Static and dynamic testing of a bogie

Static and dynamic testing of a bogie

J Tittel[1], M Kepka[1] and P Heller[1]

Regional Technological Institute, Research Centre of the Faculty of Mechanical Engineering, University of West Bohemia, Univerzitni 2732/8, Pilsen 30614, Czech Republic

E-mail: tittejan@rti.zcu.cz

Abstract. The development process of railway bogie frames consists of three stages. The first stage involves stress calculations, the second stage comprises static and fatigue tests and the third one is focused on validating fatigue life data by stress monitoring during test runs on an actual track. The aim of this research is static and dynamic testing of a functional bogie model by hydraulic cylinders and subsequent evaluation of measured values. The load is determined according to the requirements specified in CSN EN 13749, Railway applications – Wheelsets and bogies – Method of specifying the structural requirements of bogie frames. In the fatigue test, the loads are composed of the static load, the quasi-static load, and the dynamic load. The bogie frame is a weldment made of S355 steel sheets, which has two transoms and two side rails ending with suspension brackets. It should be noted that the fatigue strength of a welded frame under dynamic loading is limited by the resilience of the welded joints. Attention is therefore paid to analyzing these joints. The development experience derived from this new bogie can be used to optimize the production of rolling stock. In the present experiments, the frame was examined using NDT to detect possible defects.

1 Introduction

Regional Technological Institute, a research facility affiliated with the University of West Bohemia, has developed a new concept of a bogie which departs from traditional solutions in that it uses leaf springs for primary suspension and involves innovative wheelset guidance. There are two leaf springs arranged above each other, one on top and the other below the axle box housing, which provide suspension and guide the wheelset. Their spring action is applied in an unconventional manner. One loop of each leaf spring is attached to the frame, while the centre clip supports the frame and the other loop is fixed in the axle box. Rubber bushings are inserted in each loop. The secondary suspension is provided by the bolster and coil springs. Narrow-gauge bogies require wheelsets with outer bearings and a frame with outer longitudinal members. The bogie frame is an open structure, consisting of two transoms connected with short longitudinal members ended with brackets for springs. The wheelsets are powered by a traction motor via a spur-and-bevel gearbox, with a disk brake mounted on the other end of the engine shaft. The drive is longitudinal, mounted outside the frame on full suspension. The bogie concept is illustrated in Figure 1 [1, 2].

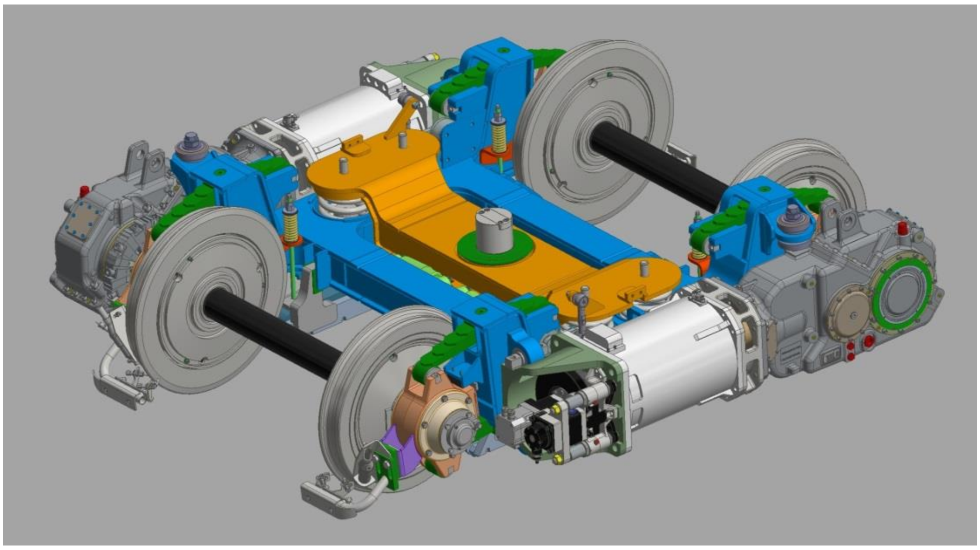

Figure 1. Traction pivoting bogie for a narrow-gauge tramway car.

