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Impact Simulations of Cars with 10-inch End-of-car Cushioning Units

Jack Schultz and Adam Klopp

Key Findings:

- Results from the impact simulations showed good agreement with measured data for both buff and draft impacts.
- For the simulation cases evaluated, increases in impact performance tended to decrease slack control, and increases in slack control tended to decrease impact performance.

Transportation Technology Center, Inc. (TTCI) conducted simulations to analyze the performance of 10-inch end-of-car-cushioning (EOCC) units in impact and in-train type environments. The study, part of the Association of American Railroads (AAR) Strategic Research Initiatives (SRI) program, simulated car-to-car impacts using TTCI's dynamic modeling software, NUCARS®*, in accordance with AAR's M-921D standard. Results from the impact simulations showed good agreement with measured data for both buff and draft impacts.

Train dynamics simulations were conducted using the Train Operation and Energy Simulator (TOES™) to evaluate the in-train performance and slack control of 10-inch EOCC units in over-the-road (OTR) type environments. The TOES™ simulations were used to establish the baseline coupler forces of trains containing 10-inch EOCC units as they negotiated different challenging revenue service routes. Additional simulations were conducted to evaluate the effects of EOCC parameter variations on impacts and in-train forces. Simulations were also conducted to evaluate other draft systems, including 10-inch EOCC units with active draft, standard friction draft gears, and asymmetric friction draft gears, to compare the impact and in-train coupler forces to the baseline 10-inch EOCC unit simulations. The goal of this effort was to develop models using real-world data from 10-inch EOCC units and use the models to simulate yard type coupling impacts, model the in-train forces on challenging revenue service routes, and begin identifying potential improvements for EOCC units and other long-travel draft systems.

BACKGROUND

The EOCC unit is used in a type of long-travel hydraulic draft system designed to protect equipment and lading by absorbing energy during car-to-car impacts. EOCC units absorb energy by forcing oil from the high-pressure cylinder to the surrounding casing through preloaded orifices over a long displacement stroke typically 10 or 15 inches. EOCC units provide protection of equipment in yard environments where impacts between cars can generate large coupler forces and accelerations, but they can also create slack action issues if many units are installed in a consist during normal train operations due to their long travel.

In previous analyses by TTCI, car-to-car impacts were simulated in NUCARS® for vehicles with 15-inch EOCC units.[1] Building on the modeling methodology developed

*NUCARS® is a registered trademark of Transportation Technology Center, Inc.

for that work, simulations were conducted to evaluate the impact performance of autoracks equipped with 10-inch EOCC units according to AAR's M-921D standard.[2] Additionally, train dynamics simulations were conducted in TOES™ to evaluate the in-train performance and slack control of cars with 10-inch EOCC units in an OTR type environment.

IMPACT SIMULATIONS

A typical M-921D impact test to evaluate the performance of a 10-inch EOCC unit includes the following test configurations:

- Impact performance test, buff simulations
  - Hammer car loaded to 150,000 pounds
    - Equipped with 10-inch EOCC unit on the striking end
  - Anvil car loaded to 220,000 pounds
    - Coupled to two back-up string cars
    - Equipped with M-901E draft gears
  - String cars each loaded to 220,000 pounds
    - Hand brake set on last car
    - Equipped with M-901E draft gears
- Train action test, draft simulations
  - Hammer car loaded to 150,000 pounds
    - Equipped with 10-inch EOCC unit on the striking end
  - Anvil car loaded to 263,000 pounds
    - Free to roll
    - Equipped with M-901E draft gears

Note that the train action tests do not have string cars or any brakes set, and a special draft sill is used in the hammer car to allow draft loads to be developed on the cushion unit during buff impacts. Buff simulations were performed for speeds from 1 to 8 mph, and draft simulations were performed from 1 to 3 mph.

Four instances of the standard loaded hopper car model from NUCARS® were used with their weights altered to match the M-921D standard. EOCC units were modeled as a series of staggered damper connections that allowed the overall damping of the EOCC model to progressively increase with the stroke to simulate a decreasing available orifice area with the stroke.

