Manivel et al. 2017. *Int. J. Vehicle Structures & Systems*, 9(2), 91-94
ISSN: 0975-3060 (Print), 0975-3540 (Online)
doi: 10.4273/ijvss.9.2.06

International Journal of Vehicle Structures & Systems
Available online at www.maftree.org/eja

Material Optimization of Rail Track Welding and Validation using Finite Element Simulation

R. Manivel[a] and R. Shanmuga Prakash[b]

Dept. of Mech. Engg., M. Kumarasamy College of Engg., Karur, India
[a]Corresponding Author, Email: manivelrajj@gmail.com
[b]Email: sunmugaa1691@gmail.com

ABSTRACT:

Railways provide a long and continuous journey for passengers and goods at an affordable cost. The rails and rail joints should be of high quality to ensure a safer transportation of people and goods. The tracks (rail) are made of alloys of iron and are fastened to other rails using fasteners. Nowadays, these fasteners are replaced with welded joints because of rising maintenance issues. Thermite welding is a globally adopted process for welding the rails. This article aims to best utilise the Aluminium composites for the welding of rails. The composites were prepared using stir casting route and a wear test was done on the casted samples to test their durability. Also, some of the mechanical properties of the composite material were found. The rail and track models were made and imported into ANSYS Finite Element Analysis software. The predicted results show that aluminium composites have considerable strength when compared to any other composite material.

KEYWORDS:

Welded rails; Thermite welding; Rail; Testing; Standards; Rail welds

CITATION:

R. Manivel and R.S. Prakash, 2017. Material optimization of rail track welding and validation using Finite Element Simulation, *Int. J. Vehicle Structures & Systems*, 9(2), 91-94. doi:10.4273/ijvss.9.2.06.

1. Introduction

Railway transportation system is undoubtedly a great invention for the mankind in the 19th century. It has extended the limits, to enable closer interaction between the people and faster transportation of materials, goods etc. The railways extend a sophisticated long and continuous journey for passengers and goods along with safety. The safety and economy are elements for its development. Stone slabs and wooden blocks were laid to reduce the friction between the wheels of carriages and the road in the tramways of collieries in the mid 18th century in United Kingdom. The tracks are made of alloys of iron in suitable composition based on their application and profile. The two adjacent tracks are joined using flat plate and fasteners. Due to the maintenance issues, these fastened joints have been replaced with welded joints in the recent years. Quality of rails and rail welds plays a remarkable role in general functioning and safety. Regulated standards for rail testing help to maintain the quality of the tracks.

The railway track consists 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. 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. Fig. 1 shows the structure of the typical railway track. The ballast used beneath the track ensures the stability of the rail. Pads maybe used under sleeper to reduce the ballast wear and vibration isolation.

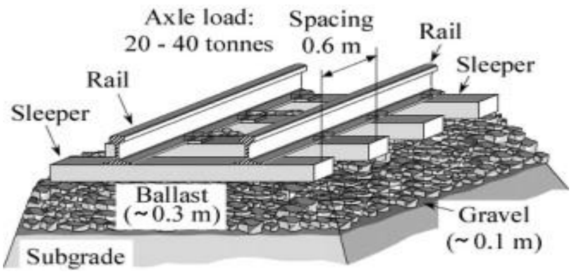

Fig. 1: Structure of the railway track

2. Literature survey & scope of work

Myers et al [1] assessed the structure and properties of the thermite welds and concluded that thermite welds are best suitable and cost-effective solution for welding and repairing of the tracks or rails. Thermite welds ease the rail transportation extensively. Sawley et al [2] decreased the number of welds in railroad to one wide gap instead of two narrow welds. The modification saves a considerable amount of time and cost reduction. Also it can be concluded that one wide gap weldment is good enough for railroads. Rajanna et al [3] examined the mechanical behaviour of the heat treated thermite welded and expulsion with heat treated thermite welded rail steel and clinched that both have similar hardness profile in the weldment region. Porosity and inclusion are higher in the heat treated rails than the other.

