result for UTS [7-8]. Finally the main objective of this project is study on the different thickness of
the steels and there shear strength of the brazing joints with various clearance [9]. The main objective of
this work is to analyze the production process of MIG brazed joints of CR steel using a filler material
CUSi3 In order to meet the purpose of joinery strength. Helium as a shielding gas. Overlapped sheet metal joints shearing strength testing practically.

1.1. Objectives
The objective of this study to get the effective brazing parameters and tensile shear strength of the brazing
joinery by analysing the variable clearance in ring shaped panels. in real time manufacturing it is not
possible to maintain the nominal tolerance as defined by the design. Practical tests conducted to verify the
brazing tensile shear strength variation wrt variable thickness of sheet metals and variable clearance.

2. Experimental work
2.1. Test samples
Reference used in this experiment is car BIW (Body In White) production process of the ring-shaped
panels. generally, CR (Cold Rolled) low carbon alloy steels and these may be similar or non-similar
strength specification steels are used for parts manufacturing. to join this type of assembly MIG (Metal
Inert Gas) brazing are used for joining the weld joints and CuSi3 as a filler material. this is Copper and
silicon-based alloy material in order to meet the purpose of joinery strength. Helium and CO₂ gases are
mainly used as a shielding gas in this process.
2.2. Clearance variation in ring assembly

In practical scenario at mass manufacturing process, maintaining the even gap and specified nominal tolerance with joinery is all most not feasible due to manufacturing variations. Likely part stamping quality, sheet metal material property, parameters of welding, fixture quality, human errors, operation sequencing and welding bead geometry/size is one of the critical characters contribute the brazing joint. There is one more major dynamic input to this variation is large part loading to the fixture. Because this sheet metals parts are big in size and very flimsy due to thickness less. However, the thicknesses of the lower thin sheets from 0.6 to 1.0 mm and higher sheet panel thickness are from 1.0 to 2.0 mm used. Generally, for the ring assembly nominal clearance tolerance is maintained from ±0.30 ~ ±0.50 mm with bilateral tolerance in the design. In the worst-case stack-up scenario clearance vary from 0.0 to 1.00 mm and in the RSS (Root Sum square) tolerance specification is ±0.39 mm.

Table 1. Tolerance stack-up details for clearance variation.

| Tolerance | RSS  | Worst case |
|-----------|------|------------|
| ± 0.30 mm | 0.39 mm | 0.6 mm |
| ± 0.50 mm | 0.5 mm | 1.0 mm |
2.3. Theoretical analysis

Strength of the welded joint: The main failure mechanism of welded lap joint is tensile failure. Therefore, the strength of a lap joint is \( F = t f L S \)

\[
F = t f L S \\
t = 0.707 \times s \\
f = \text{Allowable stress} \\
L = \text{Length in mm} \\
s = \text{Leg size in mm} \\
F = \text{Tensile force in Newton} \\
FS = \text{factor of safety} \\
t = \text{Throat thickness}
\]

\( f = 360 \text{ Mpa filler material} \) \\
\( L = 20 \text{ mm} \) \\
\( s = 1.0 \) \\
\( F = ? \) \\
\( FS = 1 \)
Result: Theoretical analysis of the welded joint shows that maximum stress at the 1mm throat thickness weld joint and tensile force is 25.45 KN. This is lesser then the load applied on practically at 28.14 KN is minimum. Hence for 1 mm throat thickness design is safe.

2.4. Specimen details
In this study, a cold rolled steel sheets are selected for joining by MIG brazing process. Steel Specimen of 2.0mm 1.0 mm thickness are used. The filler metal is solid wire with a diameter of 0.8 mm, Filler material spec is CuSi3. MIG-brazing operations are performed with robot and purpose to analyse the effect of shear strength of joint. MIG brazing operations are carried out in a Robotic MIG welding machine shielding gas ratio ware used Argon + CO\textsubscript{2} (80+20 Ratio) are used as a shielding gas flow rate of 14 liters/min. The surface of the specimen was cleaned by the thinner to remove the grease and dust, emery paper are used to removal of rust. CuSi3 filler material dia of 0.8mm spool are used for brazing. Specimen dimensions is 20 x 70 mm two different thickness. combination of specimen are 1.0 mm and 2.0 mm. Specimen are cut from the large blank sheets. Ensured there is no surface damage and bend during the cutting of the large panel. 3 set of Specimen prepared for welding. Specimen are cleaned, deburred and removed all the oil contamination on the metal surface.

Table 2. Material properties – CR Steel.

| Sl no | Properties             | Specification |
|-------|------------------------|---------------|
| 1     | Yield strength         | 180-250 MPa   |
| 2     | Tensile strength       | 300-360 MPa   |
| 3     | Percentage elongation  | Min. 34       |
| 4     | Young’s modulus        | 210 GPa       |
| 5     | Density                | 7.85 g/cc     |

Table 3. Material properties – CuSi3.

| Sl no | Properties          | Specification |
|-------|---------------------|---------------|
| 1     | Yield strength      | 120 MPa       |
| 2     | Tensile strength    | 350 MPa       |
| 3     | Percentage elongation | Min. 40   |
| 4     | Young’s modulus     | 117 GPa       |
| 5     |Density              | 7.85 g/cc     |
2.5. Work cell
Fronius advanced CMT machine TPS 400i brazing machine and KUKA MIG welding robot KR22 system are used for welding the brazing joints. Lap joints are used for specimen welding. CMT is an advanced technology, which works with the short-circuiting transfer process which is named mechanically assisted droplets deposition, which is applied to control the short circuit. Welding process only cutting the metal droplets. The electrode filler wire tip makes the contact with the base material molten spool, the robot cater drive which is in servomotor reverses the wire by digital controlled process. With this effect the feeding wire retract promoting the droplets which will transfer the depicted. Mainly the CMT reduces the HAZ (Heat Affected zone) in the welding joints which will help to avoid the residual stress, deformation and mechanical properties of the material due to welding heat as compare to regular MIG welding process. Also help to achieve the accuracy, aesthetic and finishing of welding joints. CMT also used laser brazing mainly in car roof welding especially at VW body manufacturing plants.