The characteristics of the simulated EOCC unit were tuned by iteratively repeating the simulations with slightly altered preload and damping values until the EOCC unit force and displacement curves agreed with the manufacturer-provided data. Simulations did not match the provided data exactly; however, the general shape of the force and displacement time histories, maximum force, and maximum displacement were targeted to be similar for all speeds. Figure 1 shows the maximum forces and displacements for buff and draft impact simulations.

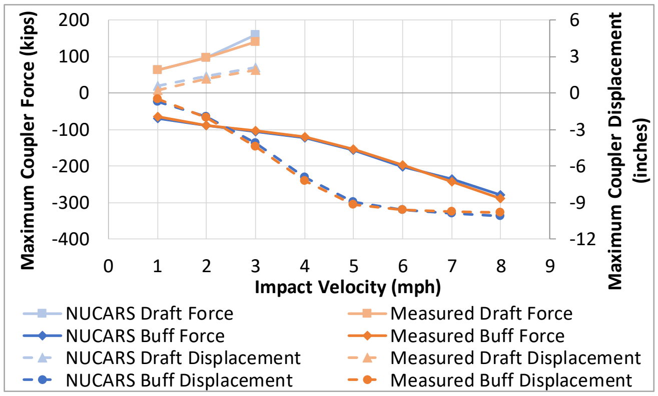

Figure 1. Summary of maximum impact forces and displacements for 10-inch EOCC unit simulations and measured data

OVER-THE-ROAD SIMULATIONS

Once the NUCARS® 10-inch EOCC model was validated for buff and draft impacts at the appropriate speeds, characteristics from the NUCARS® 10-inch EOCC model were used to develop a TOES™ model for use in OTR simulations. TOES™ was used to simulate 100-car unit autorack trains with 10-inch EOCC units operating over two different challenging revenue service routes with undulating grades. One of the routes included a crest in the track where the grade transitions from an uphill grade to a downhill grade. As the train negotiates the crest in the track at this location, it experiences a slack run-in and an increase in buff forces toward the rear of the train. The other route includes a sag in the track where the grade transitions from a downhill grade to an uphill grade. As the train negotiates the sag in the track at this location, it experiences a slack run-out and an increase in draft forces toward the rear of the train.

Figure 2 shows a plot of the maximum buff and draft forces that occurred at each car in the unit autorack trains with 10-inch EOCC units during the TOES™ simulations on both challenging revenue service routes. Buff forces are indicated in the plot as negative values, and draft forces are indicated as positive values.

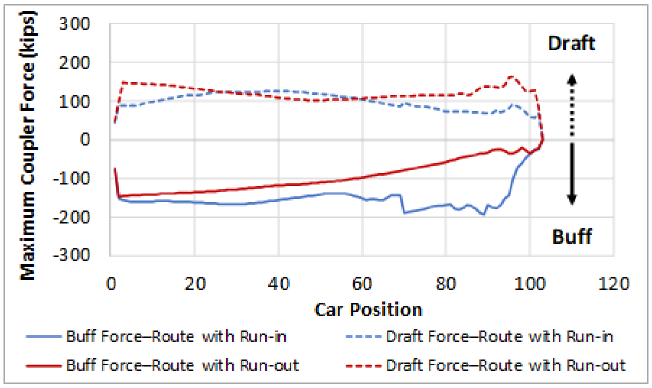

Figure 2. Maximum buff and draft forces at each car in the train during the baseline simulations with run-in and run-out events

The results shown in Figures 1 and 2 were then used as baseline values for comparisons with simulations that featured different EOCC unit variations and other types of draft systems.

PARAMETRIC VARIATION SIMULATIONS

Simulations were conducted using variations of the baseline 10-inch EOCC unit model to evaluate the effects that various parameters have on the impact and in-train performance and identify characterstitics that could improve the overall performance of 10-inch EOCC units. Improved EOCC unit characteristics should balance the need to provide protection in yard impacts by absorbing energy, and the need to control slack action and in-train forces during run-in and run-out events in revenue service. Several parameters of the 10-inch EOCC unit model were varied in the analysis, including preload, orifice area, and stroke length. Figures 3 and 4 present example results from the parametric variation analysis showing the effects of varying the preload of the 10-inch EOCC unit model. The baseline preload of the EOCC model was 50 kips and was varied in the analysis by ±50 percent of the baseline value.

