Recent Trends in Welding Processes in Railway Factories

Ravi S. Kochak, IRSME
C.Eng., FIMechE, FIE
Additional Member (Production Units)
Ministry of Railways, Railway Board
Email: kochak@gmail.com

B.L. Bairwa, IRC&M
Dy.CCMT, RWF
Bangalore
Email: dyccmtrcf@gmail.com

Summary

This paper brings out the processes of welding being followed in different Factories of Indian Railways. The recent developments and trends in practical application of welding processes in four Workshops, two Production Units and one Public Sector Undertaking of Indian Railways are highlighted. The authors discuss the practical welding challenges being faced in these factories and the solutions adopted By Indian Railways to resolve these issues. Knowledge gained from the experiential learning process brought out in this technical paper, has added positive value in enhancing quality of welds in Railway applications.

1.0 Introduction to Basic Welding Concepts and Processes

1.1 Welding Procedure

When welding is being done on plain carbon steel, the procedure can be qualified by conducting the following tests on the welded test coupon:

- Transverse tensile tests: 2 nos.
- Root Bend Test: 2 nos.
- Face Bends: 2 nos.
- Or Side Bends: 2 nos.

1.2 Welder Qualification

After qualifying the welding procedure, the welder needs to be qualified to verify the skill/capability of the welder to deposit good quality metal. The welder can be qualified by witnessing the welding of the test coupon of the welder in different positions and then either testing for bend tests or by carrying out radiography test of minimum six inches of weld length.

1.3 WELD JOINT DESIGN

A weld is like a casting where molten metal is allowed to solidify in a mould. During welding, the molten metal solidifies in the groove of the weld. The Weld Geometry should ensure:

- Prevention of weld defects
- Minimum amount of weld deposit, to give the required strength with minimum distortion.

"Joint Geometry" is the shape and dimensions on the cross section of the weld joint. The basic joints used in fabrication are: Butt Welded Joint(single weld/double weld), corner Weld Joint, Tee Weld Joint and Lap Weld Joint. The shape of the weld joint is decided based on the thickness (VUJX) with a view to get the required joint strength, having minimum weld deposit. Basic elements of Joints are Joint root, groove fact, foot face, root edge, root opening, bevel, bevel angle, groove angle, groove radius

1.4 WELDING SEQUENCE

1. In welded fabrication one often faces problems of distortion. The distortion should be controlled, so that the product meets the design requirement and thus prevents premature failures.
2. Distortion is caused due to uneven expansion and contraction of material during welding (heating and cooling)
3. The Thermal stresses introduced during heating and cooling, sometimes exceed the yield point of the material, which leads to distortion.

1.5 Rules to Minimize Distortion:

Optimized geometry, minimized weld deposit, reduced heat input, use lesser number of layers, avoid high welding current/slow speed/excessive weaving, follow sequence of welding (skip/skip-step back) preheat during welding for t 25 mm. Use proper Jigs and fixtures. Preset with negative allowance.

1.6 SELECTION OF CONSUMABLES

The following considerations must be given while selecting a consumable for welding:

- Chemical composition and mechanical properties of the base metal
- Chemical composition and mechanical properties of the welding consumable.
- It must be ensured during welding that the strength of the weld deposit made by the consumable should be more than the base metal, or at least equal to the base metal.
- For welding materials of different strengths, the consumable suiting the material of the lower strength material may be selected.

To have efficient selection of consumables, it is necessary to know:

1. The composition and strength of the base metal

2. Type of joint
3. Position in which the welding must be done
4. Required physical properties of the weld deposit
5. NDT requirements.

1.7 PRE WELDING INSPECTION

- Ensure availability of a qualified welding procedure and qualified welders.
- Weld fit-ups should be clearly checked and rejected, if not conforming to welding procedure requirements.
- Pre-heat temperature should be determined.
- Ensure right quality of consumables, equipment and aids.

1.7.1 Check the Cut Edges to be free from following

- Cracks, laminations, slag inclusions or other material defects.
- Slag, rust, scale, paint, grease, oil or any other foreign material.
- Thermal cut edges shall be cut back by machining/grinding by 1.5mm, to ensure sound metal by removing detrimental heat affected material.
- Track welds should be examined during welding to ensure they are not broken.
- Control the use of proper consumables.
- Control of preheating and interpass temperature is to be ensured.
- Review/approval of NDT and PWHT must be done.

