# MATERIAL OPTIMIZATION OF RAIL TRACK WELDING AND VALIDATING USING FEA


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**Abstract:**

The railways provide a long and continuous journey in terms of passenger or goods. The long continuous journey is carried out using the rail tracks. The tracks are made of alloys of iron for a particular length based on their application and profile. The two adjacent tracks are made to be in contact using fasteners and a flat plate. These fastened joints are been replaced by welded joints in recent years based on the maintenance issues. Quality of rails and rail welds plays a significant role in railway safety and general functioning. Testing of rails and rail weld plays a major part in quality control for rails and rail welds. Testing of rail weld is regulated by relevant standards, regulations and legislations.



***Key words:*** welded rails; thermit welding; rail; testing; standards; rail welds; testing of rail welds.


## 1. INTRODUCTION

The railways provide a long and continuous journey in terms of passenger or goods. The long continuous journey is carried out using the rail tracks. The tracks are made of alloys of iron for a particular length based on their application and profile. The two adjacent tracks are made to be in contact using fasteners and a flat plate. These fastened joints are been replaced by welded joints in recent years based on the maintenance issues. Quality of rails and rail welds plays a significant role in railway safety and general functioning. Testing of rails and rail weld plays a major part in quality control for rails and rail welds. Testing of rails is regulated by relevant standards, regulations and legislations.

This work is focused on analysis of welded rail tracks. This work deals with modeling, structural and thermal analysis of tracks welded using thermit welding process. For this purpose, the track profile selected is **45E3**, European standard rail profile. The profile is converted into a wooden pattern and this is used for the preparation of the track of 1inch length using Aluminium alloys prepared by stir casting process. The track made of aluminium alloy will be subjected to mechanical tests and its properties will be evaluated and then used for analysis purpose. For analysis of the track, ANSYS workbench will be used and for modeling of the track, solid works have been used.

## 2. RAILS AND RAIL WELDS

Railway transportation system is, no doubt, a great invention of the 19th century. It opened a new horizon for the mankind, enabling closer interaction between the communities and faster movement of materials and goods. The essential elements in its development are simple. In order to reduce the friction between the wheels of carriages or wagons and the road surface, stone slabs and wooden beams were laid flush with the road surface in the tramways of collieries in the United Kingdom in the middle of the eighteenth century.

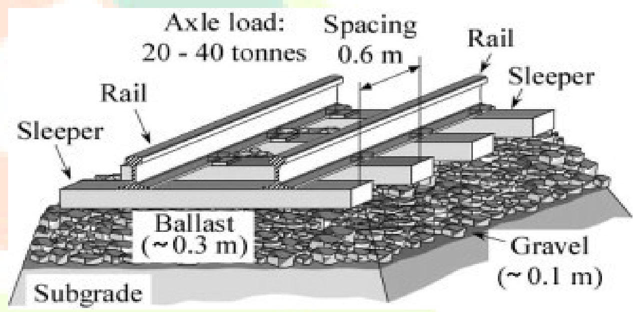


Figure-1 Structure of the Railway Track

The railway track is a structure consisting of parallel lines of rails with their sleepers, fittings and fastenings, ballast, etc., to provide a road for the movement of locomotives and coaches/wagons for the transportation of passengers/freight, etc. The gauge of track is the distance between the inner edges of the heads of rails in a track, measured at 16 mm below the top surface of the rail.

## 3. LITERATURE REVIEW

**[1]** This paper provides the various stresses i.e. Bending and Torsion which occurs in weld joint on applied load. ANSYS being the integral part, basics framework of this stress analysis, has really come up with minute as well as the detail view and distribution of the stresses on the weld joints. Stress concentration areas, the maximum stress bearing area around weld region are easily determined. The differences between theoretical and analytical values has been compared and found approximately equal

**[2]** A ballasted railroad track consists of rails, fasteners, ties, ballast and the underlying sub grade. Realistic simulations of the track response to interactive vehicle-rail loads will require detailed models of each component. In this paper, finite element (FE) models are developed for some of the ballasted track components including wood and concrete crossties, ballast and sub grade. A user material subroutine is employed to predict the failure of wood ties based on an orthotropic stress criterion. The concrete tie is modeled as a heterogeneous medium with pre-stressing tendons embedded in a concrete matrix.

**[3]** In the current study, a thermal model was used to investigate the effects of welding parameters on the distribution of temperature in wide gap alumina thermit rail welds. To validate the predictions, the modelling results were compared with the experiments and despite some utilized simplifications; a reasonable agreement was found between numerical and experimental results. The effects of welding variables such as preheating; initial liquid temperature and weld gap on temperature distribution were studied.

