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Crashworthiness Improvement of Pardis Train Set using Thin Walled Tubes - Simulation

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ABSTRACT:

This paper presents improvement of the crashworthiness of DH4-1 Iran Pardis train set using thin walled tubes in the nose structure. The impact of train set with other moving rolling stocks is simulates using LS-DYNA software. The model is verified as per ECE R 66 standard. The absorbed energy ratios and hourglass energy are calculated and reported. It is demonstrated that by using thin walled tubes, it is possible to delay the shock and considerably reduce the amount of shock load to the vehicle structure.

KEYWORDS:

Crashworthiness; Train set nose; Thin walled tubes; Energy absorption; LS-DYNA.

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1. Introduction

The DH4-1 Pardis train sets are the fastest rolling stocks in service along Iranian national railroads. Proper maintenance and improvement in impact properties of these machineries are of prime importance for railway operators. When studying the subject of the vehicle crashworthiness, the main idea is to reach a proper design for the vehicle exterior that can absorb most of the impact energy through deformation in case of impact. At the same time there needs to be a proper space to safeguard passenger lives. Therefore, it needs to transmit the least possible energy to the occupants of the vehicle [1]. The analyses of major accidents prove that head-on crashes cause the highest number of fatalities and injuries to the train passengers. Usually under such circumstances, the rail cars override. Therefore, the most effective method in reducing the number of fatalities in rail car accidents is to improve crashworthiness of the two ends of the rail cars and to prevent the head-on collisions, if at all possible [2].

The concept of managing energy absorption as a strategy to improve the passenger and the equipment protection during collisions was initiated in 1850 [1]. However, research concerned with the real case scenarios of railcar crashworthiness was started during 1980 [3]. The background in research for the crashworthiness of the railway rolling stocks is not very extensive. Most of the research in this field dates back to the last two decades. Many of those researches have been concerned with identifying the causes and setting some useful criteria. Few good examples of such research programs are:

- Test of impact between two vehicles by ORE.
- Dynamic test of TGV train during impact with 80 tones ballast car by SNCF.
- Dynamic test of a railcar at impact with a wagon with rigid end. This test was performed by the European safe train project, in late 90s.
- Two dynamic tests involved with the impact of the railcar and rigid walls, in 1999 and 2004 [4].

There have been a number of research projects on crashworthiness of high-speed rail cars in Iran. The use of energy absorbing foams in vehicle nose [5] and a study on the effects of angle of attack and length of vehicle nose on the energy absorption are amongst such studies [6]. The aim of this research is to study the collision and to propose ways of increasing the passive safety of rail cars. Therefore, a proper sample from the rolling stocks available in Iran is selected for the modeling purpose. The use of energy absorbing thin walled tubes as a proposal for improving the crashworthiness of railcar is investigated. It is also ensured that no major changes should happen to the original design of the railcar structure. The proposed remedies need to be practical and applicable under the current regulations of the Rail industries.

2. Vehicle impact modeling

The growing number of population demands the need for increased rate of travel. This has caused the need to raise the speed of travel. As a result there is higher risk of collisions between moving vehicles. Saving lives becomes a major priority for the railway operators. It raises concerns about crashworthiness of the vehicles in service. At lower speeds of travel the possibility for accidents is lower. Therefore, in such cases the intensity of damages and fatalities are lower [7]. The modeling should include a railcar that is capable of travelling at higher speeds. DH4-1 Iran Pardis train set designed by Siemens Austria is selected for the modeling purposes in this research. Four major scenarios that have been the most common causes of accidents in European railways include the following:

1. Head-on collision of two similar trains;
2. Head-on collision of a train with another type of rolling stock;
3. Collision with heavy road vehicles;
4. Collision with lighter road vehicles and animals [8].

Considering the fleet of the Iranian railway tracks and the ratio of the number of Pardis train set to the total number of rolling stocks, the possibility for the collision between two train sets is low. Statistics has shown that the intensity of damage that can be resulted upon collisions at level crossings cannot cause major damage to the railway fleet. Therefore, it is concluded that the possibility for collision between the train set and some other type of railway rolling stock is higher. The design of energy absorbing zone in the vehicle needs to comply with the EN 15227 standard [8]. A schematic of such a design is shown in Fig. 1. As one of the two crumble zones lies at the front of the vehicle, this research is focused on improved design of the vehicle nose for collision energy absorption. The vehicle model is developed using Solidworks 2011 software. The frontal structure and vehicle nose model is shown in Fig. 2. Abaqus/CAE 6.9-1 software was used to mesh the model. FEMAP v9.1 software is used to convert the model for solving using LS DYNA software.