Mutton et al [4] performed thermite welding with limited preheating in the rails. This process is influenced by preheating time. For better results, the preheating duration should be of minimum 5 minutes. Barbosa et al [5] utilized ANSYS and analysed the concrete structures. Cracking forms when principal stress reaches the compressive or tensile strength and the critical regions form in perpendicular with local residue stresses. So a high performance computer with nonlinear iterative solver is required. Li et al [6] altered the microstructure and metallurgical discontinuities by applying an axial force to the thermite weld fusion zone, thus enhancing the fatigue behaviour of the rail joints. Schroeder and Poirier [7] assessed the mechanical properties of the thermite welds in rail alloys and concluded thermal treatment is much helpful in increasing the rail weld durability. Hauser [8] researched and found that rail weld failures are due to presence of voids, porosity, gouges and inclusions in the weld zone. Overcoming these defects helped to reduce the failures in the rail welds. Sunil Patel et al [9] developed a 3D finite element model for the rail joints and estimated the fatigue life by applying dynamic load to the joint bars. The model was created in Autodesk Inventor and analysed in ANSYS. They suggested that the reasonable estimate can be derived from the finite element approach.

This work is focused on analysis of welded rail tracks with modelling and structural analysis of tracks welded using thermite welding process. For this purpose, European standard rail profile - 45E3 is selected as the track profile. The profile is converted into a wooden pattern and this is used for the preparation of the track of 1” length using Aluminium composite alloys prepared by stir casting process and subjected to mechanical tests and its properties were evaluated. For modelling of the track, Autodesk Inventor was used and for analysis, ANSYS workbench was used.

3. Rail weld profile

The profile of rail weld as shown is Fig. 2 is the cross section of the rail, which is perpendicular to the rail length. Wood, cast iron and wrought iron were used for rails in earlier days. Nowadays, the rails are hot rolled steel of definite cross sectional profile with higher dimensional stability. Generally, the profile resembles I-shape with symmetric about its horizontal axis because of the variation in the head and foot of the rail. This ensures the good ride, stability and less wear on the top of the rail. Fig. 3 shows the isometric view of the rail weld profile modelled in CAD. This model clearly shows the top head facilitates for smooth movement of the wheel and foot is extended to give superior support to the rails even at higher speeds.

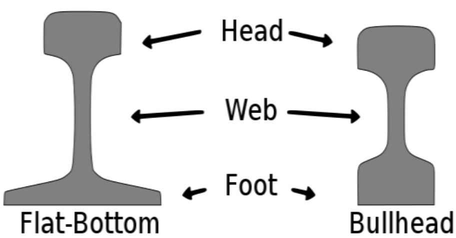

Fig. 2: Rail weld profile

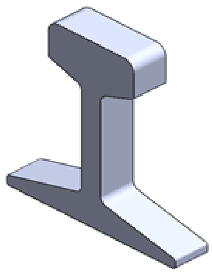

Fig. 3: Isometric view of rail weld profile

4. Welding methods

Thermite welding (TW) and Flash butt welding (FBW) are the two most prominent welding methods adopted for effective joining of two rails. Rails of 25 to 150 metres length can be joined by FBW process in off-site location and that are transported to the site to get continuous rails by joining them using TW. Thermite welds are more vulnerable to failures because of the defects in their microstructure and quality of casting. Failure rate for TW is 17% while FBW has 7.9%. But the heat treatment of TW considerably enhances the mechanical properties of the welds. The major constituents of the TW are Iron and Iron oxides along with Aluminium. In the proposed material condition, along with iron and aluminium, Magnesium is added for the betterment of strength along with some additives for better bonding purpose. The proposed metal is prepared by using stir casting process and the composition of mixing the metal will be of following constituents like Iron, Magnesium and Aluminium. The size of the powders used is of the size 50 μm. The chemical composition of Aluminium composite sample is shown in Table 1. The sample is prepared using stir casting process which is one of the metal matrix composite production methods. The metals listed in Table 1 are mixed in the stir casting process and then poured in the sand mould prepared from wooden pattern. Fabricated rail weld profile and samples are shown in Fig. 4 and Fig. 5 respectively.

