US Department
of Transportation

Federal Railroad Administration

Research Results

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ADVANCED TRUCK FOR HIGHER-SPEED FREIGHT OPERATIONS

SUMMARY

A major constraint for higher-speed freight trains is truck hunting, or lateral instability. The three-piece truck, a workhorse for the railroad industry for over 100 years, is inherently susceptible to hunting in empty car conditions above 45 to 50 mph. This speed limitation on any train that has an empty car leads to operations restricted below the hunting speed.

The Federal Railroad Administration, through the U.S. Department of Transportation Small Business Innovative Research (SBIR) Phase I program, sponsored the development of a Higher-Speed Truck (HST) for freight trains. The major objective was to develop a concept, which would raise the hunting speed of a freight truck to 150 mph without compromising the performance in other regimes. From this intense effort, a concept for a higher-speed freight truck intended for 70-ton regular freight was developed. The truck utilizes a rigid frame (H-frame) and an independent, compliant, primary suspension (springs/damping between the wheel-set/bearing adapter and the frame) for its basic architecture. Constant contact side-bearings and yaw dampers were added to improve dynamic performance.

Under the HST Phase-II project, a prototype truck was designed and fabricated. The fabrication process has been completed and a prototype of the assembled truck is shown in Figure 1.

Figure 1. Fabricated Prototype Higher-Speed Truck

BACKGROUND

North American freight railroads are generally restricted to a maximum operating speed of 80 mph. While loaded trains are able to run at the near maximum speed, empty train speeds are controlled by the lateral instability known as truck hunting. The three-piece truck, a workhorse for the railway industry for over 100 years, is inherently susceptible to hunting in empty car conditions above 45 to 50 mph. This speed limitation on trains with any empties may cause restricted speed operation.

To understand the design features and the operating constraints that control performance of a typical three-piece freight truck, under HST Phase I development, an extensive literature and product review was conducted. The major objective was to develop a concept, which would raise the hunting speed of a freight truck to 150 mph without compromising the performance in other regimes.

The literature survey identified that using primary suspension(s) on freight trucks improved curving performance and stiffening the truck frame (warp stiffness) increased the critical hunting speed.

Over the years, truck manufacturers, constrained by the operating requirements, have incorporated minor modifications to the three-piece truck, such as longer travel springs (type D7), hydraulic dampers, wider friction surfaces, variable damping friction wedges, improved wear surfaces (on side-frames, bolsters, and wedges), elastomeric bearing adapter pads, etc. These changes have improved truck performance. The major innovations included radial trucks that allow axles to take a radial position during curving, thereby minimizing flange contact and improving curving performance. Another example was the H-Frame trucks which have primary suspension steel-coil springs, to improve ride quality, reduce unsprung mass and decouple lateral carbody movement from lateral wheel set movement.

Analytical evaluation of these designs using vehicle dynamic simulation tools revealed that although these trucks offered significant improvement in higher-speed stability and curving performance, none of these met the overall goal of providing stable operation at 150 mph.

Out of this intense effort, a concept for a higher-speed freight truck intended for 70-ton regular freight was developed. The truck concept uses a rigid frame (H-frame) and an independent, compliant, primary suspension (springs/damping between the wheel-set/bearing adapter and the frame) for its basic architecture. Constant contact side-bearings and yaw dampers are added to improve dynamic performance.

RESULTS

Truck Concept Evaluation:

To investigate whether the concept would meet the desired performance goals, vehicle dynamics simulations were carried out using VAMPIRE, an industry–wide, accepted simulation tool. These simulations included all regimes prescribed in the Association of American Railroads' (AAR) Manual of Standards and Recommended Practices, Chapter XI, Service-Worthiness Tests and Analyses for New Freight Cars.

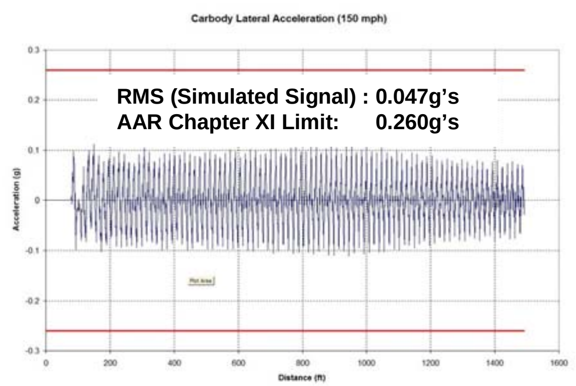

Figure 2. Hunting Simulation of HST at 150 mph

Figure 2 shows the lateral car body acceleration time history at a speed of 150 mph. In these simulations, track is initially perturbed laterally to observe if the carbody lateral motion will grow, die out, or show sustained oscillations. The time history in Figure 2 shows small oscillations persisting at 150 mph, indicating a need for small damping. The absence of growing oscillations shows that the truck is essentially stable. Overall, the truck shows excellent behavior, as the lateral carbody motions are limited to an RMS acceleration level of 0.047g compared to the AAR's criteria of 0.26g.

