The Fifth International Conference on Railway Technology
RAILWAYS 2022
22–25 August 2022
Montpellier, France

Proceedings of the Fifth International Conference on
Railway Technology:
Research, Development and Maintenance
Edited by J. Pombo
Civil-Comp Conferences, Volume 1, Paper 32.6
Civil-Comp Press, Edinburgh, United Kingdom, 2022, doi: 10.4203/ccc.1.32.6

Experiment on abrasive water jet on the maintain of rail

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Abstract

With the growth of the global economy and technological breakthroughs, not only the mileage and scope of railways have greatly increased, but also the speed and load of trains have also increased rapidly, which has brought enormous pressure to the rails, resulting in increasingly prominent problems such as rail fatigue and wear. Therefore, it is necessary to repair the rail regularly. The current mainstream online repair method is the repair of the rail repair car, which mainly includes the repair of the rail grinding car and the repair of the rail milling and grinding car. However, metal sparks, dust and noise will be generated during the operation. The environment is harsh and may cause the rail to turn blue, the maintenance cost is high, and the versatility is poor. Abrasive water jet machining technology is a cold working technology. If applied to rail repair, it will neither cause thermal damage to the rail surface nor produce metal sparks, dust and noise. The working environment is comfortable and environmentally friendly. Therefore, this paper studies the theoretical and practical feasibility of abrasive water jet repairing rails combined with the existing rail repair technology and abrasive water jet machining technology. The results show that after the single factor and orthogonal experiments, it is found that the factors of water jet pressure, target distance, jet erosion angle, feed speed and abrasive flow rate have different effects on the rail grinding effect. The influence of water jet pressure and feed speed within the range is the most obvious, followed by abrasive flow and jet erosion angle, and the effect of target distance is small. At the same time, when the jet erosion angle is 10 °to 15 °, the grinding effect is the best, Sand width and depth are balanced.

Keywords: abrasive water jet, rail maintenance, orthogonal experiment.

1 Introduction

Due to economic growth and technological progress, railway transportation is developing towards high speed and heavy load [1], which also brings huge pressure to the rails, resulting in increasingly prominent problems such as rail fatigue and wear [2,3]. Therefore, the rails must be repaired regularly. Grinding and maintenance operations are effective means to eliminate surface defects of rails [4].

The traditional grinding operation uses large rail grinding vehicles [5]. But there exists the following problems: Ⅰ. Low grinding efficiency: the depth of one-time grinding is relatively low, so, one cycle of grinding should repeat many times; Ⅱ. Harsh operating environment: the rail grinding operation is a continuous removal process for the surface material of the rail, a large amount of dust, smoke and sparks will be generated during the operation; Ⅲ. Degrading the material properties: local high temperature will be generated on the surface of the rail, resulting in changes in the crystal structure of the rail surface material [6].

So, a new method is needed. Abrasive water jet machining technology is a technology that drives fine abrasive particles to move at high speed through high-pressure water [7], collide with the surface of the workpiece, produce erosion wear, and converts the mechanical energy of the abrasive particles into the binding energy of the material, thereby removing the material and realizing the processing technology of the workpiece. It has significant advantages such as high efficiency, no pollution, no thermal influence, and smooth cut surface. It is a green and environmentally friendly advanced cutting technology. After decades of development, abrasive water jets have been widely used in various fields such as cleaning, rust removal, cutting and machining. Inspiring by abrasive water jets, an intelligent rail grinding technology has researched and developed by our team. It uses high-pressure jet compound cutting to realize intelligent and precise grinding of rails, which can greatly improve work efficiency and improve the working environment [8].

At present, scholars have no theoretical research on the repair of the rail with abrasive water jet. There are fewer applications of rail repair vehicles with abrasive water jet processing technology on the market. Therefore, the mechanism and parameter optimization of abrasive water jet repairing rails are studied through theoretical analysis and experimental exploration, and then a theoretical basis for the manufacture of rail repair vehicles is laid. This is not only of great research value, but also of ground breaking engineering significance.

2 Methods

The removal of rail surface material mainly depends on the comprehensive action of abrasive particles cutting, shovelling and indentation pitting and other erosion behaviors. The medium water plays the role of accelerating the particles and cooling the rail.

In order to make the established model more accurately reflect the process of abrasive water jet grinding the rail surface, it is necessary to cover as many main influencing variables as possible, so as to make the experimental results more accurate. Based on the actual situation, the amount of material removal on the rail surface is not only related to the main process parameters that affect the cutting ability of abrasive water jet processing metal materials: water jet pressure P, target distance H, nozzle feed speed v, abrasive flow Ma and jet erosion angle α, In addition to the close relationship between these five process parameters, the material removal rate and the properties of the workpiece and the abrasive particles themselves should also be taken into account, that is, the material removal rate is also related to the density of abrasive grains ρa, the average size of abrasive grains, the hardness of abrasive grains Ha and The hardness Ht of the rail is related. Overall, it can be summarized as the following model.

$$f\,(P,\ H,\ \theta,\ v,\ Ma,\ size,\ Ha,\ \rho a,\ Ht) \tag{1}$$

The type of abrasive used in the experiment is the most commonly used 80 mesh garnet, the experimental object is P50 rail, which material is U71Mn.The single factor experiment method was used to analyze the five parameters of water jet pressure, target distance, nozzle speed, feed speed and abrasive flow one by one, and the experimental analysis results were given; The influence coefficient of material removal rate is obtained, and the target machining removal function model is obtained. At the same time, the roughness of the rail surface after grinding are also measured to ensure it meets industry standards.