1.8 POST WELDING INSPECTION

- Final Geometry of the weld should be examined for size, shape, undercut, porosity and cracks
- Ground welds should be examined for excessive weld removal.
- Check for removal of spatter and temporary assembly cleats
- Care should be taken for detection of delayed cracking in some materials
- Repairs to any defective weld should be made by approved procedures.
- Heat treatment when required should be conducted as per approved procedure

1.9 Specifications being followed

ASME Section VIII Div. 1, BS 5500, IS 2825, AWS D1.1, ANSI B 31.3
API 1104, Classification Society Rules, ASME Section 1X
ASME Section V, ASME Part II B and C

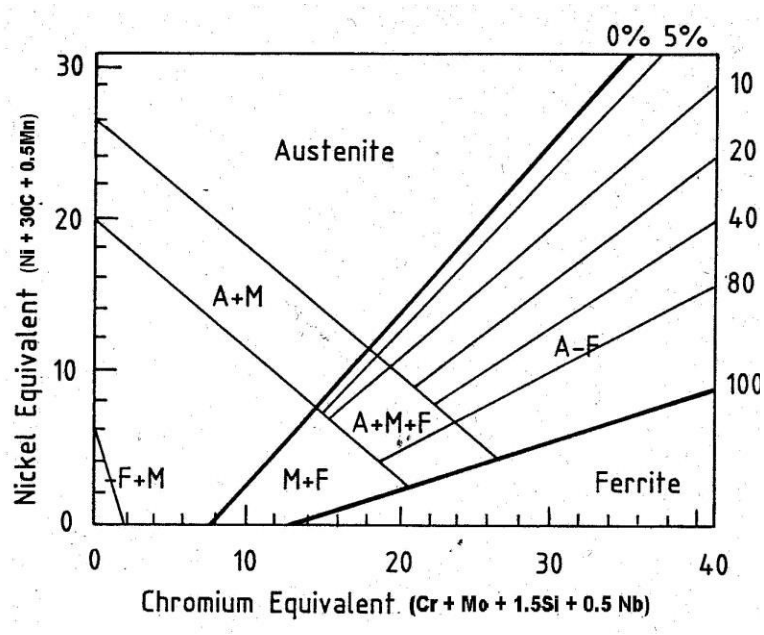

Fig 1: Schaeffler Diagram- It is used to select Fillers (M is martensite)

2.0 Recent trends in welding processes in Ajmer Diesel Loco & Wagon Workshop (ADLW)

There was a separate shop for welding related processes in Loco workshop Ajmer till 1998, where the repair and POH work of steam locomotives was done. With the switching over from Steam Locomotives to wagon repair, the welders were distributed to various shops and merged with the respective shop cadres.

2.1 Welding Processes

The main welding processes adopted at ADLW are:-

i. Gas cutting process using oxygen and LPG gases earlier it was acetylene.
ii. MMAW (manual metal arc welding) Process, where transformer type welding m/c are used.

2.2 Recent developments & trends

ADLW Workshop has adopted recent technologies, like rectifier type & IGBT type welding and MIG/MAG welding techniques for mild steel, with the starting of 'C' category repair work on BOXN wagons.

The manufacturing of new side panels and end panels & flap doors is being done by this method with the use of CO_2 gas as inert gas and class-I wire roll of 1.2 mm diameter as electrode (as per RDSO manual IRSM:28 and G-72). Now ADLW has developed Argon gas with stainless steel class-VI wire roll for stainless steel welding.

In 2009, with the starting of the work of rehabilitation of BOXN wagon to BOXNR, (Stainless steel wagon IRSM:44) a new technique using "plasma cutting" was introduced in ADLW workshop. IRSM:44 Stainless Steel cannot be cut by Oxy-LPG, therefore plasma cutting is necessary for repair of stainless steel wagons. The use of plasma cutting increases with the number of new wagons designed & developed by RDSO i.e. BOXNHL and BCNHL type wagons, which are fully made of IRSM:44, including the under frame structural members.