Figure 3 shows the maximum buff forces from the NUCARS® impact simulations when the preload was varied. These maximum impact force results are compared in the plot to the M-921D standard for maximum allowable force per impact speed.

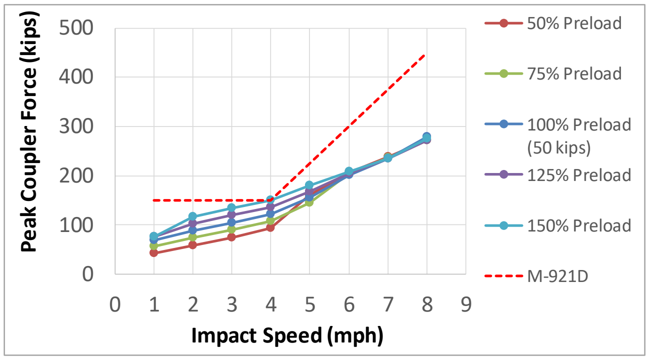

Figure 3. Maximum impact forces for 10-inch EOCC unit preload variations

The preload of the EOCC unit had the most significant effect on maximum forces at speeds of 4 mph and below because preload controls when orifices open and begin to allow unit travel. At these lower impact speeds, increases in the preload value of the EOCC unit resulted in increased maximum impact forces and decreased impact protection. At impact speeds of 5 mph and above, the effect of the preload was less significant because the preload force of all the EOCC units was exceeded quickly during the impacts. At the higher impact speeds, orifice damping, and stroke limit play a more significant role in determining the maximum forces. The orifice damping and stroke limit parameters were identical for all of the preload variations of the EOCC model, so the results of all the preload variations of the model were similar in the higher speed range.

Figure 4 shows a plot of the maximum buff and draft forces for the 10-inch EOCC units with different preloads that occurred at each car in the unit autorack trains during the TOES™ simulations on the challenging revenue service route with a run-in event. As the preload of the EOCC units in the train increased, the EOCC units provided more slack control and experienced lower maximum buff forces in the train during the run-in event. The preload variation example shown in Figures 3 and 4 illustrates the key trade-off inherent to draft system designs. Increases in impact protection tend to decrease slack control and increases in slack control tend to decrease impact protection.

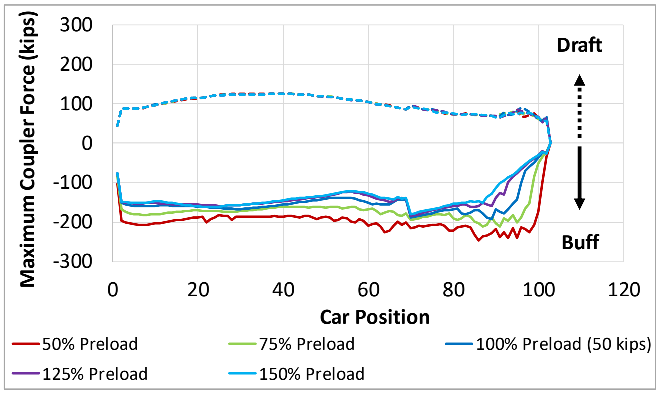

Figure 4. Maximum buff and draft forces at each car in the train during the simulation, run-in event for 10-inch EOCC unit preload variations

MODELING OF OTHER DRAFT SYSTEMS

Other types of draft sytems were simulated in this analysis to compare against conventional 10-inch EOCC units regarding impact and in-train performance. The other draft systems evaluated in this analysis included 10-inch EOCC units with active draft, conventional friction draft gears, and asymmetric friction draft gears. The asymmetric draft gear had the same characteristics in draft as the conventional friction draft gear, but it allowed twice the displacement in buff for a given force. Figure 5 shows the maximum buff forces from the NUCARS® impact simulations of the different draft systems compared to the conventional 10-inch EOCC units. These maximum impact force results are plotted alongside the M-921D standard for comparison purposes.

It should be noted that the M921-D standard was used to evaluate 10-inch EOCC units, and other draft systems (e.g., friction draft gears and asymmetric gears) are not required to meet the M-921D standard.

