QUALITY IMPROVEMENT IN THE FABRICATION OF RAILWAY COMPONENTS - CASE STUDIES

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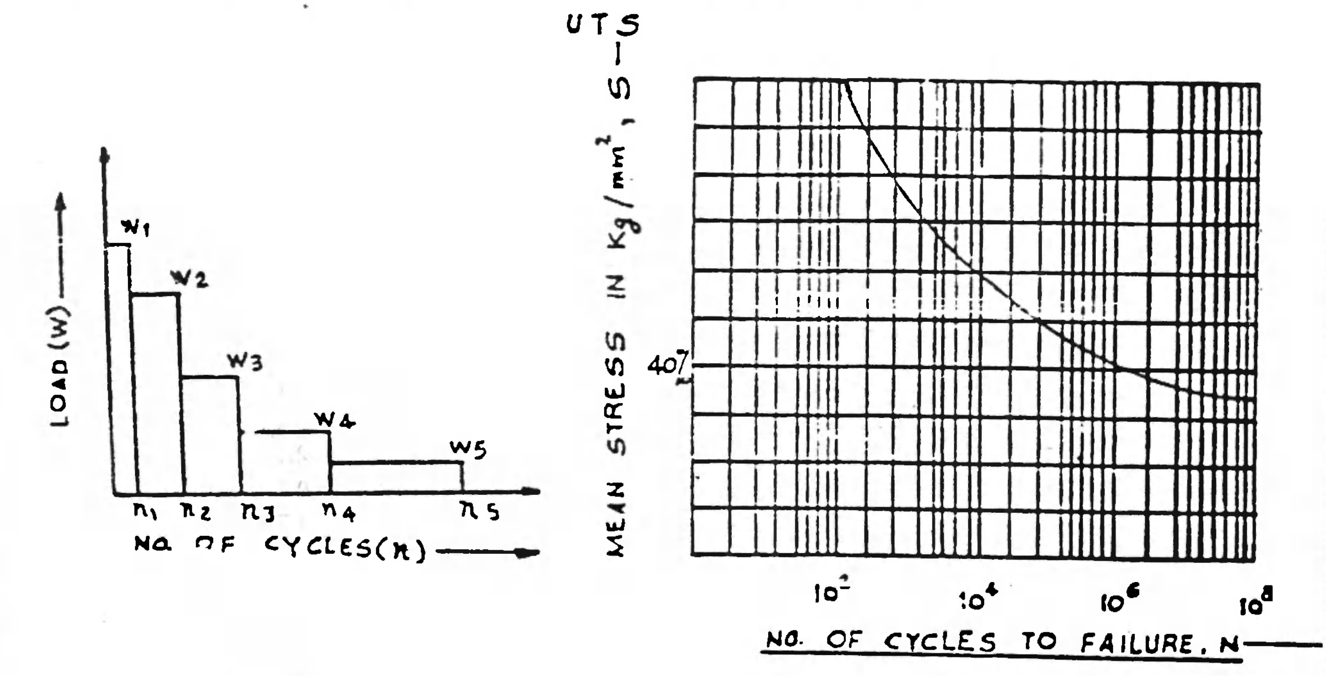
INTRODUCTION

Indian railways are today one of the largest users of welding consumables in the country, through welding as a fabrication tool was recognised only in the fifties with the setting up of the production units e.g. Chittaranjan Locomotive works, Integral Coach Factory, Madras and Diesel Locomotive Works, Varanasi under foreign collaborations. After about 15 to 20 years of service, some of the fabricated components started showing fatigue failures. Some repair practices were introduced in the sheds and sicklines. The welds would stand for few days and then give way. These repairs had been made with popular fallacies, some of which die hard while some got removed in course of time, when specialisation in welding came into the picture.

Plea for quality consciousness and productivity in structural fabrications has been expressed by all concerned. The poor quality in welding has been due to faulty design (30%), poor workmanship (30%) improper quality of material and consumables (20%) weld reliability (10%) and wrong welding procedure (10%).

Since faulty deisgns and poor workmanship cater to maximum percentage for poor weld quality, this paper deals upon these two factors with few case studies, which relate mainly to fatigue failures.