2.3 Practical challenges & solutions adopted

Practically these techniques help in increasing production, with lower consumption of electricity and lower cost. But difficulty is faced in the repair work because of more number of attachments and of very sensitive electronic circuits. The daily installation & starting time of machines reduces the user friendliness of the machine. For example, in the MMAW process, a welder starts welding within two minutes and joins cable and earth with welding plant, but in MIG process, he has to install wire roll to machine, do setting up of the machine, CO_2 cylinder, heater, tip, nozzle etc., which takes considerable time to start the work. Dusty environment in wagon repair units increases the breakdown frequencies of the welding machines. Problems are also faced by the workshop for repairing of rectifier/IGBT type electronics welding machines, as staff is not familiar with maintenance of such machines. Even suppliers of machines are not co-operative in providing maintenance services and spares.

For Making these machines welder friendly, seminars are organized from time to time on MIG, Plasma cutting and other various types of new technologies, within the premises of ADLW, and also on the shop floor, for welders and supervisors. Training programs are being organised in the Basic training centers and Supervisors training centers for new welders and apprentices. The welders of the workshop units are regularly trained at RCF Kapurthala and Bhopal training centers, in theoretical & practical training in welding of stainless steel.

Fig 2: IGBT welding machine

Fig 3: CO_2 Welding Machine

2.4 Experiential Learning:

Experience in the last few years shows that these welding machines are very good and effective in Production Units of IR. However, but in the repair depots of IR & workshops, which have dusty environment, these machines ace problems due to very sensitive electronic circuitry and extra handling. Insufficient training on maintenance & troubleshooting of MIG and Plasma machines by electrical maintenance and millwright staff is a major limitation and needs improvement.

Fig 4: CO_2 Welding

3.0 RECENT TRENDS IN WELDING PROCESSES AT LOWER PAREL WORKSHOP W.RLY.

Major welding activities are carried out at

A) Normal welding at Carriage body repair shop, with Man Hrs less than 600.
B) Heavy corrosion repair shop, with Man hours more than 600

3.1 Recent Developments and Trends

A) **Normal/General welding** is done in fitting shop and other non safety locations with "A" class general electrodes (E6013) for IS 2062 steel welding, and M4 class electrodes for stainless steel welding with arc welding process.

Fig 5: Welding work at End Panel

B) **Specialised SMAW welding and MAG (CO2 Shield Gas)** is used on coach under frame /Bogie and super structure. In this category 'D' class coated electrode E8018 is only used of M/S Esab, M/S Advani Oerlikon and M/S D & H, in preheated condition to avoid Hydrogen embrittlement. The size of electrodes used has initial root run of 2.5mm and subsequent run of 3.15mm electrode is given. This welding is done after preparing the joint with groove, alignment and proper earthing. For MAG (CO2) welding, continuous feeding spool with 0.8 and 1.2mm Copper coated feed wire of equivalent class is used .Normally this welding is used where continuous run of long lead is available. Parel Workshop is using Machines of M/S Panasonic for CO2, M/S Kemppi and M/S Technocrat for SMAW welding. This system was introduced in PL shop in 2010.

Fig 6: Filler Welding

C) Special purpose welding

For welding of water tanks and other component of LHB having SS 304 are being attended with GTAW (TIG) welding with SS filler rods and Argon gas shielding. Similarly, Aluminium water Tanks are also attended with similar process, except bare filler rod of Aluminium is used. In this process, welding machine of M/S Kemppi is used. Apart from above, basic welding is being done only after preparation of joints by V groove, alignment check etc.

3.2 TRAINING OF WELDERS

- Regular training is being imparted at different technical training institutes to enhance the skill of welders
- Refresher courses in welding are conducted at BTC /Parel. All the welders are covered in the refresher training at an interval of 3 years.
- After completion of training and refresher course, practical and theoretical tests are conducted and grading is also awarded by a Neutral agency, which is ACMT/PL in accordance with IS specification.
- Only A and B grade welders are deployed for welding of coach super structure, which has vital structural components.
- No major problems are being faced by Parel workshop in day to day welding.

