Introduction

The Indian Railways are one of the largest in the world and is in the process of modernisation for quite sometime with respect to infrastructure, rolling stock, and locomotive & control system. Indian manufacturing units under public sector and also under private sector are involved in the process.

With the launch of “Make in India” programme this process is going to get a much needed push for accelerated growth to catch up with the competitive technology & cost from all over the world towards assuring required safety and hazard reduction at higher speed of overall operation of passenger traffic and freight movement with optimum utilisation of assets. This involved design concepts with newer parent materials, consumables and their fabrication processes including welding. Stainless Steel (IRS M 44) is being used widely for rail coach fabrication at RCF-Kapurthala and also by BEML - Bengaluru.

It is in the above background, that this topic is relevant today for the success of the modernisation program of the Indian Railways. It should be used to define the correct procedure and monitor them for continuous compliance. Welding costs actually go down when a quality system like ISO 3834 and specifically EN 15085 related to railway rolling stock and related accessories are followed.

A close look at the factors affecting welding cost with an example given, of the benefit of using GMAW process will amply to illustrate the need for such investigative audit for all current practices of welding fabrication activities in railway workshops to determine the optimum procedure in the light of modern technological developments.

Understanding the Cost of Welding

It is essential to know the cost of a weld to make manufacturing decisions. An understanding of welding economics / costs and the value added by technology allow a company to manage them and become more profitable. Let's look at several of the variables that effect per piece or per weld cost. Equipment, labour, materials, energy and other overheads affect cost.

Production Cost

Total welding costs incurred should include: time spent preparing a joint, blasting, removing oils, assembly, preheating, tack-up, positioning, welding, slag removal, spatter removal, inspection, changing electrodes, transportation times, machine setup times, repair and rework. Material costs include: electrodes, shielding gas / gas mixtures, electric power, and gas for preheating.

Production rates and whether the weld will need to be replicated are factored into manufacturing decisions. Robotic or automated welding may have a considerably higher equipment cost, but are ideal for high production. An accurate understanding of current operating costs will allow for comparison of manufacturing options. A company can consider how changing a welding process will affect overall costs. Savings that accrue with automation may justify enough of a return on the initial capital investment of more costly equipment.

When calculating labour costs, some choose to divide time into value-added time and total hours worked. Unless the arc is struck, the joining process is not taking place. The ratio of hours spent welding to total hours worked is referred to as the operating factor. Operating factors are often expressed as a percentage.

Material Cost

Material cost includes base and filler material as well as gases in GMAW. In Indian context base / parent and filler material costs generally make the highest percentage of overall costs. Energy costs based on arc time and drawing welding power will vary, but is usually a single digit percentage of the total welding cost and the same is the shielding gas. Material costs increase when special weld properties are needed for specific applications.
Overhead Costs
Overhead costs are often added to labour costs. Overhead can include plant, equipment, supervision, QA system and personnel, indirect labour (office personnel).

Process Set up
1. Drawing Study
2. Standard & Hiring of Competency
3. WPS
4. Welder Training & Qualification
5. Equipment & Financial impact
6. Direct expenses such as cost of hiring special machinery

Pre-weld Preparation
1. Time required for cleaning the plates of dust, grease, rust, oxide or any other foreign matter.
2. Time taken for tack welding or holding the job in fixtures.
3. Cost of base plate & inventory
4. Cost of welding Consumables & Inventory cost.
5. Cost of trials if necessary to optimize welding parameters, etc.
6. Preheating

Welding Operation
1. Labour charges.
2. Cost of power consumed.
3. Welding time.
4. Efficiency of welding machine.
5. Fatigue and personal allowances for the welder.
6. Waste material, small electrode pieces etc.
7. Time taken to clean work place

Post Welding
1. Time & cost of cleaning slag, spatter etc.
2. Post Weld Heat treatment
3. Inspection, Testing – NDT
4. Rework
5. Certification as per Product Standard if applicable

Basic Costing Procedure in Welding for reference

Total Welding costs =
(Labour and overhead costs) + (Welding consumables) + (power cost)

Labour and Overhead Costs per Job =
(Total meters (m) of weld) x (Labour and overhead charge/hour) / (Welding speed, m/hr) x (Operating Factor)

