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FEASIBILITY OF VIBRATION TEST UNIT MODIFICATIONS FOR TGMS VALIDATIONS

SUMMARY

The Federal Railroad Administration (FRA) sponsored a research team from ENSCO to determine the feasibility of using the Vibration Test Unit (VTU) located at the Transportation Technology Center (TTC) to validate the accuracy of track geometry measurement systems (TGMS). The VTU can dynamically input deviations occurring at each wheel to create a simulation of a full-scale rail car moving along a track. TGMS systems use optical sensors consisting of lasers and cameras to measure the position and shape of the rail relative to the rail car. Inertial sensors are used to determine the position of the rail car in space as a reference plane and thereby compensate for vehicle movements. The team evaluated adding a complementary fixture to the VTU to allow assessment of TGMS accuracy under dynamic scenarios in a controlled laboratory environment. The fixture would dynamically move short railhead samples, providing the same rail deviation input to the optical sensors of the tested TGMS that the VTU is inputting to the rail vehicle. Researchers explored two potential concepts for the fixture, one based on a Stewart platform and the other using a set of linear motor actuators. The team found that the VTU fitted with the additional fixture can be used to validate TGMS systems in tangents with reasonable fidelity, despite the inability to input gage deviations. This concept also would not be able to evaluate the performance of TGMS systems in curves due to VTU's inability to replicate centripetal accelerations and forces.

BACKGROUND

The VTU is a computer-controlled device that holds an entire full-scale railroad car and can input track geometry deviations to the wheels of the rail car to simulate a rail car moving along the track at a given speed. The VTU uses large hydraulic actuators to move the wheels vertically and laterally based on actual or simulated track geometry data input to the machine. Each wheel receives different data input based on the track geometry at the simulated point on the rail where the wheel is located at a given moment in time. Therefore, the vehicle suspension responds the same way it would if it were actually traversing the track from which the track geometry data was taken.

TGMS systems are mounted to specially outfitted rail cars. TGMS uses non-contact optical sensors to measure rail position and inertial sensors to compensate for suspension movements of the car relative to the track. The VTU can be synchronously paired with an additional system to accurately mimic rail movements the TGMS optical sensors would observe when performing a measurement run. Such a system would have the potential to add a unique capability for laboratory-controlled validation testing of full-scale TGMS.

OBJECTIVES

The objectives of this study were to determine feasibility and limitations of using the VTU with a supplemental fixture to validate TGMS systems in a laboratory setting.



METHODS

The team reviewed historical technical documentation and drawings of the VTU. This information, along with in-situ investigation and measurements of the machine, was used to create a detailed 3D CAD model of the VTU. This model was later used to assess spatial clearances and mounting options for the additional fixture.

The VTU is capable of moving the wheels of the rail car vertically and laterally at the required frequency and amplitudes to simulate track geometry on tangent track at desired simulated speeds up to 70 mph. However, the VTU cannot simulate curving and the associated centrifugal forces nor independent lateral movement of individual wheels on a single axle because the lateral actuators on each axle wheelset are tied together and follow the same alignment. Therefore, the track geometry used as input for the VTU must be modified to use a single alignment trace and, therefore, constant gage for each axle.

Researchers conducted a comprehensive literature review to understand how systems capable of dynamically moving objects in a precise and controlled way could be used for the additional VTU fixture. The team also investigated key factors, known limitations, performance characteristics, and requirements for potential solutions.

The team developed a list of technical requirements for the complementary fixture based on the original FRA specifications, initial assessment of the VTU capabilities, and the literature review. The following requirements were used to develop two conceptual solutions for the complementary system:

- Compatibility with the current structure and functionality of the VTU
- Longitudinally adjustable to accommodate varying placement of measurement systems on full-scale rail-bound vehicles

- Create alignment, profile, and crosslevel defects with maximum range of 4 inches vertical and 3 inches lateral
- Ability to test zero speed TGMS beams or other systems that use more than one beam simultaneously
- Maximum simulated testing speed 70 mph
- Ability to vary rail section on the fixture
- Optional ability to change rail cant (i.e., the angle of the rail relative to the tie).

RESULTS

The team found it feasible for the complementary fixture to be a short sample of railhead placed in a position under each optical sensor (i.e., at a gage distance from each other) and activated by an array of actuators to simulate the same track geometry conditions that are being used to control the VTU actuators.

Researchers developed two possible technical solutions for the rail sample actuator subsystem. The first concept uses a Stewart platform which is a six-degrees-of-freedom, off-the-shelf actuator assembly used to move components under computer control. An example of a Stewart platform is shown in [Figure 1](#). The base is firmly attached to a fixed structure and the platform on the top can be computer controlled to move to any position and angle within the movement range limitations of the device.

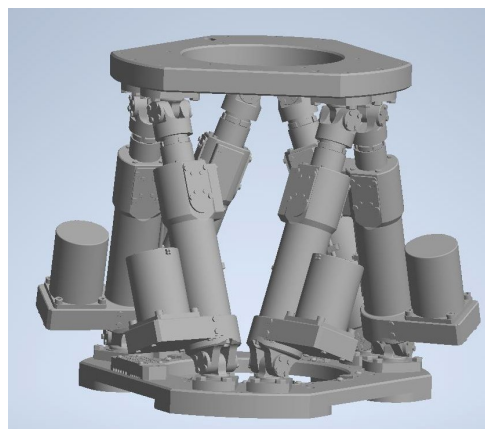


Figure 1. Stewart platform device (Zonda S by Symetrie)



Figure 2 shows a Stewart platform installed inside a frame attached to the lateral crossbeams of the VTU. These lateral crossbeams would be positioned near the point where most track geometry systems observe the rails, usually within 36 inches of the adjacent wheel, in accordance with FRA requirements [1].

