The Deployable Gage Restraint Measurement System -
Description and Operational Performance

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ABSTRACT

A new generation of Gage Restraint Measurement System (GRMS) has been developed. The system has been installed on the Federal Railroad Administration (FRA) GRMS Vehicle, designated T-18. GRMS utilizes a split railroad axle to laterally load the head of both rails of the railroad track in order to measure the lateral deflection under a combined vertical and lateral load. GRMS is used to detect weak ties and rail to tie connections.

The new GRMS uses a fifth axle that is deployed from the frame of a railcar instead of using one of the vehicle’s running axles. The GRMS split axle is attached to a suspension that can raise and lower it, apply vertical loads, and properly align it with the track. The suspension permits the necessary degrees of freedom to allow the axle to track the rail while constraining others.

The new GRMS system advances the safety and utility of the GRMS technology by reducing the risk of derailment of the GRMS vehicle by decoupling testing axle derailment from vehicle running axle derailment. The new technology minimizes damage to GRMS hardware if the testing axle derails by limiting test axle movement and quickly lifting the test axle. With the new technology, GRMS testing speed has increased above 35 mph while still maintaining data quality.

This paper provides a complete description of the new system and demonstrates the improved performance of this system through test results under a variety of track conditions and speeds.

Key Words: GRMS, DGRMS, Track Strength
INTRODUCTION

Since its development in the early 1980’s, gage restraint measurement system (GRMS) technology has improved railroad safety by helping to identify locations with a high potential for wide gage derailment. GRMS uses a performance based criteria to evaluate track strength and fastener integrity. This performance based approach helps to end subjective appraisals of track conditions during visual inspections. By automating the process of conducting tie and fastener inspections, railroads can better use their resources to repair deficient track conditions rather than looking for them.

The GRMS uses two gage measurements to determine track strength and derailment potential. The first gage measurement is taken in an unloaded condition, while the second is taken under a combined lateral and vertical load applied by a special split railroad axle. Based on these gage measurements, two calculated parameters, projected loaded gage (PLG) and gage widening ratio (GWR), are derived. The PLG value represents the value the gage is expected reach under an extreme loading condition. GWR represents the amount of gage widening that is expected under standard service loading conditions. GRMS technology has undergone several upgrades since the initial prototype to improve operational performance and data reliability. The systems have been modified to fit both towed and self-propelled cars. Despite these enhancements, several major limitations have endured throughout the history of GRMS. Potential for test vehicle derailment is higher due to the nature of the split axle, which replaces one of the running axles in the truck. Due to this higher derailment potential, test speeds have been limited to 35 MPH. Also, test loading configurations have typically been dictated by the weight of the vehicle.

To overcome these operational and safety limitations, a new generation of GRMS, the Deployable Gage Restraint Measurement System (DGRMS) has been designed and constructed. The DGRMS, as the name implies, is deployed from the frame of the car body during testing.
using a custom suspension. This suspension allows the axle to move with respect to the car body as needed while applying the correct lateral and vertical forces. The suspension ensures that axle remains perpendicular to the centerline of the track regardless of super elevation and curvature. Since the split axle is not one of the running axles of the car, the risk of split axle induced vehicle derailment is eliminated. The deployable nature of the split axle also allows the vertical test load to be varied which, in turn, allows the lateral load to be varied.

**ORIGINAL GRMS DESIGN LIMITATIONS**

The original GRMS design used the approach of replacing one of the standard railroad axles in a truck with a special split axle. The vertical force was applied through the bearings outboard of the wheels, while the lateral force was applied by hydraulic rams used to separate the split axle. The axle was held together by a heavy steel barrel which allowed the split axle to telescope while absorbing the large bending moment created by the application of the lateral and vertical forces. Figure 1 shows the split axle installed in a freight truck.

GRMS requires the measurement of several key parameters to determine track strength and derailment potential using GWR and PLG, respectively. Loaded gage, unloaded gage, vertical force, and lateral force measurements must be taken at an interval of 16 inches or less. In the original GRMS, loaded and unloaded gages were measured using displacement transducers built into the telescoping mechanisms of special split axles. Since these systems relied on the flange of the wheel contacting the rail for the gage measurement, frequent calibrations were required to account for rapid wheel wear. Vertical forces were measured by custom bearing adapters instrumented with strain gauges. It was necessary to build and calibrate these custom bearing adapters for each GRMS delivered. The bearing adapters have been through several design changes using both load cells and strain gauges to measure vertical force. The lateral force was measured using wheels instrumented with strain gauges. The instrumented wheels required
significant effort to build and calibrate and additional hardware to transmit the signals from the rotating wheel to the computer for digitization.

The original GRMS design contained several undesirable requirements due to the approach used to apply the loads and measure the key parameters. The axle and barrel design needed to be able to handle the high moment and associated stresses generated by the combination of the outboard bearing and lateral force on the flange of the wheel. The hydraulic cylinders were required to operate at extremely high forces to correct this moment and allow the axle to slide in the barrel freely. Figure 2 shows the force balance on the half axle assembly. Due to the stresses induced by operating at such high forces, the components needed to have significant mass. The weight of the components combined with the inherent friction of the telescoping barrel limited the responsiveness of the axle to rapid gage changes. The effect of limited responsiveness is seen as the amplitude of lateral force variations while traveling down the track.