Table 1: Chemical composition of Aluminium Composite sample

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

Fig. 4: Fabricated rail weld profile

Fig. 5: Fabricated samples for testing

The mechanical test report reveals that the tensile strength is 123.96 MPa and yield strength is 115.23 MPa and elongation is 0.29%. The wear test was carried out under dry sliding condition with an applied load of 9.8 N at room temperature. The pin had a diameter of 5mm. The wear test results are presented in Table 2. These test results show that the material is good enough for application to welding of rails. Visual examination is carried out on the welds by the welder or inspector for finding the defects that are visible to the naked eye after the welding process. Furthermore tests like hardness, slow bend, examination of surface fracture, macro and micro structure examination are done in the laboratory testing conditions. TW and FBW weld methods are similar to each other and are given in European Standards (EN 14730-1) railway applications, Part-1 welding process approval.

Table 2: Wear test results

Initial weight (g)	Final weight (g)	Abrasion (g)	%
3.2928	3.0862	0.2066	6.27

5. Results and discussion

The track and wheel models were developed in Autodesk Inventor as shown in Fig. 6 and CAD model was imported into ANSYS Finite Element Analysis software. The moment of Inertia of rail track cross section is 3.055×10^{-5}, Young's Modulus of material is 207 GPa and Poisson ratio is 0.28. Surface to surface contact type was established with CONTACT 173-3D elements. Meshed model is depicted in Fig. 6. For solving, Euler method was followed to make effective contact surface, it would consume less computational time. SOLID 186 higher order solid element was used to discretize the track and wheel [10]. The model was assumed to be linearly elastic with no applied pre-stress. The nodes at the bottom of the track are constrained as fixed boundary condition in all degrees of freedom. The applied load is calculated on the basis of TARE weight being 36 tones (36000 kg). The load acting on each wheel will be based on equal distribution of TARE weight 8 wheels, i.e., 36000/8 = 4500 kg (45000 N). The displacement is applied such that the wheel to be moved 100mm in the vertical axis. Downward gravity of 9.8 m/s^2 is considered. Fig. 7 shows the assigned boundary conditions for the track and wheel finite element analysis. Boundary conditions help to specify the model interaction with the whole system.

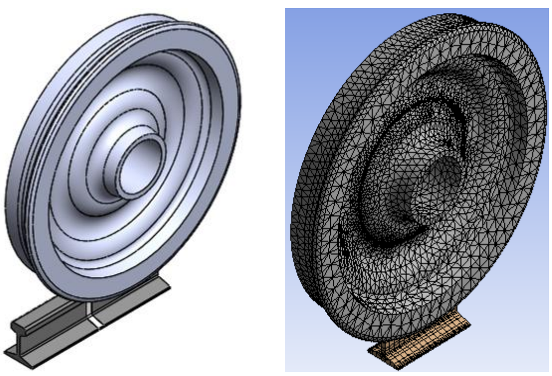

Fig. 6: CAD model of rail track/wheel (Left) and finite element model mesh (right)

Finite element analysis predicted the stress values which were induced by external force and body force. Metal on metal surface always produces higher stress than any other combination of contact pair. Equivalent vonmises stress results for the rail with proposed material is shown in Fig. 8. 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. Higher level of stress was predicted at the contact region of the rail and track was to be 173.39 kPa. This predicted result is better than any other material.