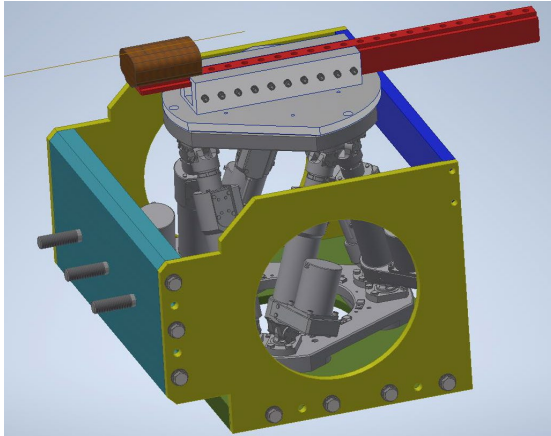


Figure 2. Complementary fixture concept using a Stewart platform device

A railhead is attached to the top of the Stewart platform. The longitudinal position of the railhead sample can be adjusted to place it under the laser of the track geometry system.

The advantage of a Stewart platform is that it is an off-the-shelf device with software used to translate positional changes to the required movements of the six actuators. The disadvantages are the slow speed of a Stewart platform, the need to transform motion data, and the addition of three more actuators than are required.

The second solution uses three linear motor actuators to achieve the required degrees of motion: lateral, vertical, and roll. The linear motor is shown in Figure 3. It uses magnetic force to move a rod through the body of the motor to a desired position with both positional and force feedback.

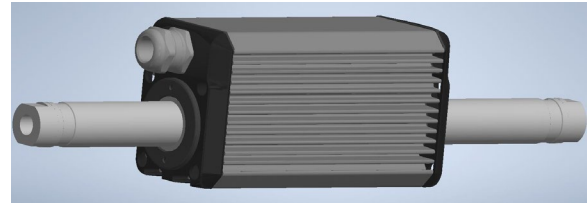


Figure 3. Linear motor actuator (Orca 6 by Iris Dynamics)

Figure 4 shows the rail sample actuation subsystem using the three linear motors. The adjustable rail is connected to a frame that rides on vertical guides and attached to a second frame riding on lateral guides. The first frame has a hinge that allows for the cant rotation. The use of the linear motors and nested frames allows the entire package to be compact.

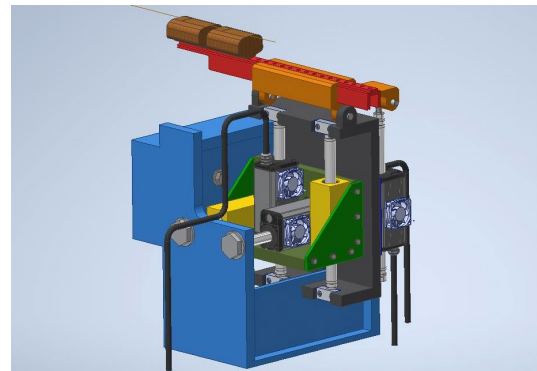


Figure 4. Complementary fixture concept using a linear motor

The linear motor subsystem will attach to the VTU's lateral cross beams as shown in Figure 5.

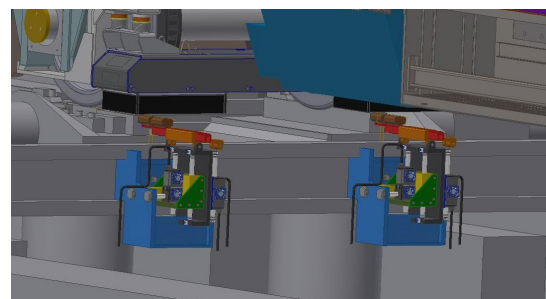


Figure 5. Complementary fixture mounted to the VTU crossbeams



CONCLUSIONS

The VTU equipped with the proposed complementary fixture can serve as a valuable verification tool for TGMS systems in tangents despite the inability to simulate gage. The inability of the VTU to simulate curved track, while being another limiting factor, does not reduce the ability of this system to evaluate track geometry systems. Even on tangent track, all of the inertial sensors, as well as the optical sensors and the software, are thoroughly exercised. The only exceptions are the long wavelength inputs to the gyro sensors related to centrifugal force, which occur only in curves.

The proposed approach for the complementary fixture would dynamically move short railhead samples, providing the same rail deviation input to the optical sensors of the tested TGMS that the VTU is inputting to the rail vehicle. Both potential concepts for the fixture, one based on a Stewart platform and the other using a set of linear motor actuators, were determined to be feasible during this study.

FUTURE ACTION

The next steps for this project would be to further develop proposed concepts, select a preferred solution, design the rail sample actuation subsystem, and develop the control logic based on the use of actual track geometry data.

REFERENCES

[1] [Code of Federal Regulation, Title 49 Subtitle B Chapter II Part 213 Subpart G § 213.333.](#)

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