The benefits of this configuration include a small wheelbase of 1700 mm, with radial steering of the wheelset in a curve, and therefore less wear on the wheelset and rails, less noise, and less weight of the bogie, approx. 3600 kg. The welded bogie frame consists of two transoms and two longitudinal members ending in brackets for attaching leaf springs. Both longitudinal members and transoms are weldments from two strips and two vertical webs. The sheets used were of standard S355NL steel. The weight of the bogie frame alone is 454 kg.

2 Basic specifications of the problem

Transport vehicles are an ordinary part of our daily lives. The class of rail vehicles includes tramways, train units and underground railway units. These vehicles experience static and dynamic loads in service. Their key assemblies include welded bogie frames and other structures to which individual components are attached. Development of railway bogie frames comprises three stages. The first stage involves stress calculations, the second one comprises static and fatigue testing, and the third stage is concerned with validation of fatigue life data by on-track testing. This research work focused on static and dynamic testing of a functional model of a bogie on a test rig fitted with hydraulic cylinders, and subsequent evaluation of measured data [3].

3 Loading

The structure was subjected to test loads in Inova testing equipment. The functional model shown in Figure 2 was supported on fixtures attached firmly to T-slots in the test bed for adequate stiffness. Static and dynamic forces were then exerted by hydraulic cylinders. Vertical loads were applied by two cylinders acting on the points of attachment of springs. Lateral force, i.e. the transverse load, was applied by a single cylinder. The magnitudes of loads were determined in line with CSN EN 13749, Railway applications - Wheelsets and bogies - Method of specifying the structural requirements of bogie frames [4]. In a fatigue test, the load comprises a static component, a quasi-static component and a dynamic load component.

Figure 2. Loading on bogie frame.

The deformation response of the frame was measured by means of fourteen strain gauges positioned according to Figure 3. The strain gauges were mounted onto those locations of the frame where the highest stresses were anticipated, based on a computational model and measurements on an earlier type of frame. The strain gauges were 1 – LY 11 6/120 type from Hottinger Baldwin Messtechnik GmbH. They were attached using a two-component adhesive. They were coated with a sealant to provide protection from air humidity. Data from the strain gauges were captured and recorded in QuantumX module and evaluated using the software Catman HBM.

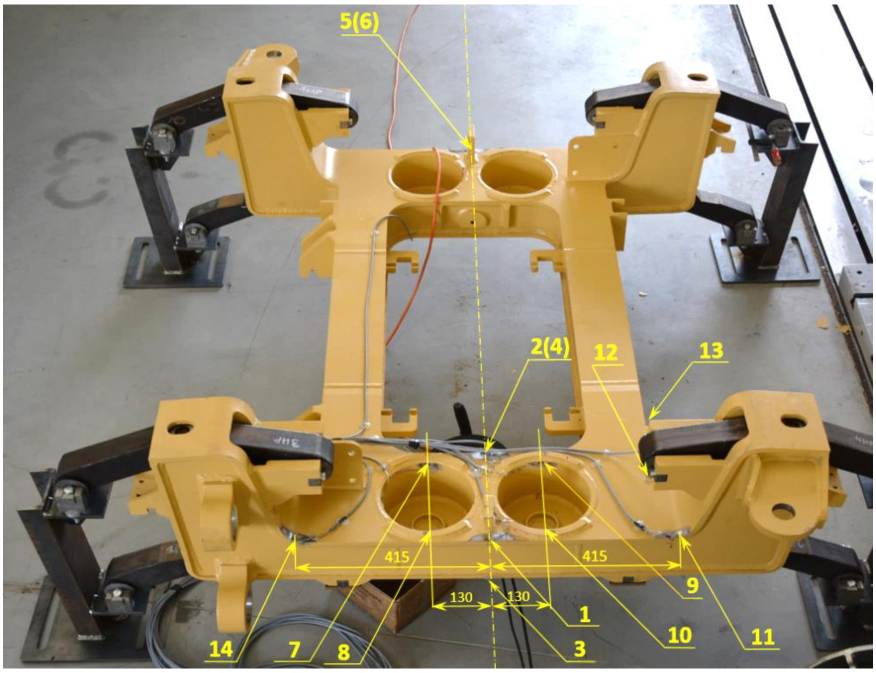

Figure 3. Locations of strain gauges on the bogie frame.