Truck Design Description:

The finalized design of the HST consists of an H-frame, pedestals, spring yokes, hydraulic dampers, and side bearings, as shown in Figure 3.

Number	Component	Quantity	Construction
1	H-Frame	1	Fabricated
2	Pedestal	4	Fabricated
3	Spring Yoke	8	Fabricated
4	Primary Damper	4	Koni
5	Side Bearing	2	Miner
6	Spring Yoke Pin (not visible in figure 1)	16	Machined
7	Wheel Set	2	Per AAR standards
8	Disc spring set (not visible in figure 1)	8	Off-the-shelf
9	Spring cap	8	Machined

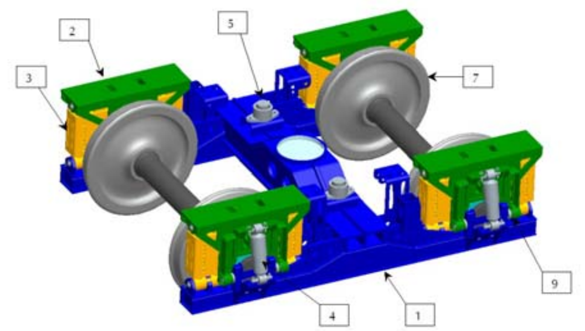

Figure 3. HST CAD Model and Truck Components

The pedestals also house sets of disc springs to provide longitudinal stiffness. The H-frame essentially replaces the two side frames and the bolster of a conventional three-piece truck. The truck employs an innovative suspension arrangement, in which the frame is hung from the wheel sets via the pedestals, creating a true pendulum suspension system. This system creates an inherently stable configuration for lateral movements thus raising the hunting speed to the desired level.

The HST has been designed to use a conventional truck-mounted brake system to provide safe braking capacity with tread brakes up to 110 mph. Beyond 110 mph, the truck will be additionally equipped with disc brakes (yet to be designed) to achieve safe and reliable braking up to 150 mph.

Prototype Fabrication

To fabricate a prototype HST, components such as constant contact side bearings, hydraulic dampers, and suspension springs were directly purchased from vendors. The yoke assembly, pedestal, and H-frame were fabricated from steel plates. Pictures of the constant contact side bearings and hydraulic dampers are shown in Figure 4. The yoke assembly and pedestal are shown in Figure 5, and the fabricated H-Frame is shown in Figure 6. An assembly procedure developed to assess the manufacturability was used. In the assembly process, yokes were assembled first and installed on the frame. Wheel sets were also installed. Once the wheel sets were in place, pedestals were installed. Finally, hydraulic dampers and side bearings were mounted.

Figure 4. Off-the-Shelf Constant Contact Side Bearings and Hydraulic Damper

Figure 5. Fabricated Yoke Assembly and Pedestal

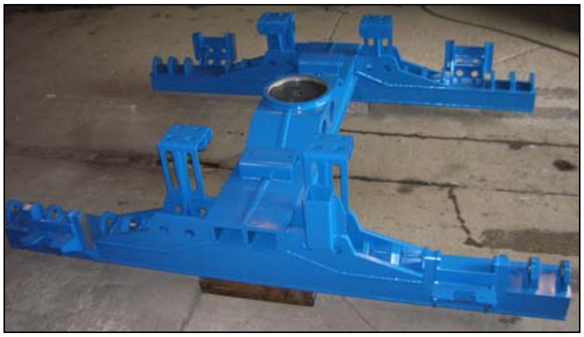
Figure 6. Fabricated HST H-Frame Assembly

HST Track Test

The HST was designed for use under an Amtrak material Handling (MHL) type car (MHL 1400 Series). Since an MHL was not available, an end platform of an articulated spine car was modified so the HST could be placed under the car. The car platform was loaded with a container and ballast to generate wheel loads on the HST equivalent to a wheel load of a 70-ton empty car.


Figure 7. HST Negotiating a Tight Yard Curve

A yard switcher locomotive was used to pull the car at permissible speeds around the yard track with a reverse curve and a sharp yard curve of approximately 24°, as shown in Figure 7 above. Two passes were made over the track. Initial tests indicate the truck performs as well as expected under the extreme track conditions. No issues were identified during the simple yard track roll tests.

CONCLUSIONS

A new freight truck for higher-speed operations has been conceptualized, simulated, designed and prototyped. The design features and simulations indicate that it meets the original goal of designing a freight truck capable of stable higher-speed operations up to 150 mph. In addition, the truck design accomplished its major goal without sacrificing any of the general performance requirements expected of freight car trucks per AAR recommendations.

FUTURE ACTION

The future plans for this project include a comprehensive review of the design features, and assembly and disassembly procedures to determine if any modifications are needed. Once this process is complete, any minor modifications will be made and a second truck fabricated. The plans are to provide a set of trucks to be fitted under a freight car and conduct on-track tests to assess track worthiness performance.

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