3 Results

First, a preliminary experiment was carried out. By adjusting the nozzle angle, water pressure, flow rate and other processing parameters, the experimental rail sample was successfully polished. At the same time, multi-point measurement of the roughness of the polished rail was selected, all of which met the industry standard. The comparison chart before and after grinding is as follows.

After single factor and orthogonal experiments, it was found that the influence of water jet pressure, target distance, jet erosion angle, feed speed and abrasive flow factors on the rail grinding effect was different. The influence of jet pressure and feed speed is the most obvious, followed by abrasive flow and jet erosion angle, and the effect of target distance is small.

The strength of the jet pressure directly determines the erosion kinetic energy of a single abrasive particle. As the water jet pressure increases, the abrasive particles generate enhanced normal and shear stresses on the material. The average particle size of the abrasive determines the mass of a single particle. Larger abrasive particles have higher energy levels and higher removal rates of materials. The feed rate and abrasive flow together determine the total number of abrasive particles impacting a specific area of the workpiece material and eroding in unit time. Therefore, as the feed rate increases, the number of abrasive particles involved in erosion per unit time also decreases. An increase in the feed rate resulted in a downward trend in the material removal rate. The change of abrasive flow is relatively complex. In addition to directly affecting the number of abrasive particles participating in the erosion action per unit time, it also affects the interaction between particles, thereby affecting the total kinetic energy of the particles. The effect of pressure on single particles is limited, so when the pressure of the water jet is constant, increasing the abrasive flow increases the total kinetic energy of the particles on the one hand, which can increase the material removal rate, and on the other hand, it also increases the possibility of particles colliding with each other, and then Part of the particles are fragmented, resulting in a decrease in the kinetic energy of the erosion of part of the abrasive particles. And at a certain pressure level, the increase of the total number of particles will also reduce the erosion kinetic energy of a single particle.

4 Conclusions and Contributions

Abrasive water jet machining technology is a cold machining technology. Compared with grinding and milling, through the reasonable arrangement of nozzles, there will be no thermal deformation and thermal stress due to friction and heat during the repair of rails, which effectively improves the machining process. quality. Moreover, it is possible to repair different types of rails by adjusting the number and angle of nozzles, as well as processing parameters such as water pressure and flow rate. The preparation time is short, the versatility is strong, and the operation efficiency is high.

The traditional rail grinding process mainly relies on the rail grinding car or the grinding wheel and grinding head installed on the tool to carry out contact grinding of the rail profile. There are certain defects in grinding conditions, grinding accuracy, and cost of use. Through in-depth research on the condition maintenance of rail transit infrastructure and the mechanism of water jet grinding, it is proposed to replace the traditional grinding wheel and grinding head grinding operation with water jet cutting operation, improve grinding conditions, improve grinding accuracy, and optimize grinding strategy. It is reflected in the following aspects:

I. In the process of water jet grinding the rail, there is no dust and smoke, and the vibration and noise are small.

II.Water jet rail grinding is a cold operation, which will not cause changes in the metallographic structure of the rail surface material, and the heat generated by grinding is taken away by the high-speed water jet, and the rail always maintains a low temperature without fire hazards.

III.The water jet beam is concentrated and the cutting is accurate, and the parameters such as the working pressure of the jet are easy to adjust and control in real time.The nozzle wear is small, and there is no need to consider the replacement of the actuator (nozzle) during the operation. At the same time, the lateral force generated by the water jet on the rail is extremely small, the grinding surface is smooth and smooth, and the roughness is controllable.

IV. There are no indirect costs such as disassembly and assembly of trackside equipment, fire protection, line cleaning, and replacement of operation execution parts, and the utilization rate is high.

References

[1] D Li, et al. "Analysis of Heavy Haul Railway Wear on Wheel/Rail Contact Geometry." International Conference on Transportation Engineering 064-69.M. Bond, "A bear called Paddington", Collins, London, United Kingdom, 1958.

[2] Garnham, J. E., and C. L. Davis. "The role of deformed rail microstructure on rolling contact fatigue initiation." Wear 265.9-10(2008):1363-1372.

[3] Zhou, Y., et al. "Field and laboratory investigation of the relationship between rail head check and wear in a heavy-haul railway." Wear 315.1-2(2014):68-77.

[4] Schoech, W., R. D. Frhling, and A. Frick. "Rail Maintenance: Same Target-Different Approaches A Review of Grinding Practices Applied in Heavy Haul Railway Systems." (2009).

[5] Yu, Zhou, et al. "Application of On-Line Rail Milling in Rail Maintenance of High-Speed Railways." Journal of Southwest Jiaotong University 018.002(2010):140-144.

[6] Steenbergen, and M. "Rolling contact fatigue in relation to rail grinding." Wear 356-357(2016):110-121.

[7] Gostimirovic, M., et al. "Evolutionary optimization of jet lag in the abrasive water jet machining." The International Journal of Advanced Manufacturing Technology (2018).

[8] Hashish, M., "A Modeling Study of Metal Cutting With Abrasive Waterjets." Journal of Engineering Materials and Technology, Transactions of the ASME 106.1(1984):88.