(a) Typical Load Spectrum *(b) Typical S-N curve for m. S. Steel*

Fig 1 : Showing fatigue phenomenon

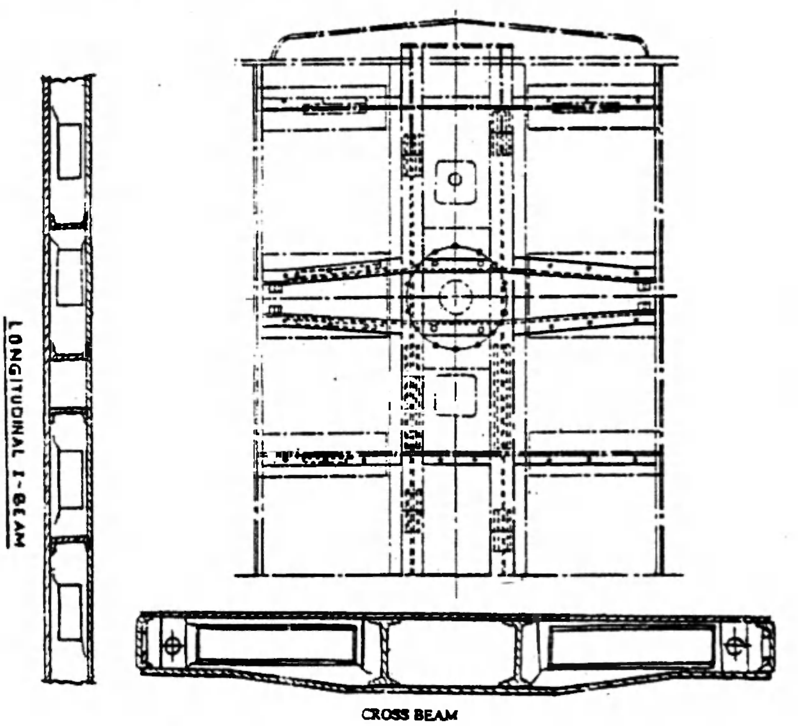


Fig : 2 Showing typical cracks at Bigic frames

The facts of fatigue

A component or structure which survives a single application of load may fracture if the application is repeated many times. This would be termed as fatigue which can be defined as the number of cycles that occur before cracking and hence the time taken to reach a predefined failure criterion.

The designer's objective is to anticipate the sequence of service loading throughout the structure's life. The magnitude of the peak load, which is vital for static design purposes, is generally of little concern as it only represents one cycle in millions. Loadings are usually simplified into a load spectrum, which defines a series of bands of constant load levels and the number of times that each band is experienced (Figure 1). In any welded joint there are few potential locations at which fatigue cracks may develop. These are at the weld toe in each of the two parts joined, at the two ends and in the root besides at the weld itself.

Cracked underframes of DC Electric Locomotives

DC electric locomotives are operated only in Bomaby Ghat sections. These locomotives, built by Chittaranjan Locomotive Works with indigenous designs were put into service in 1961. But after about twenty two years service, cracks were noticed at the airduct openings, longitudinal beams as well as at the cross members of the underframes at the centre point locations on both the cab ends (Figure 2). Stiffener plates welded at these openings had also cracked. Few other deviations were also noticed in the openings for the air ducts made on the web plates which were too big with sharp fillet radius at the corners. These deviations therefore, had contributory effects towards the crack formation.

On investigation of the cracks after opening out, the failures were found to have originated at the corners where the stiffener plates were welded on the duct of the I-Beam. The fracture was progressive in nature and advanced towards the flange portion. The nuciel of the progressive zones were situated at the weld where welding defects like undercuts, vold slag inclusions etc. were observed. Undercuts/voids of different degree were also observed on other welded are as of the stiffener plates.

The materials for both the beam and the plate conformed to mild steel, the chemistry and the mechanical properties being as follows

Chemical composition :	Beam	Plate
C%	0.20	0.21
Mn%	0.65	0.68
Si%	0.11	0.11
S%	0.042	0.040
P%	0.040	0.038
Mechanical properties :		
UTS (Kg/mm^2)	48.0	49.0
Elongation %	25.0	24.0

The micro structure of one of the welds revealed medium grained ferrite pearlite.