The use of custom strain gauge force measurement devices was also undesirable. The instrumented wheels required the use of replaceable tires due to the rapid wear rates seen on GRMS wheels. These tires were difficult to replace and exposed the strain gauges to extreme heat during the retiring process. The strain gauges required extensive weatherproofing and physical protection which complicated maintenance and repairs.

**DGRMS DESIGN AND CONSTRUCTION**

Due to the lack of operational reliability and high maintenance costs associated with the T-6 research vehicle, which contained the original GRMS prototype, the Federal Railroad Administration (FRA) Office of Research and Development decided to build a new GRMS vehicle. The design of the GRMS would be revisited to address some of the limitations with the original prototype. Several goals were established at the onset of the design phase of the next
Increasing test speed while decreasing derailment potential was paramount. To achieve this, the split axle needed to be removed from the running truck. The concept of deploying the axle from the car body was the only possible solution. From this approach, other limitations of the original design could be improved upon. The vertical force could be moved inboard of the wheel, thereby canceling the moment generated by the lateral force on the flange rather than adding to it, as seen in figure 3. The lower moments would require less balancing forces from the hydraulic rams and induce less stress, which meant the components could be lightened. The lower stresses also allowed for the use of linear guides to extend and retract the axle rather than the telescoping barrel. The combination of the lighter components and lower friction in the linear guides help to increase responsiveness, which improves data quality at higher operational speeds. The low friction in the linear guide also allowed for changes in the location of the lateral force measurement. It was now possible to use a load cell at the connection of the hydraulic ram to the half-axle assembly rather than the strain gauged wheel. The suspension of the deployable axle could be used to control the vertical force applied, which would allow different load combinations to be used during testing.

With such significant design changes at hand, several challenges had to be overcome. The suspension of the axle was critical. It had to allow the axle to translate laterally and vertically as well as roll with respect to the car body while maintaining vertical force and perpendicularity to the centerline of the track. Figures 4 and 5 show the suspension design and how it permits and constrains the required degrees of freedom.

With the details of the suspension design completed, the new FRA DGRMS car, the T-18 was built. All of the targeted limitations were improved. The axle was no longer part of the running gear of the car. Now if the axle derails, it is sensed by the vertical displacement of the axle from the car body and immediately lifted. The strain gauged wheels were replaced by load cells at the
connection of the hydraulic rams to the half-axle assembly. The strain gauged bearing adapters were replaced by load cells at the connection of the lower swing arm to the half-axle assembly. The axle is light and responsive. The wheels are easily replaced in the field by the use of a locking hub. The axle can be easily stowed for dead head movements or non-GRMS testing.

**DGRMS SYSTEM PERFORMANCE**

Since the DGRMS was built, it has been through several tests to evaluate its performance against the design goals. The preliminary results indicate the DGRMS is performing as anticipated. The lighter, more responsive axle has significantly reduced the variations in lateral force seen while traveling down the track. Figure 6 shows a comparison of the standard deviation of lateral force at various speeds for both the original T-6 GRMS prototype and the T-18 DGRMS. After the initial system shakedown and evaluation, tests were conducted to evaluate the performance at higher speeds. Figure 7 shows the performance of the DGRMS at 50 MPH. The system responds very well to changes in track conditions and maintains valid test loads for all but one point in the dataset. Valid test loads are zones II and IV on the plot.

The design goal of variability in the applied loads has also been satisfied. Since the DGRMS is the first system capable of varying its test loads, it was well suited to investigate the effect of load configuration on the calculated parameters PLG and GWR. Data collected by running tests at different load configurations over the same section of track was analyzed. The analysis was able to identify the lack of a vertical load term in the GWR equation which could lead to discrepancies in exception counts from different qualified GRMS vehicles. After a new equation had been developed, the data collected by the DGRMS was reprocessed to evaluate the formula. Preliminary results indicate the new formula outputs consistent values regardless of the applied loads.
CONCLUSION

Gage Restraint Measurement Systems have been in operation since the 1980s. The technology has provided a performance based approach to the evaluation of tie condition and fastener integrity. The original system was able to provide useful data, but suffered from operational limitations. A new generation of GRMS was designed to prevent test vehicle derailments, increase operating speed, reduce variations in applied loads, and permit operation at multiple load configurations. To achieve these goals, the design called for the GRMS split axle to be deployed from the car body frame instead of operating in the running truck. The approach of deploying the split axle provided solutions to the limitations of the original GRMS, but presented additional design challenges in order to track the rail appropriately. Once the design was finalized, the system was built and evaluated. The system was able to provide less variation in the applied loads which has opened the possibility for increased operating speeds. Preliminary results from 50 MPH testing show the applied loads stay within the desired range. The system has also successfully been used at different load configurations.
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- Upper Swing Arm (Vertical Translation)
- Load Frame (Lateral Translation)
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