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Development of In-suit Welding Technique to Repair Rail Welded Joint with Defect

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Abstract: *With the fast construction of high-speed train railway, moving flash butt welding has beencommonly employed for railway track welding, however, these joints sometimes do not achieve the performance required for high speed train operation due to the welding defects. In this research, a new method of in-situ welding technique was developed and applied to repair rail welded joint with defects, and it has many advantages such as saving time, reducing the consumption of rail during welding, decreasing cost of transportation and so on. In addition, it is more economic and efficient to solve welding defects without increasingthe number of rail welded joints, which can further avoid the risk possibility during actual service conditions.*

Keywords: *moving flash butt welding, welding defects, in-situ welding technique, insertion of short rail technique, fixed temperature, mechanical stretch.*

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I. Introduction

With the rapid development of china high speed railway construction, especially several domestic passenger lines have achieved continuous welded rail through advanced rail welding technology (Wang, 2011; YU et al. 2015) which not only improves smoothness and overall strength of rails but also driving conditions of trains, so as to ensure that the train maintains a comfortable environment at high speed (Pan, 2012; Jiang et al. 2017). Long railways are transported to the site bylong railway transport vehicles, then laid down and welded to continuous welded rails with welded turnout in the case of newly built railways.

At present, the welding methods for rail joining mainly include moving flash butt welding, exothermic welding and gas-pressure welding (Jiang et al. 2017). Because of the advantages of high degree of automation and stable welding quality, moving flash butt welding has become a widely used welding method in rail welding (Chen et al. 2008; Ding et al. 2010). However, moving flash butt welding could generate rail welded joint with defects due to some factors such as equipment, environment, base materials and so on (Dong et al. 2013; Han et al. 2012), which will severely affect the inspection and delivery of the project, as well as the subsequent operation and maintenance without handling it in time. In the traditional high speed train railway construction, all rail welded joints with defects are cut, and then,short rail is inserted (length about 25 m). However, this method will increase the number of butt welded joints, which will lead to increased costs and inefficiency. In-situ welding technique can avoid above problems and improve efficiency.

Due to the requirement of mechanical performance, Godefroid et al. (2014, 2015) examined the fatigue fracture. Concentrating on the microstructure and mechanical properties, Porcaro et al. (2019)considered the microstructure and mechanical properties of flash butt welded joint with pearlite rail. Mutton et al. (2016) studied the microstructural characteristic of flash butt welded joint due to the rolling contact fatigue damage. Shen et al. (2018) considered the microstructure evolution and mechanical properties of flash butt welded joint with Inconel718 rail. Meanwhile, Weingrill et al. (2017) examined the temperature profile during the flash butt welding of railway rails for temperature field evolution.

In this study, the in-situ welding technique is conducted to deal with rail welded joints with defects, and it hasachieved the economical and efficient treatment to repair rail welded joints with defects through comparison between the proposed method and the traditional method.

II. Theory and Proposal of In-suit Welding Technique

In order to achieve continuous welded rail, moving flash butt welding has been used for seamlessly rail joining, insertion of short rail and in-situ welding technique were applied to deal with rail welded joints with defects. The relevant theories were introduced as follows.

2.1 Moving flash butt welding

Flash welding, a form of resistance welding, is used during rails welding. The welding circuit consists of a low-voltage, high-current energy source (usually a welding transformer) and two clamping electrodes, one stationary and one movable (Limpel, 2014). Two pieces of rail to be welded are clamped in the electrodes, and one is moved toward the other until they meet, making contact. Energizing the transformer causes a high-density current to flow through small areas that are in contact with each other because of microscopic surface roughness or asperities (Ozakgul, 2015). The end face metal is continuously melted and accompanied by a flash until the forging head reaches a predetermined condition, and the upset is applied to complete the flash welding.

2.2 Insertion of short rail technique

The traditional method of handling rail joints with defects is to insert short rail. It is necessary to transport short rails to the site that meet the specified length of the line (the general requirement of passenger lines are more than 25 meters), saw the rails containing the rail welded joint with defects, insert short rail, and then weld it. Insertion of short rail technique has following steps in dealing with the rail welded joints with defects: transporting short rails to the site, sawing joints, loosening rail fasteners and putting short rail into groove, welding the first joint, rail bending, welding the second joint, heating treatment after welding, checking the condition for rail welded joints.