It can be seen that there was some lacuna in the quality of the welds of the highly dynamically loaded structure of the locomotives. The repairs involved extensive welding. Since this sort of repair practices was for the first time in the railway no code or welding procedure was available. We had, therefore, to evolve one such procedure keeping in mind the different nature of stresses coming on the welds, We had to qualify the welders also accordingly, particularly in vertical-up and overhead positions, as most of the weldments had to be done in these positions.

In order to carry out the repair work, it was necessary to run out the bogies and support the locomotive body at the jacking points after cleaning the bottom of the underframes from the pipes cables etc. The locomotive was supported in such a way so that the joints being made, during welding, do not get stressed. All electrical and mechanical equipments, floor plates, traction motor etc. had to be removed. The underframes were then once again inspected and all the small/ big cracks are identified. The transverse centre line of the pivot and longitudinal centre line of the locomotive was also indentified and marked.

Preparation of different members i.e. longitudinal I-beams, cross members and top plates had to be made separately prior to taking up welding.

Top Plates

The top plates of the underframes were oxy-cut as per the dimensions required. The cross members between the longitudinal I-beam and side channel were seperated by oxycutting from the longitudinal I-beam without damaging the side channels. Top plates of proper dimensions were placed in its position and butt welded with the existing one. Intermittent fillet welding was carried out for fixing the top plates with the underframes. Plug welds were also made to hold the plates onto the I-beams and also cross members, In addition to the fillet welds on outer side of I-beams and cross members. All these welding were done after the

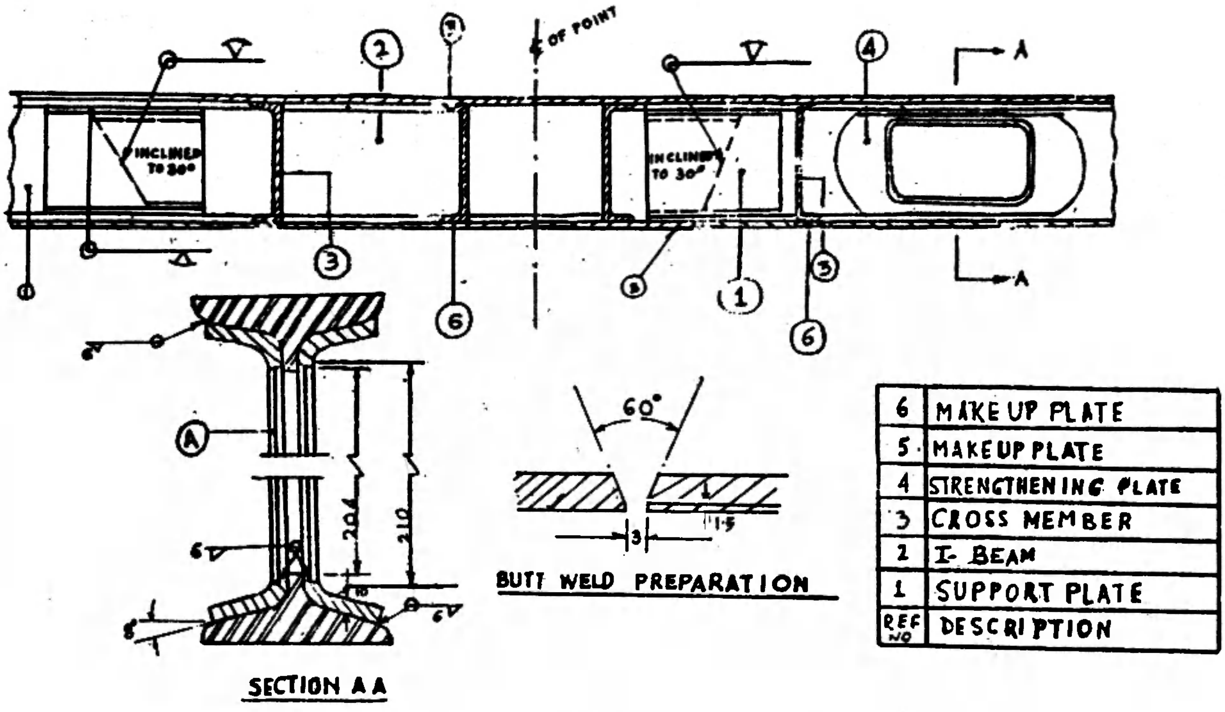


Fig : 3 Sketch showing joints of I-beam support and stiffening plates

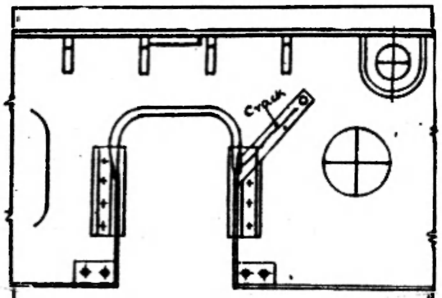
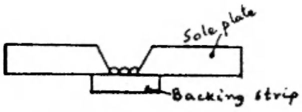
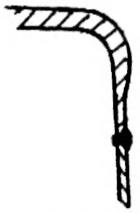