**[4]** This paper aims to present a set of experimental studies of mechanical behavior, where various samples are recorded from base metal zones and areas of thermit weld. These samples are taken from broken rails that have been used in service. After the benchmarking a micro structural differences have been identified by the optical microscope and the scanning electron microscope between the area of the base metal and the rail thermit weld.

**[5]** A three-dimensional finite element analysis of rail joint bars is carried out in ANSYS after importing from Autodesk Inventor. The static and dynamic loads are being applied to estimate fatigue life and endurance strength at the section.

## 4. RAIL WELD PROFILE

The rail weld profile is the cross sectional shape of a railway rail, perpendicular to the length of the rail. Early rails were made of wood, cast iron or wrought iron. All modern rails are hot rolled steel of a specific cross sectional profile. Typically the cross section (profile) approximates an I-beam but is asymmetric about a horizontal axis (however see grooved rail below). The head is profiled to resist wear and to give a good ride, the foot is profiled to suit the fixing system.

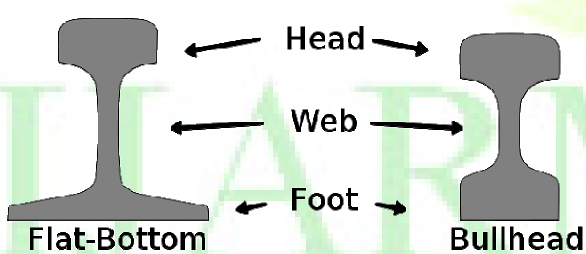


Figure-2 Rail Weld Profile

Rails are produced in fixed lengths and need to be joined end-to-end to make a continuous surface on which trains may run. The traditional method of joining the rails is to bolt them together using metal fishplates, producing jointed track. For more modern usage, particularly where higher speeds are required, the lengths of rail may be welded together to form continuous welded rail (CWR).

## WELDING METHODS

The two main welding methods used for joining rails are: Thermit welding (TW) and Flash butt welding (FBW). FBW is used to join the short about 25m to 150m rails which are then shipped to the site and joined together by the TW to produce continuous rails. Out of the two welding methods used the TW are more likely to fail due to their microstructure and cast defects. About 17% of rail features occur on TW in comparison 7.9% in FBW. The mechanical properties of the TW welds can be improved by heat treatment.

Table 1 Chemical composition of Composite sample:

| Mn | Fe | Mg | Ni | Zn | Al |
|---|---|---|---|---|---|
| 0.002% | 5.457% | 5.285% | 0.002% | 0.001% | 89.253% |

## MODELING OF WELD PROFILE

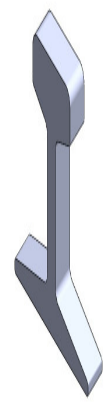

Figure 3 Modeled Isometric view of rail weld profile

The major constituents of the thermit welding are iron and iron oxides along with aluminium. In the proposed material condition, along with iron and aluminium, the magnesium is added for the betterment of strength along with the some additives for the better bonding purpose.

The proposed metal is prepared by using Stir casting process and the composition of mixing the metal will be of following ratio.

- Iron
- Magnesium
- Aluminium

The size of the powders used is of the size 50mgm.

## FABRICATION PROCESS

The sample will be prepared using stir casting process which is one of the metal matrix composite production method. The above listed metals are mixed in the stir casting process and then poured in the sand mould prepared by wooden pattern.

 

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Figure 4 Fabricated Rail Weld Profile

Figure 5 Fabricated Samples for testing

## RAIL WELD TESTS

The first test after the welding is visual examination of the weld for visible defects such as geometry and is usually carried out by the welding personnel on sight. The tests carried out in the laboratory are hardness test, slow bend test, surface fracture examination, micro and macro structure examination. Test methods for both TW and FBW welds are similar and the requirements for thermit welding process are given in pr European standards EN 14730-1 Railway applications. Part-1 Approval of welding processes.

## RESULTS & DISCUSSION

The following are the results obtained for the given boundary conditions and appropriate solver settings.