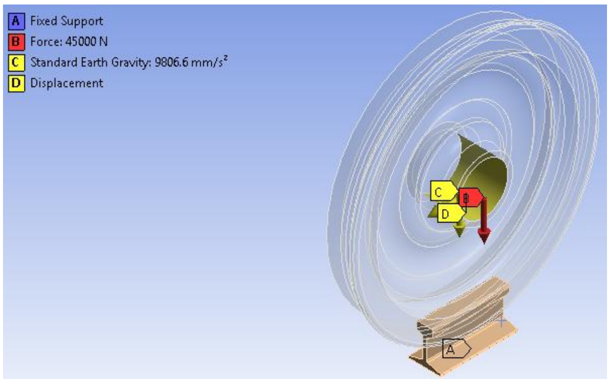

Fig. 7: Loads and boundary conditions to the finite element model

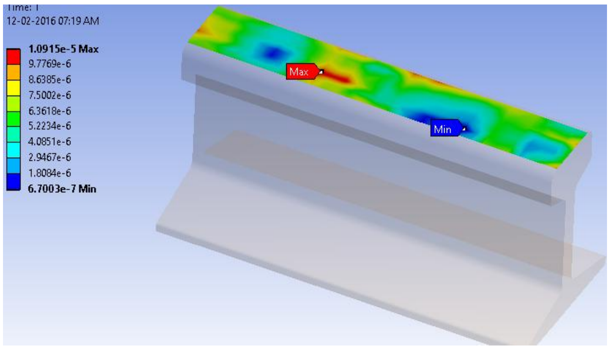

Fig. 8: Equivalent vonmises stress (in MPa) results

6. Conclusions

This project was aimed to avoid the failures in Thermite 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 finite element analysis software. From the result, it was clear that the proposed material is having lesser contact stress (10.915 Pa) induced in it when compared to that of the stress in thermite welding which has 173.39 kPa. But in case of the other materials which have very high stress concentration in them. It can be concluded that the existing material when compared with the proposed material which is having less induced stress in the track implies that the track profile is having good weight carrying capacity.

ACKNOWLEDGEMENTS:

Authors acknowledge the help extended by Mr. S. Sathish Kumar at Dept. of Mech. Engg., M. Kumarasamy College of Engineering, Karur, India.

REFERENCES:

[1] J. Myers, G.H. Geiger and D.R. Poirier. 1982. Structure and properties of thermite welds in rails, *Welding J.*, 258, 8-19.

[2] K. Sawley, J. Sun and D.R. Poirier. 1999. Widegap welds offer railroads potential savings, *Railways Track and Structures*, 4, 12-14.

[3] S. Rajanna, H.K. Shivanand and B.N. Akash Deep. 2009. Improvement in mechanical behavior of expulsion with heat treated thermite welded rail steel, *Int. J. Mech., Aero., Industrial, Mechatronic and Manufacturing Engg.*, 3(12), 1545-1549.

[4] P.J. Mutton and E.F. Alvarez. 2004. Failure modes in aluminothermic rail welds under high axle load conditions, *Engineering Failure Analysis*, 11, 151-166. https://doi.org/10.1016/j.engfailanal.2003.05.003.

[5] A.F. Barbosa and G.O. Ribeiro. 1998. Analysis of reinforced concrete structures using ANSYS nonlinear concrete model, *Computational Mechanics: New Trends and Applications*, 1-7.

[6] Y. Li, G. Kang, C. Wang, P. Dou and J. Wang. 2006. Vertical short-crack behavior and its application in rolling contact fatigue, *Int. J. Fatigue*, 28 (7), 804-811. https://doi.org/10.1016/j.ijfatigue.2005.06.047.

[7] L.C. Schroeder and D.R. Poirier. 1984. The mechanical properties of thermite welds in premium alloy rails, *Mat. Sci. Engg.*, 63, 1-8. https://doi.org/10.1016/0025-5416(84)90159-9.

[8] D. Hauser. 1978. Welding of Railroad Rails-A Literature and Industry Survey, *ASTM Special Tech. Publication 644*, 118-144. https://doi.org/10.1520/stp27106s.

[9] S. Patel, V. Kumar and R. Nareliya. 2013. Fatigue analysis of rail joint using finite element method, *Int. J. of Research in Engineering and Technology*, 2(1), 80-84. https://doi.org/10.15623/ijret.2013.0201016.

[10] ANSYS 16.0 Users Manual.