3.3 Recent trends in welding processes in Modern Coach Factory

Modern Coach Factory (MCF), Raebareli is the newest Production Unit added to the existing major production units on Indian Railways, built exclusively for manufacture of lightweight stainless steel coaches for operation at speed of 160 kmph. The installed capacity of the Production Unit is 1,000 coaches per year.

3.4 Welding Processes at MCF

Following welding techniques are employed in coach manufacturing at MCF

1. MIG/MAG
2. Resistance spot welding
3. Laser welding

These welding processes are used manually as well as with welding robots. At present, approximately 25 welding robots are deployed at MCF.

3.5 Recent Developments and Trends

MCF/RBL incorporated "Automated Robotic Welding Line" for Bogie Fabrication Work. Also the process of incorporation of Automated Robotic Welding Line for Shell assembly manufacturing is under installation and commissioning for which TDC is June 2016.

3.6 Practical Challenges

The conventional welding procedures have been seamlessly integrated in-line with the welding procedures being practiced in other Production Units. However, efforts for further optimization and continual improvement are being evolved. However, issues of dimensional tolerances and feasibility of procedures require enormous effort for stabilizing robotic welding, especially in LHB bogie manufacture.

3.7 Solutions Adopted

With initial teething troubles encountered in bogie fabrication, multiple strategies had to be planned for stabilization of robotic welding line procedure is as follows :

1. Set of different programs for different input components have been implemented.
2. Strict control on component dimensions made in-house, as well as of those procured through trade is being monitored.
3. Changes have been made for pre-fabrication activities like grinding & tacking has been done properly.
4. Jig fixture improvements for finer product accuracies have been done in welding lines.
5. Stage wise monitoring of product is being done to achieve welding as per drawing.

3.8 Experiential Learning

It has been realized that special inputs in the form of the following is desirable, to enhance the welding work output and quality of welds :

1. Fabrication of components on accurate jigs & fixtures.
2. Special emphasis on surface finish i.e. radii, profile etc.
3. Customized designed tools, jigs & fixtures must be used.
4. Latest techniques incorporating logging of welding inputs like current, voltage, speed, flow of gas, torch efficiency etc.
5. Staff knowledge upgradation is essential to adapt and perform in dynamic scenario.

4.0 RECENT TRENDS IN WELDING PROCESSES AT BURN STANDARD COMPANY LTD, (A RAILWAY PSU)

M/s Burn Standard Co. Ltd. (BSCL) is a PSU under Ministry of Railways. They have recently bagged orders for two self-propelled river barges. Processes of Welding for Ship Building Structures on proven procedure adopted by BSCL for construction of River Sea Vessel. The welding procedure adopted by Burn Standards Co. Ltd is of high grade technology involving SMAW & MIG welding keeping in view BSCL objective projection for complete construction of Inshore Patrol Vessel like RS (River and Sea going vessel), Warship, Frigate, Corvette, Light Combat Utility Vessel, Blocks upto 120t (with individual block DMR 2498 Steel). The procedure for welding for River & Sea vessel warship are same, except lower operable temperature restriction for DMR steel which is required for Warships. The operable temperature is achieved by

