A Study on Energy Absorbing Capacity on Collision and Corner Posts of EMU according to APTA SS-C&S-034-99 standard.

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Abstract

The purpose of this paper is to validate energy absorbing capacity that satisfies APTA SS-C&S-034-99, REV.2 with North America type Electric Multiple Units. The FE model for collision and corner post simulation was developed. Two different type of simulation were conducted. One is Quasi-static analysis and the other is dynamic impact analysis. Totally, the results of two types were assimilated. So as if finite element model is considered sufficient confidence compared with test, requirements for design will be saved.

Introduction

The operation of cab cars were exposed the operator to risk in the event that the cab car strikes an object that fouls the train right-of-way. Actually, many accidents occurred in the end of 20th century. So that reason, the American Public Transportation Association (APTA) issued an industry standard in 1999 that included additional requirements in end frame designs [1]. These standards subsequently revised so as results of various studies. Currently, these standards include both increased strength requirements for cab car vertical frame members – collision and corner posts as well as deformation requirements. So as the most of rolling stock companies is required study and validation about APTA standards for sales to North America region. The purpose of this study is to validate energy absorbing capacity that satisfies APTA SS-C&S-034-99, REV.2 with North America type Electric Multiple Units.

Criterion

APTA SS-C&S-034-99, REV.2 issued about collision post and corner post for Cab-End. Each collision post on cab car shall be capable of absorbing a minimum of 135,000lb-ft (0.18MJ) of energy when loaded longitudinally at a height of 30 inches above the top of the underframe over a maximum area of 6inches of height and width. The collision post shall not permanently deflect more than 10 inches (254mm) into the operator’s cab or passenger seat area and no completely separation of the post, its connection to the underframe or its connection to the roof structure. Each corner post on cab car shall be capable of absorbing a minimum of 120,000lb-ft (0.16MJ) of energy when loaded longitudinally at a height of 30 inches above the top of the underframe over a maximum area of 6inches of height and width. The corner post shall not permanently deflect more than 10 inches (254mm) into the operator’s cab or passenger seat area and no completely separation of the post, its connection to the underframe or its connection to the roof structure. As recommended alternative clause, dynamic items mentioned. The cab-end collision post shall resist the impact with a 10,000 pound cylindrical shaped object (outside diameter of 48 inches and width of 36 inches) at a vehicle speed of 21 mile per hour. The object shall impact the collision post 30inches above the top of the underframe. The object shall not intrude more than 10 inches into the operator’s cab or passenger seating area and without complete separation of the post, its connection to the underframe, or its connection to the roof structure. The cab-end corner post shall resist the impact with a 10,000 pound cylindrical shaped object (outside diameter of 48 inches and width of 36 inches) at a vehicle speed of 20 mile per hour. The object shall impact the collision post 30inches above the top of the underframe. The object shall not intrude more than 10 inches into the operator’s cab or passenger seating area and without complete separation of the post, its connection to the underframe, or its connection to the roof structure.
FE model development

Numerical simulation is kind of method validate performance of the railroad car. For this study, it will be developed that North America type Electric Multiple Unit (EMU) numerical finite element sub-assembly model is developed. Numerical finite element model for analysis is composed 2D element and 3D element. 2D element is shell element: about 113,756 elements and 3D element is solid element: 584 elements. Figure 1 is shown the developed finite element model. The post was constructed from an A710 material and the actual material’s yield strength was used. Figure 2 is shown used A710 material curve for post.

![Fig. 1 Developed FE Model of EMU for Numerical simulation.](image1)

![Fig. 2 Curve of A710 material property](image2)

Analysis is carried out using LS-DYNA 971 package under HP workstation xw8200. The material property used in the 3-D analysis is listed at Table 1.
Table 1 Mechanical Property of Used Materials

<table>
<thead>
<tr>
<th>No.</th>
<th>Material</th>
<th>Yield Strength (kg/mm²)</th>
<th>Ultimate Strength (kg/mm²)</th>
<th>Young’s Modulus (kg/mm²)</th>
<th>Poisson’s Ratio</th>
<th>Remarks</th>
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<tr>
<td>1</td>
<td>A710</td>
<td>&gt;56.0</td>
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<td>SUS301L-ST</td>
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<tr>
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<td>&gt;95.0</td>
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<td>5</td>
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<td>20,897</td>
<td>0.3</td>
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</tbody>
</table>

Analysis scenario

Four analyses were conducted. Quasi-static and dynamic simulations were conducted on the collision post and corner post. Quasi-static analyses are longitudinal load applied on the collision post and corner post at a height of 30 inches (762mm) above the top of the underframe over a maximum area of 6 inches of height and width. As load distribution applied all same rates, all nodes that were applied load defined nodal rigid body. The load was ramped up slowly a number of load increments. Rear end parts of this FE model are fixed 6 degree of freedom. The entire FE model was applied self impact sliding interface.

The condition of dynamic analyses are rigid coil with speed of 21 mph (33.8km/h) crashing each collision post and corner post at a height of 30 inches (762mm) above the top of the underframe. Rigid coil have 48 inches (1,219 mm) diameter, 30 inches width. The weight of rigid coil is 10,000lbf (4,536kg) and width is 30 inches (762mm). All degree of freedom of FE model is free. Sliding interface condition was defined between the FE cab model and impact coil. For reduce calculation running time, used half FE model. Figure 3 is shown schematic of dynamic simulation.

Results

- Quasi-static analysis
  Figure 4 shows the energy absorption curve of collision post in quasi-static loading condition. The maximum absorbing energy of the collision post is 135,270 lb-ft (0.184 MJ). Figures 5 show the plastic strain of global FE model. It is shown that the plastic deformation occurs at connection area of collision post and anti-telescoping plate. The strain value is 0.467
Figure 6 shows the energy absorption curve of collision post in quasi-static loading condition. The maximum absorbing energy of the collision post is 121,390 lb-ft (0.165 MJ). Maximum deformation value is 5.7 inches (147.3mm) and occurred upside collision post connecting area. Figures 7 show the plastic strain of global FE model. It is shown that the plastic deformation occurs at connection area of collision post and anti-telescoping plate. The strain value is 0.27.
- Dynamic analysis

Figure 8 shows the energy absorption curve by total kinetic and internal energy of collision post. The maximum absorbing energy of the collision post is 0.192 MJ. Figures 9 show the maximum deformation and value is 141 mm. Figure 10 shows configuration of collision post and maximum plastic strain after rigid coil impact. The plastic deformation occurs at connection area of collision post and anti-telescoping plate. The Maximum plastic value is 0.251.
Figure 11 shows the energy absorption curve by total kinetic and internal energy of collision post. The maximum absorbing energy of the collision post is 0.19 MJ. Figures 9 show the maximum deformation and value is 5.1 inches (129.5 mm). Figure 12 shows configuration of collision post and maximum plastic after rigid coil impact. The plastic deformation occurs at connection area of collision post and anti-telescoping plate. The Maximum plastic value is 0.3.
Conclusion

Four FE analyses were conducted to validate energy absorbing capacity that satisfies APTA SS-C&S-034-99, REV.2 with North America type Electric Multiple Units. Results of four simulation cases are satisfied criterion. So as if finite element model is considered sufficient confidence, requirements for design are saved.

References

