Design of a Dynamic Test Rig for Railroad Wheel Axle Assembly

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Abstract

Data shared by the U.S. Department of Transportation indicates that, between the years 2013 and 2015, an estimated 11% of railway accidents were attributed to the failure of wheel-axle assemblies. These assemblies experienced fractures from continuous wear which resulted in catastrophic failures costing millions in damages. To that end, researchers at the University Transportation Center for Railway Safety (UTCRS) at the University of Texas Rio Grande Valley (UTRGV) are developing a test rig that can accommodate a complete AAR wheel-axle assembly. This dynamic wheelset tester will be used to conduct targeted testing to characterize the performance of healthy and defective wheel-axle assemblies and/or perform long-duration service life component testing. The test rig will be designed to allow vertical loads of up to 200 kN (45 kips) per bearing and train traveling speeds of up to 105 km/h (65 mph). The wireless onboard condition monitoring technologies, previous developed by UTCRS researchers, will be used to acquire loading, vibration, and thermal profiles of the wheels and bearings during testing and provide complete performance metrics to assess and characterize the wheelset condition. Hence, the proposed test rig will be able to closely simulate rail service operating conditions in a laboratory setting providing an invaluable asset and platform to test and develop new technologies for safer railway transportation. The work presented herein provides preliminary design and development steps for the proposed railcar wheelset dynamic test rig.

Figure 1. AAR Standard Wheelset Post Wear and Tear

Methodology

Rail profile 140 was used to quantify the contact stresses and contact length needed to fit the wheelset correctly on the driver railtrack. This data was then used to find an appropriate diameter of both the railtrack and shaft diameter required to drive the wheelset. To support the loads being applied, values for the friction force that will be exerted between the wheelset and driver railtrack, as well as the torque required to rotate the system were needed. The torque is later used to find the horsepower desired to run the system at operating speeds to mimic real service scenarios.

Results

The governing equations used to calculate the necessary applications to follow AAR (American Association Railroad) standards are as seen below.

Delta Value for Contact Stress	$\Delta = \frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2}$
Contact Stress for Two Cylinders [Pa]	$p_0 = 0.564\sqrt{\frac{1-\left(\frac{1}{R_1}+\frac{1}{R_2}\right)}{L\Delta}}$
½ Contact Length [mm]	$b = 1.13\sqrt{\frac{F\Delta}{L\left(\frac{1}{R_1}+\frac{1}{R_2}\right)}}$
Maximum Deflection of a Simply Supported Beam [mm]	$\delta_{max} = \frac{386}{\left(\frac{796}{30/\pi}\right)^2}$
Moment of Inertia of a Shaft [m⁴]	$I = \frac{PL^3}{48E\,\delta_{max}}$
Diameter of Drive Shaft [m]	$D_s = \left(\frac{I(64)}{\pi}\right)^{1/4}$
Static Friction Force Between Two Cylinders [N]	$F_f = \frac{2Pb}{\sqrt{r_1^2 - b_2^2}}$
Torque Required to Break Friction [kN·m]	$T = \frac{2Fr_3}{12}$
Power [HP]	$\dot{W} = \frac{T\omega}{550}$

Table 1. Governing Equations

Delta Δ	$6.109*10^{-8}$
Contact Stress P_o [MPa]	707.40
½ Contact Length b [mm]	5.74
Contact Area 1 [mm²]	408.39
½ New Contact Length b2 [mm]	3.66
Diameter of Railtrack [m]	1.60
Diameter of Driver Shaft [m]	0.32
Friction Force [kN]	7.23
Torque [kN·m]	0.48
Power [HP]	647

Table 2. Calculated Preliminary Values

Proposed Design

A Computer-Aided Design (CAD) model was designed to visualize and conduct Finite Element Analysis on. The complete assembly can be seen in **Figure 3**.

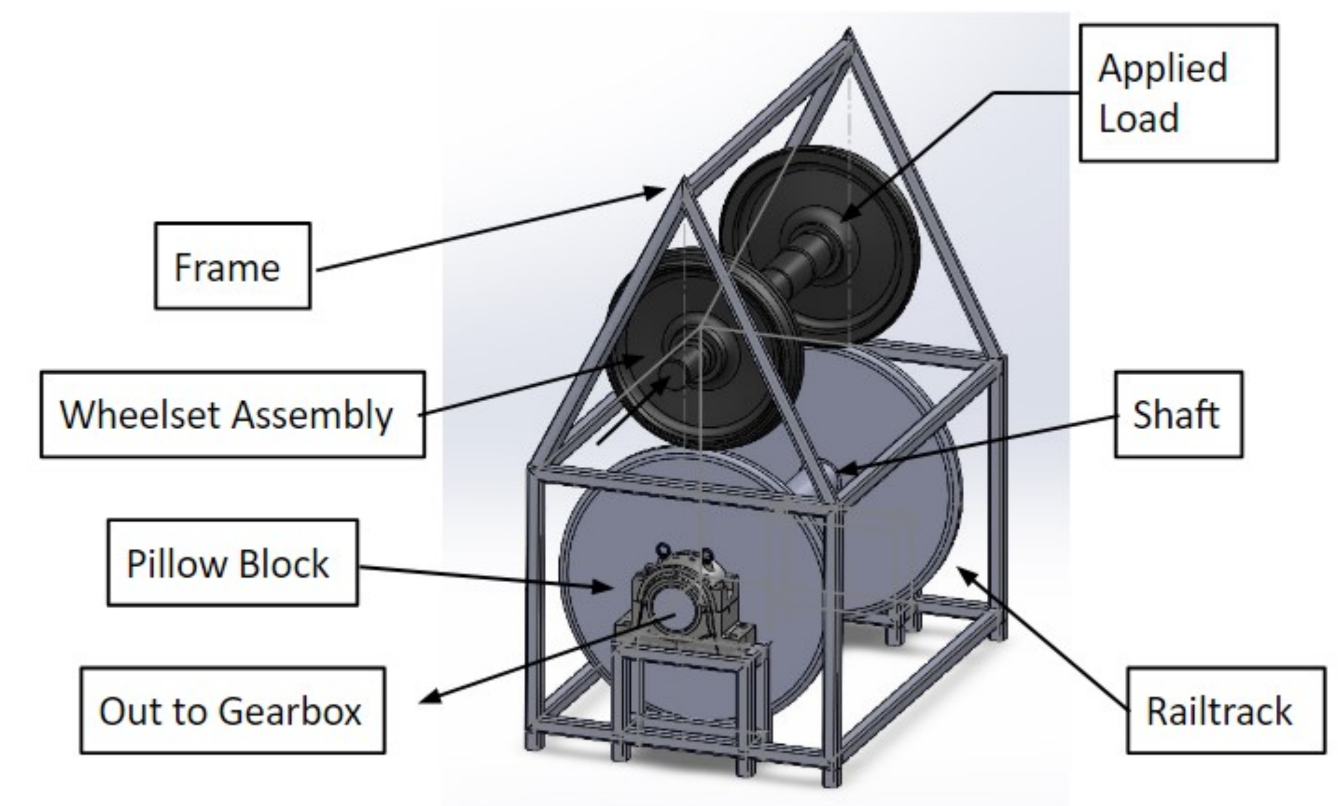

Figure 3. CAD Model of the Driver Axle, Wheelset, and Frame

Conclusions

The scale of this testing apparatus would require this test rig to be housed in a separate facility. Moreover, it is highly recommended that the driver railtrack shaft be placed underground to allow for the easy set up of the wheelsets to be tested. Once built, this test rig can provide unique testing capabilities to the rail industry.

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