When using insertion technique with short rail to solve the welded joint with defects, in order to ensure the equal number of joints on the two rails, the corresponding rail welded joints without defects need to be sawed and inserted into a same length of rail. Therefore, as long as there is a welded joint with defects,four newwelded joints willbe dealt with when using the method of insertion technique with short rail.

2.3 In-situ welding technique

Railway in-situ welding method saves time and costs because it requires less material consumption and builders. Besides, the number of rail joints will not increase, avoiding thepossibility of introducing new welded joints with defects according to increasing of rail welded joints, which reduces the work for later operation and maintenance. Therefore, it is more economical to handle rail welded joints with defects.

The rail welded joint with defects is sawn when the temperature is below the design fixed temperature during stress release of welded rail. According to the characteristics that the rail is easy to generate elastic deformation, the elongation generated by means of manual pulling or heating the rail is taken as the consumption during the in-situ welding. Rail joint in-situ welding technique has following steps in dealing with the rail welded joints with defects, including preparation, loosening rail fasteners, sawing joints in low temperature, bending rail, rail elongation, joint alignment, heating treatment after welding and locking rail in the end.

In addition, the length of welded rail with in-situ welding technique will be shorter due to the cutting and consumption of welding.Therefore, the mechanical stretch is applied to restore original length,which could be achieved by considering the rail fixed temperature.The stretch length during inner stress release of welded rail can be calculated according to thermal expansion or shrinkage of rail with the **Eq. (1)** as follows:

$$\Delta l = 0.0000118 \times \left(T_{fixed} - T_{welding}\right) \times L \quad \textbf{(1)}$$

Where, T_{fixed} and $T_{welding}$ mean the temperature when rail was fixed with fasteners and welding, L and $\Delta l$are original lengthand stretch length.

With the consumption of cutting and welding, the actual stretch length should be obtained with **Eq. (2)**

$$\Delta l = 0.0000118 \times \left(T_{fixed} - T_{welding}\right) \times L + L_{consumption} \quad \textbf{(2)}$$

Where, $L_{consumption}$ means the consumption length during in-situ welding, which magnitude is about 30mm.

III. Application of in-situ welding technique

It has many advantages to handling rail welded joints with defects by in-situ welding. For example, the number of rail joints are not increased, which saves raw materials and reduces the workload of the operation and maintenance in a later stage, so it is more economical and efficient to repair rail welded joints with defects.

3.1 Detection of rail welded joint with defects

The rail material is U71V, and its chemical composition (wt.%) and physical properties are listed in **Table 1**. The tensile strength of this kind of U71V rail steel exceeds 980MPa and elongation exceeds 8%.The flash welding parameters are shown in **Fig. 1,** including voltage, current, displacement and force. After the rail is welded, quality inspection of the continuous welded rail is checked in order to ensure the safety of high speed train. Thus, the rail joints need to be inspected for defects by the rail detector. When defects are found in the rail joint such as cracks, rail bottom over-heated, gray spot and so on, the rail joint with defects as shown in **Fig. 2**should be handled with advance repair technique so that its performance is guaranteed.

Table 1 Chemical composition (wt.%)and physical properties of U71V rail steel

Material	Chemical composition						Physical properties	
U71V	C	Si	Mn	P	S	V	Tensile strength (MPa)	Elongation（%）
	0.75	0.78	0.86	0.015	0.006	0.09	≥980	≥8