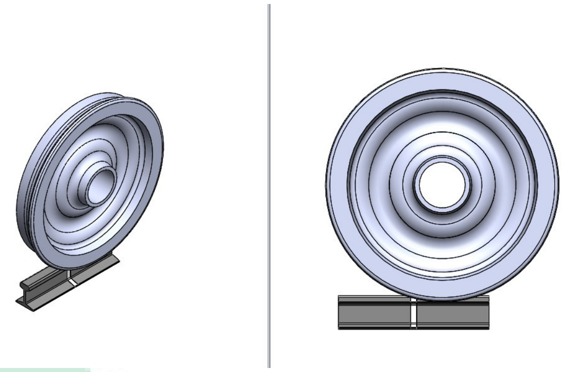

Figure 6 Rail track along with wheel

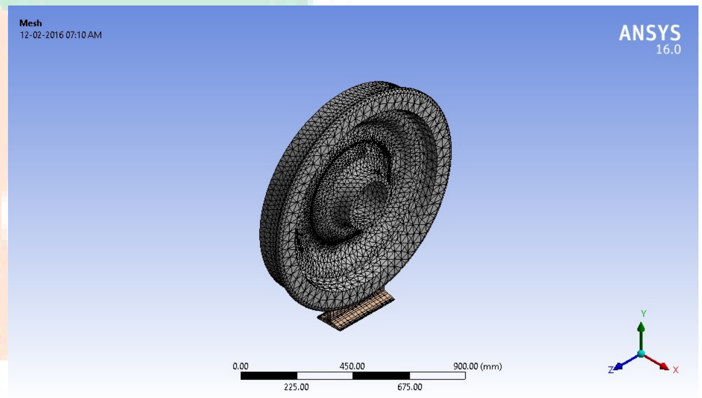


Figure 7 Meshing of the redefined geometry

The following are the Boundary Conditions assigned.
Fixed support – at the bottom of the track
Loads – 45000 N (4500 Kg)
Gravity – Downwards 9.8 m/$S^2$
Displacement – wheel to be moved 100mm in Z axis

**Load calculation:**

Weight of the TARE = 36 tones = 36000 Kg
On each Tare there are 8 wheels. Therefore on each wheel the load acting will be 36000/8 = 4500 Kg (on each wheel)
i.e., 4500 X 10 = 45000 N

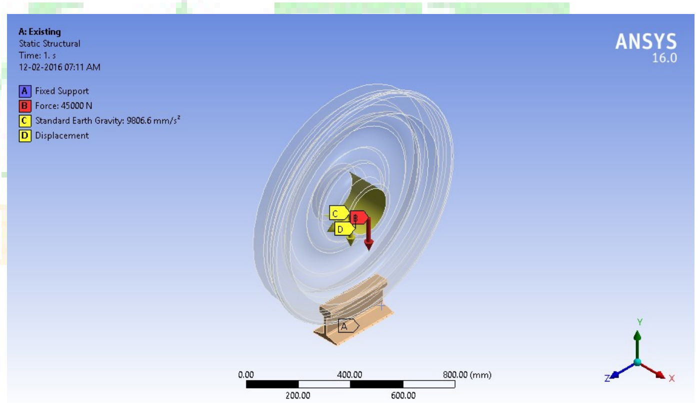


Figure 8 Boundary conditions

 

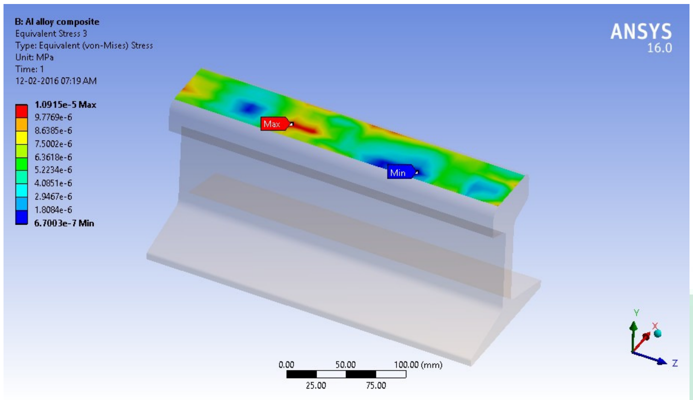


Figure 9 Stress results for proposed material

Table 2 Observation of Mechanical test reports:

| | |
|---|---|
| Tensile Strength (Mpa) | 123.96 |
| Yield Stress (Mpa) | 115.23 |
| Elongation | 0.29% |

Table 3 Observation of Wear test reports:

| Sample | Initial weight(g ) | Final weight(g ) | Abrasion (g) | % |
|---|---|---|---|---|
| AL Composite | 3.2928 | 3.0862 | 0.2066 | 6.27 |

From the results, it is clear that the stress induced in the contact region is more than the stresses at the track and entire assembly. Hence for selecting the better material, it is sufficient to compare the stress results induced at contact regions. On observation, it is clear that, the proposed material is having good weight carrying capacity and the stress induced in it is very low compared to the other materials.

## 5 CONCLUSION

This project was aimed to avoid the failures in Thermit welding by replacing the welding metal compositions thus increasing the strength of the welded portion. For this, the samples were prepared and tests were conducted and analyzed using softwares and the readings are tabulated. From the result it was clear that, the proposed material is having less stress (0.000010915 MPa) induced in it and next to it, the present material of thermit welding is having 0.17339 MPa. But in other cases, the other materials have very high stress concentration in them.

From the above, it can be concluded that, the other grades of materials are not suitable for the weight withstanding capacity and when compared to the existing material, the proposed material is having less stress induced in the track which implied that, the track profile with proposed material is having good weight carrying capacity.

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