2.5.1. Brazing operation
Brazing operation is controlled and low temperature process there is no base material melting and ensured the brazing to fill the clearance and create the joints. Filler material are used to for joining the joints of similar and non-similar materials. Welding machine having the HMI to control the welding speed and adjustment, Current & Voltage adjustment, Remote support, touch and react programming options. feature to save all the parameter in control system and programming option internally as well as externally. The MIG brazing process has been developed in the late 1960 and significantly using all most all automobile industry. Copper based alloy combination of silicon, tin or aluminium which creates the bronze has been used for filler material. Bronze melts at approximately about 950 deg. brazing is even softer than the steel. But during proper technique we could achieve the close tensile strength of MIG welding.

![Figure 4. Schematic drawing of robotic cell setup.](image-url)

2.6. Specimen preparation
This is the standard machine setup for the brazing specimen. Set the job on the machine vice/positioning table and hold specimen firmly. Using the C clamps and supporting plates for accurately holding. Must
ensure the vice or positional device should be spatter free and neatly cleaned to avoid specimen orientation issues. welding robot are KUKA -KR22 MIG welding equipped and brazing machine TPS 400i CMT Robotic MIG/MAG. Brazing is performed using the robot support which is programmed by manual jogging the and current and voltage parameter are set by the manually using the standard input and output.

![Figure 5](image-url) Specimen welding and brazing operation by torch.

2.7. Testing preparation
Post Brazing, brazed specimen has been collected from the brazing table check for visual inspection for crack, spatter or any damage. post inspection collet the specimen together and take to the mechanical laboratory for shearing strength analysis. ARM tensile testing machine are used for shearing test which is having capacity of 1000KGF.

![Figure 6](image-url) [a] welded specimen [b] Tensile test machine [c] Testing of specimen.

Firstly, loaded the 0.0 gap specimen on the tensile machine manually, fix the one side of the specimen to upper jaw and bottom portion of the specimen to lower Jaw of the machine. Push the button to clamp the specimen and push another button to switch on the hydraulic pump. Machine starts and pulls the bottom side of the specimen. Specimen will get tear within the few seconds and final strength of the specimen will display at the display board and values noted same procedure are followed for remaining 2 specimens.
3. Results and Discussion
Various design parameters are considered and result of these parameters on tensile strength of lap brazed joint is discussed. Theoretical design procedure was adopted for designing the shear strength and specimen. The specimen dimensions were finalized, and specimens were prepared by varying clearance for brazing ensured there is change of positioning of the specimen. The values of shear stress obtained from experiment and values obtained by theoretical value compared for validation of experimentation. a) The tensile strength obtained by variation of clearance shows minimum tensile strength of 28 KN with 0 mm clearance. This ensures that using 0~1.0 mm clearance for brazing joint is recommended. b) Increasing the clearance from 0.0 to 1.0 mm observed that there is no decreased tensile strength, but variation is there irrespective of clearance. c) Variation in clearance shows maximum tensile strength of 38.8 KN with 0.5 mm clearance specimen. so, variance of clearance is directly not effecting to decreases the tensile strength. So, it is recommended that brazing operation can be performed on variable clearance of sheet metal parts and variable clearance is not going to effect the significant change in tensile strength.

| Sl No | Material Thick in mm | Clearance b/w sheets | Filler material | Feeding time | A Amps | V voltage | Feeding Speed M/Min | Heat =IE KJ | Practical Tensile load (Kgf) |
|-------|----------------------|---------------------|----------------|--------------|--------|-----------|---------------------|-------------|-----------------------------|
| 1     | 2.0                  | 1.0                 | 0.0            | CuSi3        | 0.5    | 106       | 11.5                | 9           | 1.2                         | 287         |
| 2     | 2.0                  | 1.0                 | 0.5            | CuSi3        | 0.5    | 113       | 11.8                | 9.3         | 1.2                         | 388         |
| 3     | 2.0                  | 1.0                 | 1.0            | CuSi3        | 0.5    | 118       | 11.5                | 9.7         | 1.2                         | 311         |

4. Conclusion
Cold rolled steel sheet metal and variable clearance with a copper based CuSi3 filler material by using MIG brazing method was examined and it was shown that shear strength variation has been found in the test specimen irrespective of the clearance variation. Brazing process varies with current, voltage flow and time parameters. Process to be set by more experimental trials to achieve the consistent strength. In addition, to the MIG-brazing parameters on tensile properties of Cold rolled steel sheet joints with various gap has been investigated. The following experiments show more strength can be achieved with the gap of 0.5mm. Need furthermore experimental trials to achieve the consistency of brazing joint for the variable clearance.

5. Reference
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