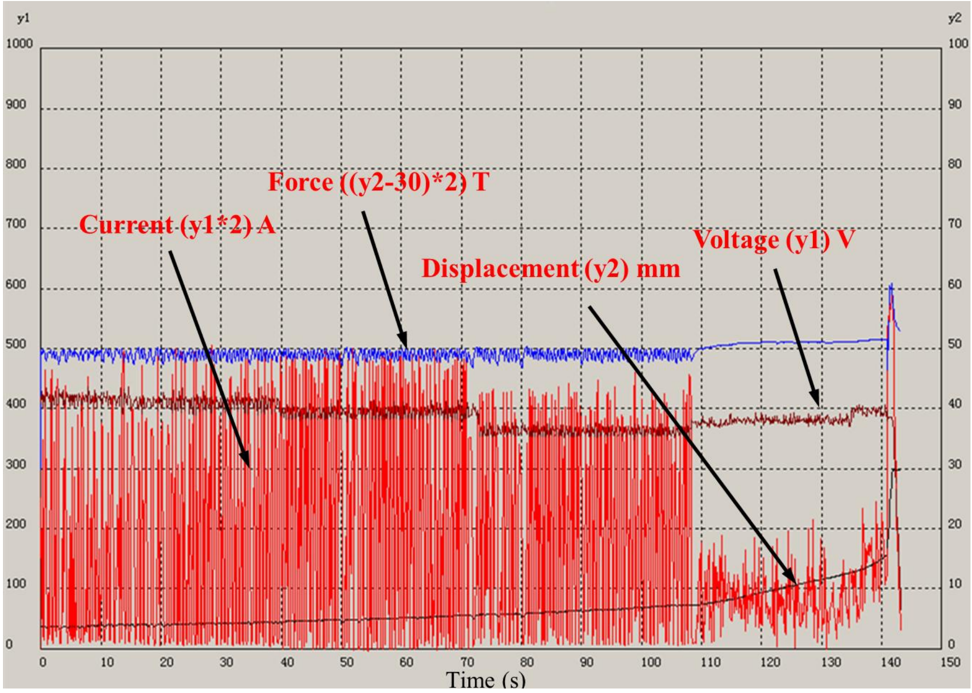

Fig. 1 Parameters of moving flash welding

3.2 Procedure of in-situ welding technique

The main reasons of generating welding defects by flash welding include environment, rust cleaning, excessive polish and abnormal equipment which will cause insufficient heating or over-burning. It is necessary to re-weld after sawing the rail welded joint with defects. Because the flash welding of rail joint needs to consume length ofrail about 25mm, so sufficientconsumption of rail before welding should be reserved that makes full use of the elongation from the rail elastic deformation. The whole flow chart of in-situ welding technique is shown in **Fig. 3**. The following is the detailed steps of it to deal with the rail welded joint with defects.

Fig 2 Defects in rail butt welded joints

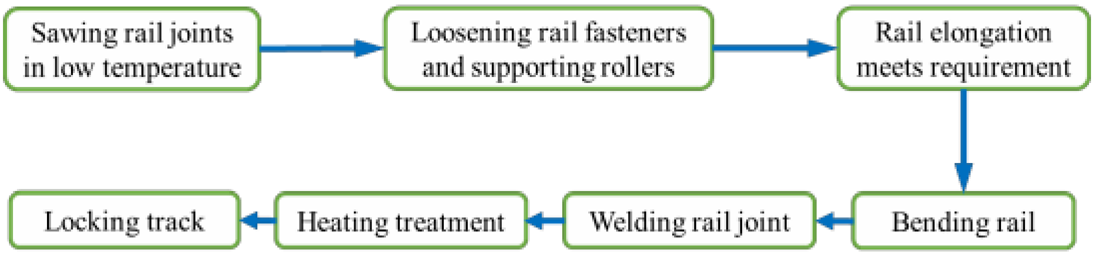

Fig 3 Flow chart of in-situ welding technique

Step 1: The rail temperature at the time of welding and stress release of the original rail, and the actual rail burnout of the flash welder were used to calculate the rail elongation. Arrange workers to check the welder condition, loose fasteners, bend rail, pre-weld and post-weld treatment.

Step 2: Firstly, use waste rails for the sawing test before handling the rail welded joint with defects. Then, the rail temperature is measured periodically. When the rail temperature is lower than the design fixed temperature during stress release of welded rail, the rail welded joint with defects is sawed vertically, and then the rail at one end is quickly dislocated asshown in **Fig 4**and **Fig 5**.