Fig : 4a Crack at the horn gap stiffener and sole plate



4b: Weld Bead



4c : Modified Design

repairs of the longitudinal and cross members.

Longitudinal I-beam

The I-beams were oxycut one by one and seperated from the bottom slab without damaging the latter. The edges of the remnant I-beam were dressed up and prepared for welding. The joints of the I-beams were made inclined at 30" to the vertical instead of straight to achieve improved joint strength i.e. in case of a point loading at the weld, there will be sufficient parent metal below the weld (Figure 3).

The finished length of the fresh I beam and its profile were made in such a way to give specified root gap between the I-beams for welding. Adequate care had been taken to ensure that the cross members come at the specified location. The I-beams were welded with each other using the specified procedure and these beams were then welded with the bottom plate.

Cross Members

The cross members were also seperated from the bottom plate as well as the side channels. The new air-duct openings were made on the channels and stiffener plates were welded around these openings. The cross members were fitted one by one with perfect allignment. The side channel was welded with the bottom plate and the I-beams.

Welding Details

Weldable quality structure steels conforming to IS : 2062 specn were used for repairs. Low Hydrogen type basic coated electrodes having better ductility and impact properties and also approved by RDSO under radiographic quality work were used. All the butt welds were made by using single "V" joint while the fillet welds were made with 6 mm fillet size. Different welding positions were used. Stray arcing was avolded. Inter-pass cleaning also was ensured. Edge distance criterion was maintained i.e. to limit the possibility of local stress concentrations occuring at the unwelded edges, continuous welding were carried out. Notches, undercuts, slag inclusions, porosities etc. all visible welding defects were avoided. Before plug welding, the holes were prepared with counter sinking and the first fun was made with slightly higher current. During the entire welding or cooling cycle, the joints and parts were not subjected to any shock or stress. Proper welding sequences as standardised earlier were followed to avoid distortion. The reinforcements of butt welds were ground flush.

Inspection and Testing

All the weldments were usually examined after proper cleaning. All the butt welds were subjected to radiographic examination. The fillet welds were subjected to dye-penetrant inspection. There was practically no distortion after repair welding.

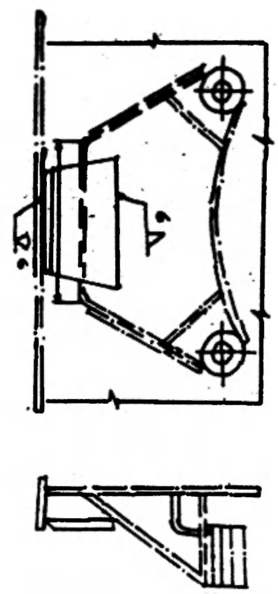


Fig 5 : Welding defect in attachment of bearing spring hanger bracket (Centre)

Cracked load pads of AC Electric locomotives

The load pads were subjected to fillet welds with the underframes. But these pads started cracking in course of service after about five years. On investigations, it was observed that insufficient fillet size together with insufficient fusion were the main reasons of failure. The welding procedure therefore was modified.

The load pads were seperated from the underframe by gouging electrodes duly ensuring that the underframe plate was not damaged. The remnant of weldment on the underframe was removed. The load pad was machined to single `J', preparation. Low hydrogen type electrodes (3.15 mm) having improved impact property and approved by RDSO under class C_2 were used for the root run. Subsequent runs were given by 4.0 mm dia of the same electrodes. Wandering sequences were followed after dividing the load pad weld area into four sectors, Proper interpass cleaning was ensured. The weldment should be free from welding defects, which were tested by magnetic crack detectors.

