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Cracking of spring planks in Wagon Truck K4

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Abstract

Based on the American swing motion truck techniques and some improvements, Wagon Truck K4 is manufactured as a new type truck. The spring plank, a key part on the truck, plays an important role in reliability of the truck. After being in service for about half a year, it was found that there were cracks 10–15 mm in length on the planks for many trucks. All cracks were located at the same positions, i.e., at the two ends of welded seams between the plank body and the fender, and then propagated into the plank body in the longitudinal direction of the plank. Chemical analysis, mechanical tests and metallurgical inspections show that the elemental composition, tensile strength and hardnesses correspond to the technical requirements and there are no abnormal phenomena in microstructures either in the bodies or in the welded seams. Fracture surface observation reveals that there are a few origins and obvious beach marks, which demonstrates the cracking is a typical fatigue failure and implies there are high stresses at the cracking positions. Mechanical simulation tests and FEM indicate that the cracking sites are vulnerable spots on the planks and there is constructive stress concentration interference. Therefore, the failures are mainly due to the high stresses at the seams. In addition, weld quality is another important factor contributing to the failures. Preventative measures, such as changing the structure of the plank or the length of the seam so as to diminish constructive interference, and polishing the weld seam so that the stress concentration becomes as low as possible, are put forward.

Keywords: Railway engineering; Weld fatigue; Wagons; Stress concentrations; Repairs

1. Introduction

Based on the American swing motion truck techniques and some improvements, Wagon Truck K4 is manufactured as a new type truck in China. There is a noticeable change on the plank, i.e., an even plank

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instead of an uneven plank, so as to simplify the manufacturing process. From May 2002 to December 2002, 1290 wagons with Truck K4, including 290 wagons equipped with Truck K4 made from the US, were put into service. Unfortunately, it was found in December 2002 that there were cracks on the planks of many trucks. All cracks were located at the same positions, i.e., at the two ends of welded seams between the plank body and the fender, and then propagated into the plank body in the longitudinal direction of the plank.

In order to determine the characteristics of the cracks and find the cracking causes, chemical analysis, mechanical tests, metallurgical inspections, fracture surface observation, and FEM analysis were performed.

2. Manufacturing process and property requirements

Chinese planks are made from CHJ590 low-alloyed steel, which was specially developed for the plank. In contrast, the American planks are made from A656M low-alloyed steel. At each of the two end holes on the plank, a fender, made from Q235A carbon steel, is welded vertically to the plank so as to confine the swing motion. 80%Ar + 20%CO_2 gas shield welding and ER50-3B rod are selected. In addition, the welds are heat-treated to 560–590 °C (1 h) after welding.

Tables 1 and 2 show the requirements of chemical composition and mechanical properties for CHJ590 and A656M, respectively.

From Tables 1 and 2, it can be seen that CHJ590 corresponds to A656M and a toughness requirement has been added.

3. Experimental methods

Four cracked planks were observed in detail. Fig. 1 shows the crack positions and patterns. Cracks may occur surrounding one fender or two fenders, and there may be one crack or two cracks. Note that there is an American plank (plank 1) in the four planks.

Because of the similarity of the cracks in the four planks, samples were removed only from plank 1 and plank 2 for chemical analysis, mechanical tests, metallurgical inspections and fracture surface observation. The metallurgical samples were cut vertically to the crack planes, so that they consisted of base material, heat-affected zone and weld seam. In addition, tensile test samples were cut from the other two planks to compare the mechanical properties between the base material and the weld.

The tests and analyses include:

- Observation and analysis on the characteristics of two typical cracks with the naked eye, stereomicroscope, scanning electronic microscope and energy diffractive spectrum.
- Metallurgical inspection and hardness test on the welded parts of the two planks.

Table 1
The requirements of chemical compositions for CHJ590 and A656M (wt%)

Material	C	Si	Mn	P	S	Nb	V	Ti	Ceq	Pcm
*CHJ590	⩽0.16	0.15–0.40	1.1–1.7	⩽0.025	⩽0.010	0.02–0.08	⩽0.06	⩽0.03	⩽0.42	⩽0.2
A656M	⩽0.18	⩽0.06	⩽1.65	⩽0.025	⩽0.035	0.005–0.15	⩽0.08	N⩽0.020	–	–

* ①Nb + V + Ti⩽0.15%; ②Als⩽0.15%; ③Ceq = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15; ④Pcm = C+Si/30 + (Mn + Cr + Cu)/20 + Mo/15 + V/10 + 5B.