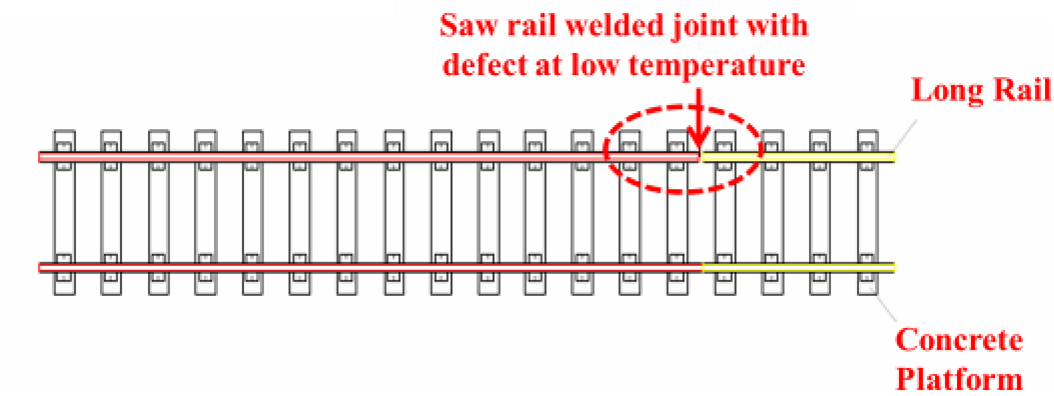

Fig 4 Sawing rail welded joint with defect

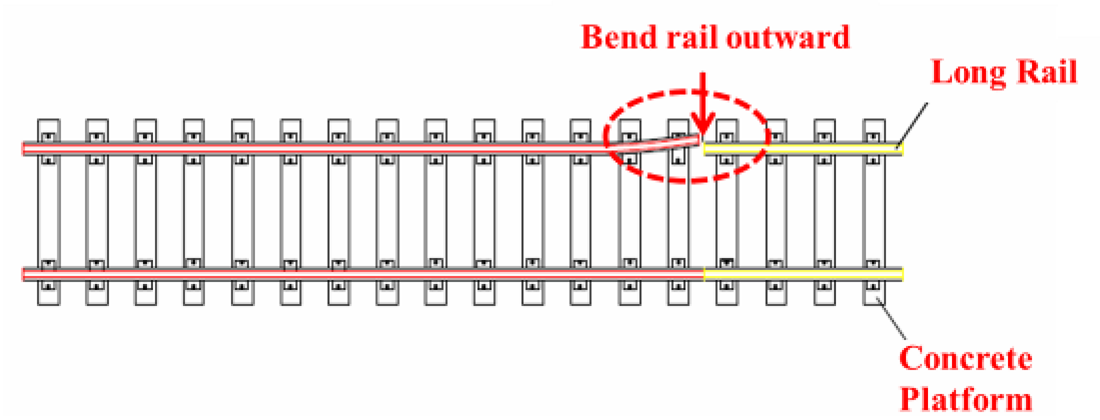

Fig 5 Dislocation of rail at one end

Step 3: Check the condition of the flash welder and thoroughly remove rust, grease and convex welding zone within the welder's clamp range.

Step 4: Combined with the design fixed temperature during stress release of welded rail and welder rail burnout, determine the length of the rail that needs to loosen fasteners according to the relationship between the temperature rise and the rail elongation (to ensure that the actual fastening down rail temperature after in-situ welding construction still meets the design fixed temperature of rail stress release). Then, loosen fasteners and support rollers. Moreover, when the fasteners are loosened, at least four internal combustion engine wrenches are evenly distributed on the rail. In addition, the rollers must beplaced in accordance with the de-stressing requirements and ensure that the rail bottom does not touch the platform

Step 5: Observe the variation of rail temperature rise and rail elongation. When the rail temperature reaches the original design fixed temperature of rail stress release and shows an upward trend, use the rail collider to hit the rail in the direction of the broken rail at an appropriate position to ensure the rail stress is uniform. It is necessary to investigate the adjacent rail actual fastening down rail temperature and the design fixed temperature of rail stress release in front of the rail welded joint with defect. During the treatment, the elongation of the rail should be accurately controlled according to the rail temperature.

Step 6: **Fig. 6**shows that when the rail elongation reaches the requirement, take off the rail collider and quickly bend the rail outward at 30 meters from the rail joint.