Bogie Frames of `Box' Wagons

`BOX' type wagons are of welded design and introduced in late fifties. After few years' service, horn-gap stiffeners, soleplates, hanger brackets, trimmer assemblies etc. were found to be cracked. Investigations have revealed that the weld failures were due to :-

(1) Unsatisfactory fit-up prior to welding
(2) Weld surface irregularities and presence of crater/ cracks.
(3) Welding defects like undercut, slag inclusions, lack of penetration, porosities etc.
(4) Discontinuity in welded seams and undersize welding.

Few of the above cases are described as follows :

Weld Defects in Horn-Gap Stiffeners

Figure 4(a) shows the welding defect in horn-gap and crack at the sole plate. It also shows the backing strip used for the repair of the cracks. The root of the initial butt joint between the bent stiffener plate and the straight strip was not properly fused, which led to the cracking of the sole plate. Without removing the entire crack, inspite of making the arrester hole a backing strip was used and then welding was carried out as per Figure 4(b). But these defects were surfaced again after some years' service. The entire procedure for rehabili-

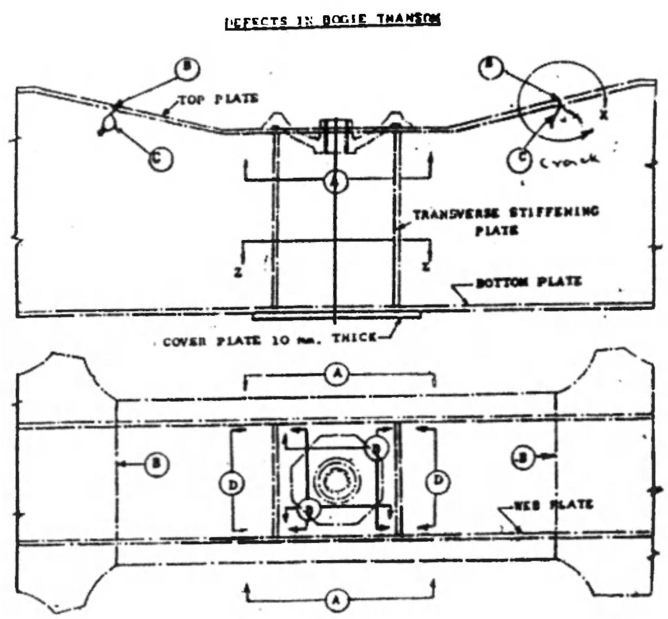


Fig 6 : Sketch showing cracks at the web plate at the junction of butt and fillet welds tation was later changed. The butt-joints were properly made after gouging the root run from the opposite side and then the crack at the sole plate was completely removed starting from the arrester hole.Since the gap at the cracked area was near about 5-6 mm, we had to use the backing strip, which was also welded by continuous seam after the crack was repaired. MMAW with low hydrogen type electrodes were used. Interpass cleaning was ensured. In the later fabrications, the design was changed as per the i.e. the bent stiffener strip was lengthened by 25 mm on either side so that the butt joint can be made with equal width members.

Spring Hanger Bracket (Centre)

Figure 5 shows one spring hanger bracket attachment. The fillet welds here were cracking. On inspection of the cracks, it was observed that the fillet weld were not properly executed. The attachment plate was revelled as per the sketch and fillet welded. It was also ensured that the members to be welded were properly matched against each other without any gap in between. Each end of the fillet welds was fully welded and without any notch due to bad craters. The leg lengths were maintained uniform.

The fillet welds in the attachments of the spring hanger brackets at the head stock ends were also similarly rectified.

Bogie Transom

Cracking had taken place at the weld plate (Figure 6) at the junction of the butt and fillet welds, It was observed that either the butt welds are left unwelded right under the fillet welds or triaxial joints had been made. The junction therefore had acted as a notch or stress raiser. In such fabrications, where members were subjected to highly dynamic stressed, an opening must be left in the vertical plate to avoid the triaxial junctions or underwelded butt joints. Accordingly, a window was provided on the vertical member just over the butt weld.

CONCLUSIONS

Throurgh the simple butt and fillet welds can be executed easily, but in welding of such structures subjected to dynamic loading and fatigue, welding has to be carried out in a proper manner. Inadequate standards of workmanship or design aspects give rise to notches, cracks slag inclusions etc. weld defects and structural discontinuities which act as "stress raisers" have to be avoided.

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