Welding Consumables Costs =
(Electrode consumption per m* of weld) x (Total meters of weld) x Electrode price) + (Shielding materials** used per kg of electrode) x (Total kg of electrode consumed) x (Shielding material price

It is possible to reduce total welding cost of fabrications by judicious choice of all the factors that goes into the cost and simultaneously achieve improved assured quality as specifically required for the application
Few Examples from the Use of GMAW to Improve Quality at Less Cost

The reasons for GMAW (MIG/MAG) gaining popularity and prominence as a major dominant process in the field of metal fabrication are

- Improved productivity with flexibility
- High weld quality with low hydrogen deposit
- Suitable for semi-automatic and automatic welding
- Increased penetration and deposition rates
- Amenable to mechanisation and robotic applications
- Adaptable to microprocessor based feed-back control
- More Environment Friendly

Now with the advancement of technology, the introduction the inverter (IGBT) power sources and the development of shielding gas mixtures have given GMAW further potential to become and retain itself as more production friendly and rewarding process in industry.

WELDING MACHINE: Compared to Generator/Thyristorised or diode Rectifier, the Inverter type Power Sources MIG operate on very high frequency (>50 KHz) giving rise to its following characteristics and in turn make GMAW process far more cost effective:

- Lower weight, smaller volume occupying less workspace in the shop floor
- Less no load losses and lower power consumption
- Higher operating efficiency due to less losses
- Excellent dynamic response resulting in lower spatter level & lower current stabilizing time
- Synergic and Pulse mode in IGBT machines give a wide variation in metal transfer mode as suitable to required job application.

SHIELDING GAS: Similarly, the introduction of Argon based gas mixture in place of CO₂ as shielding medium has given another shot in the arm of GMAW for its application as even more attractive and cost effective welding process across the industry. In order to understand it, we may examine the following facts:

Problems of using CO₂ as Shielding Gas
- Unstable arc with high level of spatter
- High fume formation rate
- Higher level of reinforcement
- Reduced speed due to high viscosity
- Undercut / sharp notch at the toe of weld
- Desired metal transfer mode “Spray” is difficult to achieve

Advantages of using Argon-based gasmixtures like,

- Argon-CO₂, Argon-CO₂-O₂, Argon-O₂, etc., are

- It produces the most desired axial spray transfer mode by
- Reducing the surface tension of the weld pool with addition of O₂ and
- producing flat weld bead giving rise to reduction of filler metal, thus saving cost
- It reduces arcing time with faster travel speed
- It minimizes spatter level and reduces post weld repair significantly

Development of Shielding Gas Mixtures

For welding mild and alloy steels which can tolerate some amount of
Oxidising gases, the pure Argon arc is modified by adding

- 1 – 5% oxygen to reduce surface tension and improve weld pool fluidity to give a flatter bead and increase welding speeds.
- 5 – 25% CO2 to increase arc heat to improve fusion and penetration and round out the penetration profile of pure argon. However the greater is the amount of CO2 added higher is the spatter.

For welding stainless steels

- Up to 2% oxygen or 3% CO2 added to improve weld fluidity and give flatter weld bead.
- 10 - 40% helium added in modern gases for improved penetration & bead shape and increased welding speeds,

![Effect of CO2 and O2 on welding speed](chart.png)

**OTHER ADVANTAGES**

- MECHANISATION: The GMAW process can be easily adapted for mechanised application for repetitive nature of jobs. This improves output by reducing unproductive time and also assures consistent quality with expert use and monitoring
- ROBOTICS: The process is now being used more and more with view to achieving higher figure cost saving with consistent quality especially for volume production.
- ENVIRONMENT: The process is more environments friendly and do not produce hazardous fumes like from MMAW process.
- POWER: The process uses less power which also adds up to reduced demand from power grid.
- Opportunity for employees to upgrade skill and competence for career development
- WELDERS HEALTH: Being relatively cleaner process it is less hazardous for welders’ health and encourages more productive time engagement.
The Chart below show the amount of savings in different welding areas possible by going from Dip Transfer with CO2 to Spray Transfer using gas mixture and with appropriate welding parameters.