IOP Conf. Series: Materials Science and Engineering **723** (2020) 012031 doi:10.1088/1757-899X/723/1/012031

3.1 Static strength test

The static test involves applying what is referred to as "exceptional load" on the bogie. They are the highest forces which may occur in service under exceptional circumstances. Permanent structural deformation must not occur as a result of this test. The purpose of static testing of the bogie frame was to ensure that no residual deformation remains in the frame after removing the load. In the static test, stress was first measured without applied load. Then the bogie was subjected to a vertical force of 157 kN, a load exerted by a full tram car with a superimposed dynamic component. After releasing the load, the values from strain gauges were recorded. The strain gauges on the bogie frame yielded the values shown in Table 1. None of the values exceeded the minimum yield stress (355 MPa) of the material of the bogie frame.

Table 1. Values measured in static test.

Load	**Strain gauge number** Measured stress value [MPa]				
0 kN	**1**	**2**	**3**	**4**	**5**
	0.08	-0.15	0.05	-0.11	-0.23
	6	**7**	**8**	**9**	**10**
	0.08	-0.09	-0.08	0.36	0.10
	11	**12**	**13**	**14**	
	-0.02	0.01	-0.01	-0.07	
157 kN	**1**	**2**	**3**	**4**	**5**
	-143.16	-120.10	74.23	66.92	-141.07
	6	**7**	**8**	**9**	**10**
	76.60	-189.95	-224.81	-188.02	-223.76
	11	**12**	**13**	**14**	
	-98.77	-165.52	123.84	-91.07	
0 kN	**1**	**2**	**3**	**4**	**5**
	-0.45	-0.04	-0.08	-0.16	0.03
	6	**7**	**8**	**9**	**10**
	-0.07	0.15	0.36	0.56	0.45
	11	**12**	**13**	**14**	
	0.18	0.57	-0.92	0.13	

The values measured after removing the load on the bogie frame suggest that the residual stress is zero.

3.2 Fatigue tests

The goal of dynamic testing of the bogie frame was to verify its life according to CSN EN 13749. The standard prescribes the use of loading forces which are ordinarily encountered in service. The loading cycles (Figure 4) simulate vertical forces from the load carried by the vehicle, loads from curve negotiation and from riding over switches and associated structures. Three load levels were applied according to Figure 5. The first load level corresponds to the full load on the bogie frame over 6×10^6 cycles. The second involves 2×10^6 cycles, in which quasi-static and dynamic components have been raised by 20 %. The third level involves another 20 % higher quasi-static and dynamic loads [2].