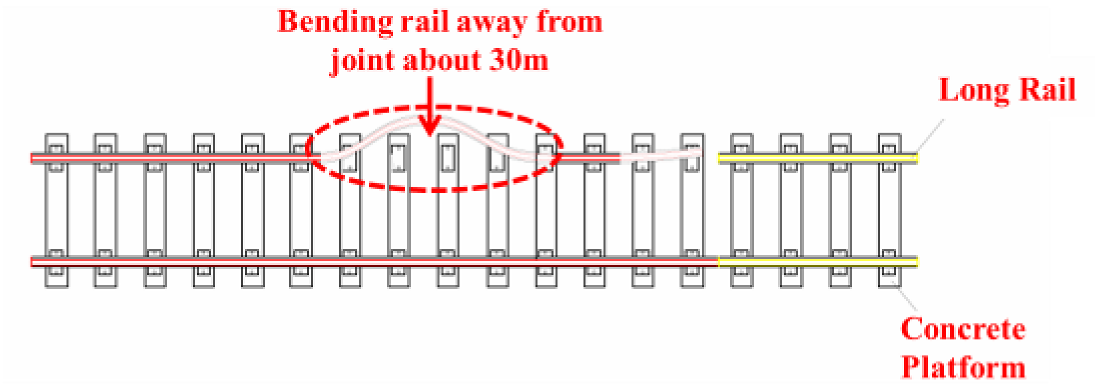

Fig 6 Bending the rail outward away from rail joint with 30m

Step 7: The elongation of the rail joint is strictly controlled,and the rail joint is welded after rail top, working edge and rail bottom are aligned. When entering the accelerated welding and upsetting process, manually straighten the rail and drop it into the bearing groove as shown in **Fig 7**.

Fig 7 Welding rail and manually straightening the rail

Step 8: At the end of the welding, check the welding data and curve to determine whether the welding process issuccessful. Visually inspect rail joint appearance and rail groove. After making sure everything is normal, and then remove the roller, and 10 fasteners are not locked around with the new joint, the connection and the other fasteners are locked to meet the de-stressing requirements. After the treatment, the relevant requirements of fastening down rail temperature of the adjacent unit rail in front of the rail welded joint with defect should be ensured. That is, the adjacent rail of fastening down rail temperature does not exceed 5 °C, and the left and right rail temperature in the same unit rail section does not exceed 3 °C.

Step 9: After the rail joint temperature is lower to the design fixed temperature of rail stress release, the bottom of rail should be polished, normalized and grinded. Observe the change of the rail temperature. If the rail temperature before the normalizing exceeds the design fixed temperature of rail stress release by ±15 °C, it should not be normalized. **Fig. 8**shows the rail is fully locked at the design fixed temperature of rail stress release.