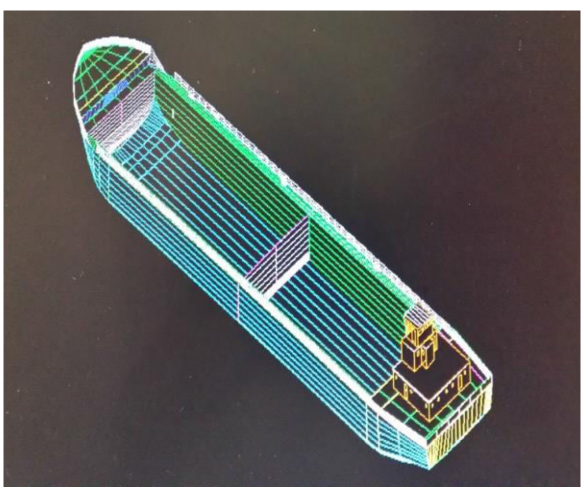

Fig 7: River Barge Sections

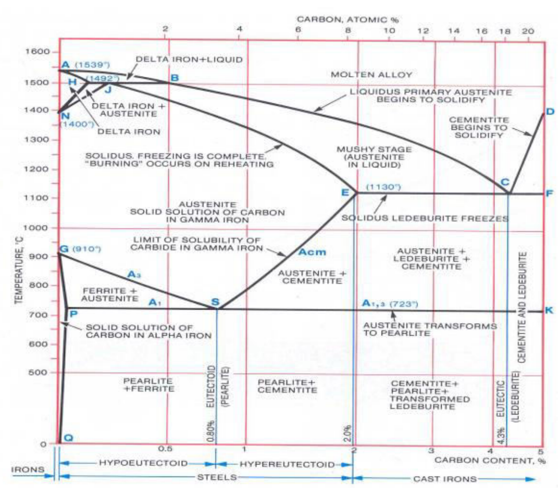

Fig 8: Iron-Cementite Phase Diagram

increased current and slow rate of metal deposition. Whereas for IS 2062 steel required for RS vessel, there is no such restriction consequent to lower Cu content of IS 2062 as compared to DMR steel.

5.0 Recent trends in welding processes at Charbagh Workshop

5.1 Welding processes in the Workshop:

With changes in traction motor technology and the type of traction in Indian Railways over the past 150 years, there also have been changes in the overhauling practices involved. And Welding forms a core supporting activity to the overall overhauling process. AC Welding plants were being used initially and DC Welding plants were also introduced with the passage of time. The following types of Welding processes are currently being used in the Workshop.

- MMAW (Manual Metal Arc Welding)
- MAG (CO2 Welding)
- Brazing (Gas Welding)
- Oxy-Cutting by DA Gas/ LPG

Fig 9: Swan neck weld repairs

5.2 Recent Developments and Trends

With the introduction of IGBT based DC Welding machines, the welding process has become smother and more accurate. The fabrication of 16T AC Bogie was started by the Workshop and MAG Welding was introduced for the same purpose. Similarly, TM Armatures were being sent to Kanpur for reclamation, but with the adoption of TIG Welding, the same is now being done by the Workshop itself. Worn out equalising beams of Diesel Bogies are also being reclaimed inside the Workshop using specialised Hard facing electrodes. Reclamation of worn out Bull Gear is also being done on Diesel locomotives, Electric locomotives and DEMU Coaches. Also, during the POH of Diesel Locomotives, cracks at L-9 and R-9 on the Power pack are being cut and welded by the Shop.

5.3 Practical Challenges and Solutions adopted

The AC Welding plants have been gradually replaced by DC Generator Plants. But the DC Generator plants were very noisy and bulky. Rectifier based DC plants were introduced with time and the latest inclusions have been the modern IGBT-based DC plants. Both plants have the advantage of less noise, minimal wear and tear, lesser maintenance requirements (less moving parts) and lighter weight (20% of the weight of DC Generator Plants).

During the POH of Diesel, Electric locomotives and DEMU units, it was observed that there were cases of damaged centre pivots and Side bearers. And the entire unit had to be overturned to perform the welding. But overhead welding has been introduced, which resulted in saving man-hours and resources.

5.4 Experiential learning

Stopper collars of DEMU Power Coaches were being received in a worn out condition on many occasions. The challenging work of their reclamation was started (along X-Axis and Y-Axis). It involves dividing the entire periphery in four quadrants and then welding by skip-quadrant method, hence avoiding the over-heating of stopper collar. The work was started on an experimental basis and is being successfully carried out till date.

6.0 Recent Trends in Welding Processes at DLW

DLW is leading manufacturer of Diesel Locomotives in the world. It is manufacturing mainly High Horse Power Locomotives. Welding is the most important & indispensible process in locomotive manufacturing.