**Savings with Argon / CO₂ / O₂ gas mixtures**  
(Case Study -1)

<table>
<thead>
<tr>
<th>Savings in Wire</th>
<th>DIP</th>
<th>SPRAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>• From reduced spatter</td>
<td>5%</td>
<td>10 – 15%</td>
</tr>
<tr>
<td>• From flatter weld</td>
<td>10 – 20%</td>
<td>10 – 15%</td>
</tr>
<tr>
<td>Total Savings</td>
<td>15 – 25%</td>
<td>20 – 30%</td>
</tr>
<tr>
<td><strong>Savings in arcing time</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Savings in power</td>
<td>Equivalent to arcing time</td>
<td>Equivalent to arcing time</td>
</tr>
<tr>
<td>• Savings in gas volume assuming flow rate same as CO₂</td>
<td>Equivalent to arcing time</td>
<td>Equivalent to arcing time</td>
</tr>
<tr>
<td><strong>Savings in weld shop productivity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• From improved welder productivity</td>
<td>5 – 10%</td>
<td>5 – 10%</td>
</tr>
<tr>
<td>• From reduced spatter cleaning and weld dressing time</td>
<td>Upto 50%</td>
<td>Upto 50%</td>
</tr>
</tbody>
</table>

The Chart below show the amount of savings in different welding areas possible by going from Dip Transfer with CO2 to Spray Transfer using gas mixture and with appropriate welding parameters for the same total required optimum weld metal deposit.

**Heavy Fabrication**  
(Case Study-2)

<table>
<thead>
<tr>
<th>Savings in Wire</th>
<th>CO₂</th>
<th>Argon Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding Parameters</td>
<td>270 A</td>
<td>280 A</td>
</tr>
<tr>
<td></td>
<td>31 V</td>
<td>30 V</td>
</tr>
<tr>
<td>Gas flow rate (lit/min)</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Arcing Time (sec)</td>
<td>440</td>
<td>306 (30% saving)</td>
</tr>
<tr>
<td>Wire Consumption (kg)</td>
<td>32.8</td>
<td>25.8 (21% saving)</td>
</tr>
<tr>
<td>Gas Consumption (M³)</td>
<td>6.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Labour – welding (Rs)</td>
<td>366</td>
<td>255</td>
</tr>
<tr>
<td>– dressing (Rs)</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>Total Welding Cost</td>
<td>2070</td>
<td>1727</td>
</tr>
</tbody>
</table>
Use of Inverter Power Source to Improve Quality at less cost in MMAW Process

MMAW Process is also used widely by Indian railways in manufacturing units as well as in repair workshops as a very flexible process for application under various conditions and welding requirement. The Traditional Welding Transformer with high power loss and other disadvantages in the welding arc control is improved by using DC power source. The rectifier / Thyristorised Power sources are now being replaced by Inverter based Power Sources having the following advantages:

- Inverter is much smaller in size with corresponding ease of handling and moving for site work.
- Much lower power consumption with savings by around 30 to 40% due to reduction in losses in Transformer.
- Inverter based power sources are getting cheaper compared to the rectifier / Thyristorised Power sources due to technological development and mass manufacturing.
- DC Power source gives better quality deposit. Inverter base power source gives additional advantage of greater control over arc penetration and weld pool control.

CONCLUSION:

✓ It is possible to achieve required consistent quality welding for an application with adaptability to advanced applications with simultaneous reduction in overall cost by using latest GMAW process
✓ It is also possible to save cost by adopting total quality concept in using other processes like MMAW also compared to prevailing status (Example not given here)
✓ It is necessary to relook at every aspect of cost in welding and related influence on quality or lack of it. Quality requirement may require to be defined fresh.
✓ A Quality System designed to specify and monitor all aspects of welding operation will pay for its cost in terms of competitive quality and cost savings with less rework.
✓ Higher speed and better utilisation of rolling stocks between overhaul require new approach to design, manufacturing, fabrication and operation
✓ Indian Railways being the biggest single organisation in an ambitious path of becoming a World Standard Railway System needs to adopt measures to make this a reality
✓ This will also require Human Resource development at all levels from Engineers to Welders, Managers to Quality Assurance personnel as an investment and not to be seen merely as a cost.
✓ Competency of personnel at all levels has to match the rapid technological development commensurate with the requirement. International level qualification and skill certification may go a long way in ensuring this.