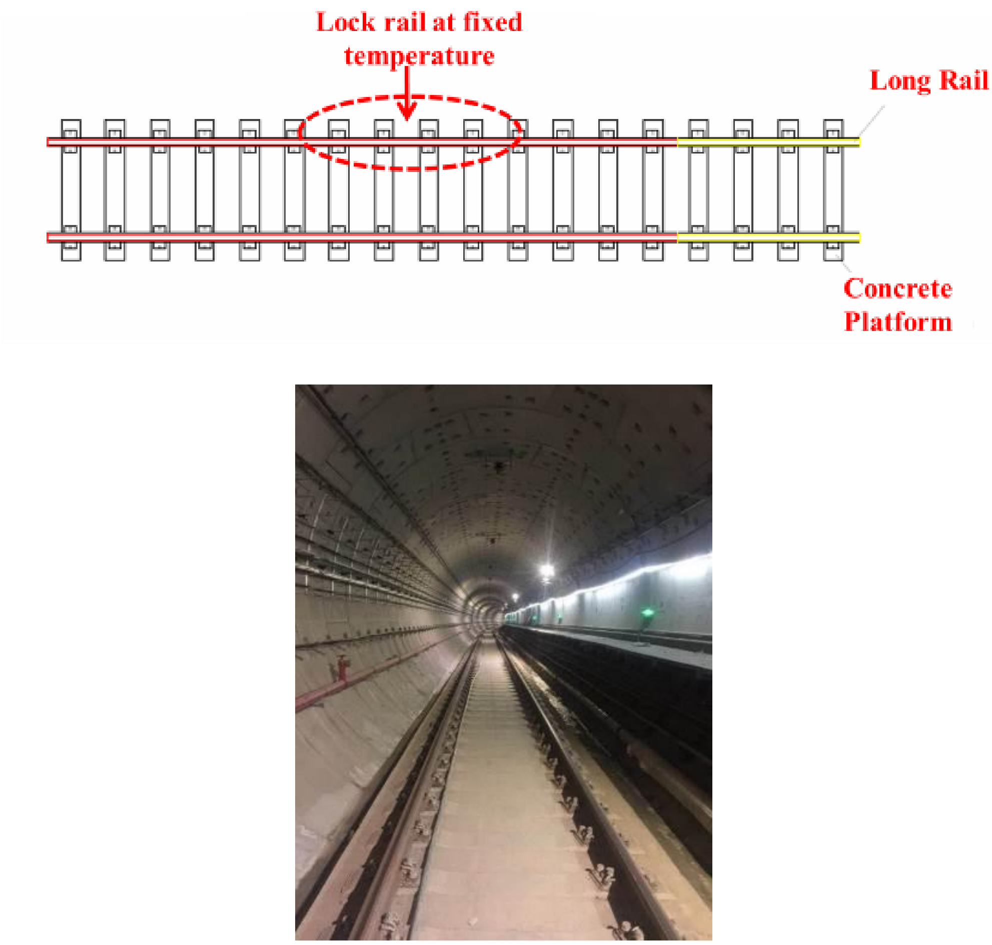

Fig 8 Fully lock the rail at the design fixed temperature of rail stress release

3.3 Attention in the in-situ welding technique

The in-situ welding construction process is controlled in accordance with the general standard of the iron standard and the flash welding standard:

(1) The rail is de-rusted and the end face is required to be smooth and free from water and oil. In addition, the joint alignment meets the requirements.

(2) Loosen and fasten fasteners in strict accordance with the requirements of the specification.

(3) Rail damage is strictly prohibited when the rail is hit by a rail collider and the rail is bent.

(4) It is strictly forbidden to make small bends when the rail is bent, so as to avoid the rail cannot be restored.

(5) Post-weld heat treatment, grinding and flaw detection strictly implement relevant standards.

In addition, the construction involves the use of rail swaying, hoisting machine and the crowbar, and the post-weld heat treatment involves the use of oxygen acetylene. Strict security measures must be implemented.

(1) Pre-employment training for workers, prohibiting unlicensed employment and operations.

(2) A full-time safety officer is set up on site, and workers are required to operate in strict accordance with safety regulations.

(3) The project department sets up the equipment inspection group. The safety inspection of the flash welder and the internal combustion wrench before use is carried out to eliminate safety hazards in time.

(4) Timely release of "Safety Symbol", requiring immediate replacement of failed or damaged safety equipment.

(5) Construction vehicles must be driven in strict accordance with the speed limit sign and the conductor signal.

(6) Construction site safety warning signs must be hung in the most conspicuous position. In the place where flammable and explosive materials are stacked, fireproof and explosion-proof appliances must be placed as required.

Furthermore, when the treatment of rail welded joint with defects by in-situ welding technique was completed and the rail was fully locked, the new rail joint should be inspected by the rail detector for whether the defects still exit. If there are defects in the new rail joint, above procedures about in-situ welding technique should be repeated until a rail welded joint without defects is obtained.

IV. Comparison of in-situ welding and insertion of short rail methods

Both in-situ welding and insertion of short-rail methods can be used to treat rail welded joint with defect, but there are significant differences in procedure and efficiency. Below is a comparison of relevant parameters of the two methods to deal with rail welded joint with defect.

When using insertion of short-rail technique to treat a rail welded joint with defect, due to the increase in the number of joints, on the one hand, the smoothness of the line will be reduced, and on the other hand, the risk of introducing rail welded joints with defects and the workload of the operation and maintenance in a later stage will be increased. In addition, the increase of short rails required during construction will not only increase the consumption of rails, but also increase the number of processes such as short rail transportation, which will undoubtedly increase costs.

Through the introduction of the two methods above, the relevant data are shown in **Table 2**including handling time, number of people transporting short rail, loosening fasteners and bending rail, rail joint and consumption of rail. The results show that in-situ welding technique is a more advanced method for handling rail welded joint with defect than the insertion of short-rail method. It does not increase the number of joints and does not require additional rail consumption. It can be more cost-effective to handle rail welded joint with defect quickly.