6.1 Various welding processes used in DLW

Welding is extensively used in Crankcase & Under frame fabrication in DLW. Following processes are mainly used in DLW -

- Shielded Metal Arc Welding (SMAW)
- Submerged Arc Welding (Linear & circular) SAW
- Gas metal Arc Welding – MIG & MAG
- Flux Cored Arc Welding (FCAW)
- Tandem Arc Welding

6.2 Recent Developments and Trends

6.2.1 Adoption of multi wire welding in SAW

DLW has adopted two wire welding tandem SAW process in crankcase air box fabrication. This is a latest welding technique in SAW process. In Tandem Arc welding there can be two or more electrode wires as Arc producer. In this technique alternately AC and DC electrodes are used. AC is leading for High penetration and DC for more deposition. Each electrode is connected with a separate power source.

6.2.2 Application of Metal/Flux Cored wire

DLW has adopted usage of metal cored wire & flux cored wire in crankcase main frame member welding to improve quality of welding and increase metal deposition rate which in turn resulted in increased productivity. It is an Arc welding process wherein coalescence is produced by heating with an electric Arc established between a continuously fed metal/flux filled tubular consumable wire and the work piece.

6.2.3 Usage of Gas Mixture in MIG welding

DLW has started to using mixture of Argon & CO_2 as shielding gas in place of earlier practice of using pure CO_2. This has resulted in reduction in rework and improved weld bead profile which in turn resulted in better penetration and improved quality of welding.

6.2.4 Automation in locomotive under frame welding-

Self-guiding trolley is being used in welding of transition joints & center sill welding to reduce fatigue of welder & to achieve uniform weld quality.

6.3 Practical challenges & solution adopted

Due to heavy sections and complicated geometry of locomotive parts various challenges are being faced by DLW in welding. Details of challenges & solutions adopted are as under

6.3.1 Hydrostatic leak proof & X-Ray quality welding joints

Number of start and end points are reduced, by adopting continuous welding in one go, & reduces leakage problem. Root pass gouging technique is introduced religiously before final welding run.

6.3.2 Distortion during welding

Welding sequence revised and optimum weld material deposition adopted to reduce heat input.

6.3.3 Welding of non-accessible weld joint location

Usage of welding manipulator introduced. In addition to this, out of box solutions i.e. rose bud welding process in which welding is done with little bit bent electrode for accessing inside corner joints are adopted.

6.3.4 To reduce fatigue of welders

Extensive use of hydraulic Man lifts, Manipulators, self-guiding welding trolleys and best in class safety equipment like auto darkening helmets are introduced to reduce fatigue & risk of welders.

6.3.5 To reduce localized stress concentration

Preheating, post weld heat treatment and shot blasting are being used to reduce localized stress concentration.

6.4 Experiential learning at DLW

1. Multi wire SAW process with combination of AC/DC welding power source results in less heat input & less distortion, higher penetration & better weld deposition.
2. Use of flux/metal-cored wire over the solid filler wire gives better weld quality & economy.
3. Use of better quality safety equipment of welders directly related to higher productivity.
4. Use of gas mixture instead of single gas for weld protection gives better results in GMAW process.

Fig 10: Use of Manipulator & Man-lift

Fig 11:Top Deck SA Welding

Fig 12: GMAW Welding for Crankcase Fabrication

7.0 Acknowledgements

The authors gratefully acknowledge the contents in this paper, provided by the good offices of Chief Mechanical Engineer, NWR; Chief Workshop Manager, lower Parel; Chief Mechanical Engineer, Modern Coach Factory Raebareli; Chief Managing Director of M/s Burn Standard Co. Ltd.; Chief Workshop Manager of Charbagh Workshop and Chief

Mechanical Engineer of Diesel Loco Works, Varanasi. The authors gratefully acknowledge few material used from Presentations of Mr. S. K. Albert, Head, IGCAR, Kalpakkam & Mr. Radhey Shyam, Retired ED/M&C/RDSO. The authors appreciate the Secretarial assistance given by Sh. V.K. Mody, Sr. PPS to Additional Member (Production Units), at Railway Board.

8.0 Suggested Further Reading

- Annual Book of ASTM Standards
- American Society for Testing & Materials
- Applied Welding Engineering: Processes, Codes and Standards
- Welding Metallurgy & Weldability of Stainless Steel
- Welding Journals
- Handbook of Stainless Steel
- Handbook of Case Histories in Failure Analysis
- Manufacturing Processes for Engineering Materials

****