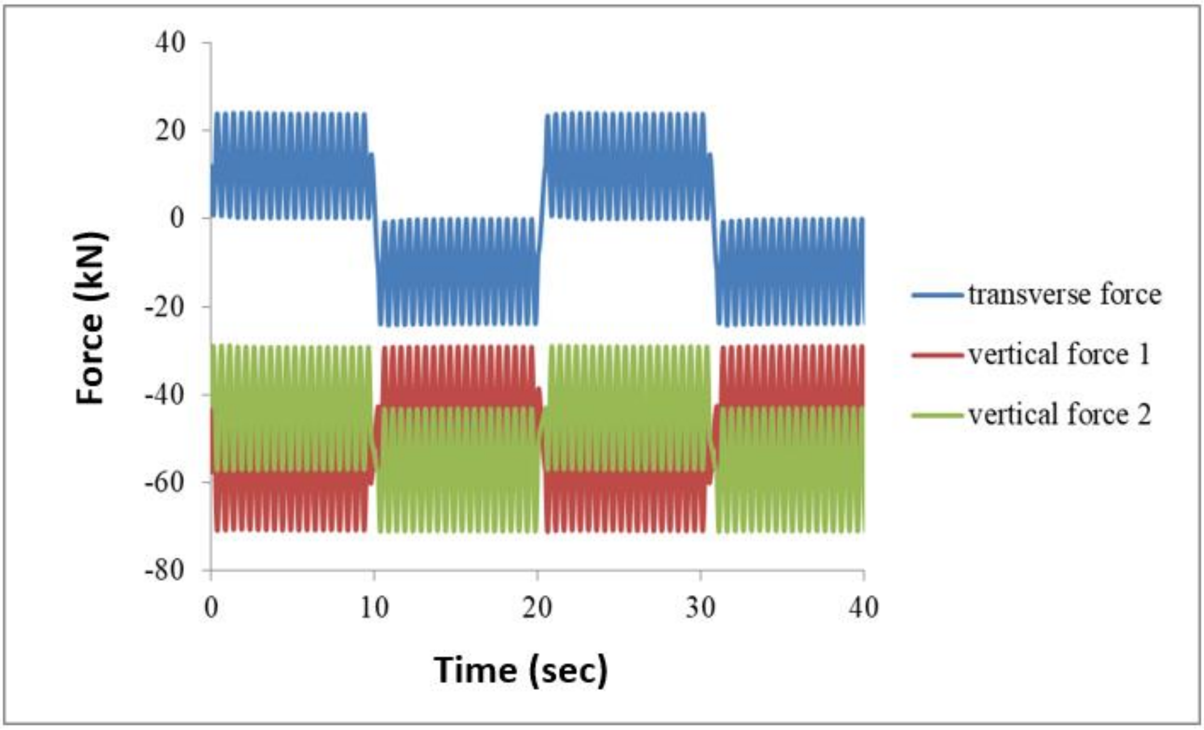

Figure 4. Example of loading during fatigue testing.

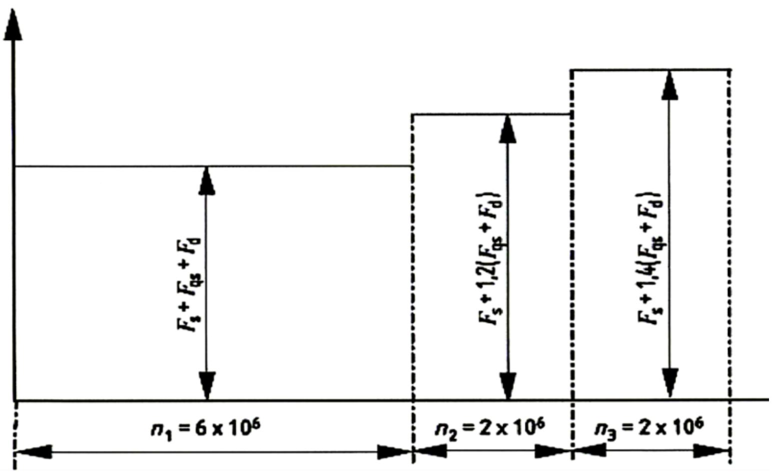

Figure 5. Distribution of dynamic load on the frame.

3.3 Non-destructive testing
Non-destructive magnetic testing was performed in order to find any defects which may have occurred. This method can detect flaws in the surface or just below the surface. The procedure for detecting flaws with a UV lamp which highlights fluorescent magnetic particles followed the standards CSN EN ISO 17638 and CSN EN ISO 9934 – 1. This method belongs to rapid, simple and inexpensive non-destructive techniques. The test was performed prior to load application and then after 6×10^6, 8×10^6 and 10^7 cycles.

4 Conclusions
A bogie frame was fatigue tested under laboratory conditions. Experimental static and dynamic tests of a bogie frame for a narrow gauge tramway according to CSN EN 13749 yielded data which are useful for further development and application of these components. Strain gauge measurements after static loading of 157 kN provided evidence of zero residual deformation in the bogie frame.

The fatigue test verified the life of the bogie frame after 10^7 cycles under loads at increasingly higher levels. Non-destructive inspections for defects were performed by the magnetic particle method before each increase in the load level. No defects were found by this method.

Acknowledgements
This article “Static and dynamic testing of bogie” was created with financial support of TA CR - project TH02010553.

References

[1] Kalina, T., Heller, P., Chval, Z., Sedlácek, F., Křížek, M., Barton, L. Numerical Simulation and Experimental Testing of Two-axle Chassis of Low-floor Trams. *Manufacturing Technology*, 2018, roč. 18, č. 2, s. 248-254. ISSN: 1213-2489

[2] Kepka, M., Kepka, M., Žlabek, P., Heller, P., Chvojan, J., Mentl, V. Fatigue Tests - Important Part of Development of New Vehicles. In MATEC Web of Conferences. New York: Curran Associates, Inc, 2018. s. 1-7. ISBN: neuvedeno , ISSN: 2261-236X

[3] Kraus V., Kepka M., Doubrava D., Chvojan J. (2019) Strength Analysis of Tramway Bogie Frame. In: Correia J., De Jesus A., Fernandes A., Calçada R. (eds) Mechanical Fatigue of Metals. Structural Integrity, vol 7. Springer, Cham

[4] CSN EN 13749, Železnicní aplikace - Dvojkolí a podvozky - Metoda specifikování konstrukcních požadavku na rámy podvozku (Railway applications – Wheelsets and bogies – Method of specifying the structural requirements of bogie frames)