Table 2 Main data comparison of two construction methods

Serial number	Project	Insert-short-rail method	In-situ welding method
1	Handling time (day)	1.5	0.4
2	Number of people transporting short rail	5	0
3	Number of loosening fasteners	6	6
4	Number of bending rail	2	1
5	Rail joint	4	1
6	Consumption of rail (m)	50	0

V. Conclusions

A new method for treatment of rail welded joint with defect by in-situ welding technique was introduced during the construction of high-speed railway line, and compared with traditional method of insertion of short rail construction. Some conclusions can be obtained:

(1) in-situ welding technique is a more advanced method for handling rail welded joint with defect than the insertion of short rail technique.

(2) Less time is used to deal with rail welded joint with defect by in-situ welding technique, saving time for the later welding of the rails. So it is more efficiency.

(3) In-situ welding technique does not increase the number of joints and does not require additional rail consumption. It can be more cost-effective to handle rail welded joint with defect quickly.

References

[1]. Chen H, Wu B, Tu M (2008). Microstructures and Properties of Flash Butt Welded Joints of Austenitic-Bainitic Alloy Steel Railway Switch and U75V Rail. Transactions of the China Welding Institution (4): 41-44.

[2]. Ding W, Song H, Luo D, Liu Y (2010). Study on Flash-butt Welding Process for U75V Rail. Hot Working Technology (9): 135-137.

[3]. Dong Z, Zhong H, CHENG D (2013). Analysis on the Welding Process and Weld Seam Quality of Flash Welder. Research on Iron and Steel (1): 36-40.

[4]. Godefroid, LB, Faria, GL, Cândido, LC, and Viana, TG (2014). Fatigue Failure of a Flash Butt Welded Rail. Procedia Materials Science 3: 1896-1901.

[5]. Godefroid, LB, Faria, GL, Cândido, LC, and Viana, TG (2015). Failure Analysis of Recurrent Cases of Fatigue Fracture in Flash Butt Welded Rails. Engineering Failure Analysis 58: 407-416.

[6]. Han H (2012). Study of Techniques Used to Connect and Weld Rails of Seamless Track. Jilin University. (Doctoral dissertation).

[7]. Jiang M, He B (2017). Investigation of Rail Welding Method and Quality Control of Welded Joint. Hot Working Technology46(13): 14-18.

[8]. Limpel, Eugene J (2014). Flash Welding. McGraw-Hill Education.

[9]. Mutton P, Cookson J, Cong Q, and Welsby D (2016). Microstructural Characterization of Rolling Contact Fatigue Damage in Flashbutt Welds. Wear, (366)368-377.

[10]. Ozakgul K, Piroglu F, Caglayan O (2015). An Experimental Investigation on Flash Butt Welded Rails. Engineering Failure Analysis, 57: 21-30.

[11]. Pan W (2012). Numerical Simulations of Mechanical Property of Flash Welding in Continues Welding Rail Seam. Zhejiang University of Technology. (Doctoral dissertation).

[12]. Porcaro RR, Faria GL, Godefroid LB, Apolonio GR, Cândido LC, and Pinto ES (2019). Microstructure and Mechanical Properties of a Flash Butt Welded Pearlitic Rail. Journal of Materials Processing Technology 270: 20-27.

[13]. Shen J, Wei Z, Zhu X, Yu L, and Xiao Z (2018). Microstructure Evolution and Mechanical Properties of Flash Butt-Welded Inconel718 Joints. Materials Science & Engineering A 718:34-42.

[14]. Wang L (2011). High-Speed Railway Jointless-Track Rail welding Technology Research. Southwest Jiao tongUniversity. (Doctoral dissertation).

[15]. Weingrill, Krutzler J, and Enzinger N. (2017). Temperature Field Evolution During Flash-Butt Welding of Railway Rails. Paper presented at the Materials Science Forum.

[16]. Yu X, Feng L, Qin S, Zhang Y, He Y (2015). Fracture Analysis of U71Mn Rail Flash-Butt Welding Joint. Case Studies in Engineering Failure Analysis4: 20-25.

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