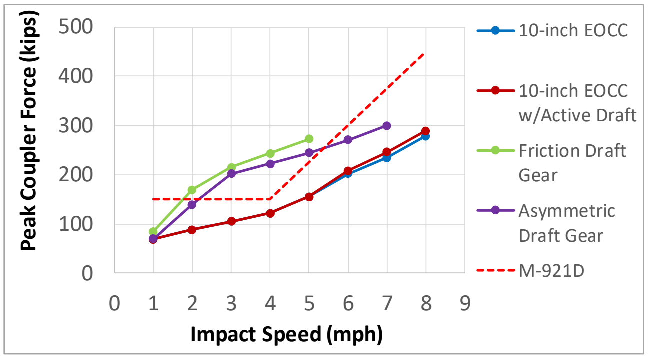

Figure 5. Maximum impact forces for various draft systems compared to M-921D standard

Figure 6 shows a plot of the maximum buff and draft forces for different draft systems that occurred at each car in the unit autorack trains during the TOES™ simulations on the challenging revenue service route with a run-in event.

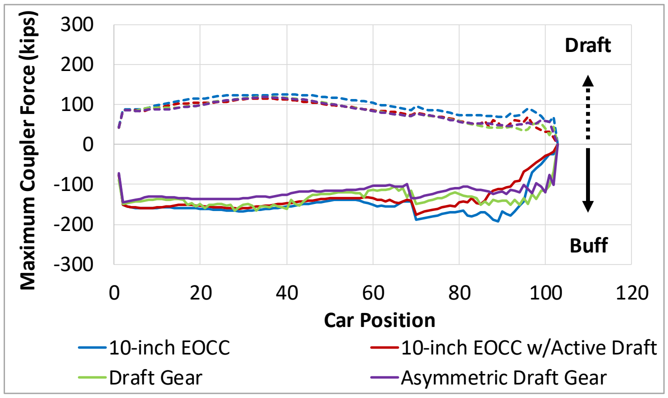

Figure 6. Maximum buff and draft forces at each car in the train during the simulation with a run-in event for various draft systems

Results from the simulations with other types of draft systems were similar in nature to results of the preload parameter variations. The draft systems that provided more impact protection and lower impact forces also provided less slack control and higher buff forces in the OTR simulation with a run-in event.

CONCLUSION

TTCI conducted simulations to analyze the performance of 10-inch EOCC units in impact and in-train type environments. The simulations included M-921D type impacts in NUCARS® and train dynamics simulations in TOES™. Results from the impact simulations showed good agreement with measured data for both buff and draft impacts, and characteristics from the NUCARS® model were then used to develop EOCC unit models in TOES™ for use in OTR simulations. TOES™ simulations were used to establish baseline coupler forces of trains containing 10-inch EOCC units as they negotiated two different challenging revenue service routes. Additional simulations were conducted to evaluate the effects that various parameter variations have on impacts and in-train forces. Simulations were also conducted to evaluate other draft systems, including 10-inch EOCC units with active draft, standard friction draft gears, and asymmetric friction draft gears, to compare the impact and in-train coupler forces to the baseline 10-inch EOCC unit simulations. For the simulation cases evaluated, increases in impact performance tended to decrease slack control, and increases in slack control tended to decrease impact performance.

FUTURE WORK

TTCI continues to analyze EOCC units and will conduct additional parameter sensitivity studies to provide guidance to the industry related to characteristics for balanced impact and in-train performance for EOCC. TTCI is in the process of deriving general characteristics for long-travel draft systems to provide recommendations about characteristics that improve impact and in-train performance. Results of this characteristics analysis will be presented in a future *Technology Digest*. TTCI is also preparing plans for impact and slack action tests that will be conducted under the SRI program. The tests will be conducted to evaluate and compare the impact protection and slack control of different types of draft systems.

References

1. Klopp, A., October 2018, “Impact Simulations of Cars with 15-inch End-of-Car Cushioning Unit,” *Technology Digest* TD18-025, AAR/TTCI. Pueblo, Colorado.
2. *Manual of Standards and Recommended Practices,* 2012, M-921D, “Cushioning Devices, End-of-Car-Motor-Vehicle-Carrying.” Association of American Railroads. Washington, DC.

For comments or questions about this publication, contact Jack_Schultz@aar.com