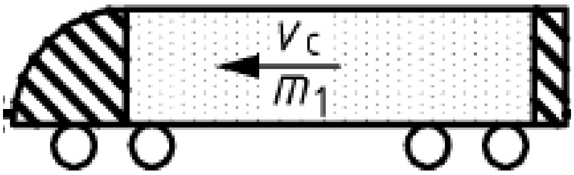

Fig. 1: Energy absorbing zones in a railcar [8]

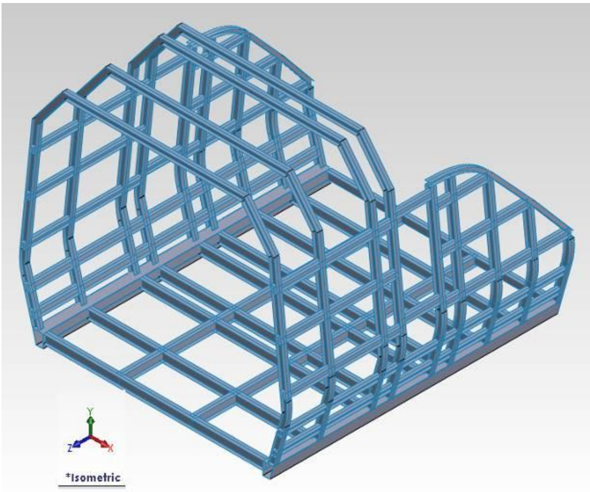

Fig. 2: Pardis railcar frontal structure model

According to EN 15227 standard, vehicle travelling at 36 km/h collides with an 80 tons wagon and it needs to be confined in all directions except the translation in the horizontal direction. The end wall has to be a rigid wall [8].The assumption of 80 tons wagon increases the calculation time and the complexity of the solution procedure. Therefore, by considering the past exercises [3, 9, 10, and 11] in such situations, a rigid wall approach is used in this research. According to ECE R 66 standard, software simulations are valid when the energy ratio lies within 1±0.05 domain and the hourglass energy is less than 5% of the total energy. The calculated energy ratio throughout the modeling is shown in Fig. 3. The energy ratio stays well within the prescribed limits at all times of the simulation. Fig. 4 shows the total energy and hourglass energy during the course of collision simulation. The hourglass energy is very small when compared to the total energy. Therefore, the developed model complies with ECE R 66 standard and is reliable.

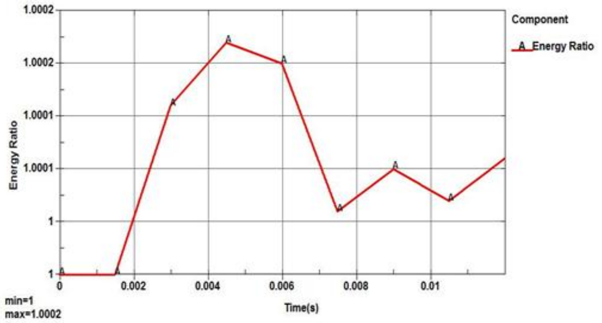

Fig. 3: Collision energy ratio vs. Time

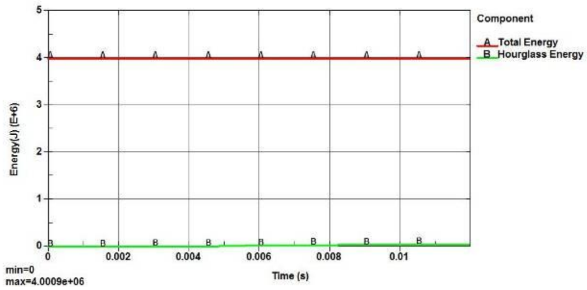

Fig. 4: Collision and hourglass energy vs. Time

3. Results and Discussion

The collision simulation of the existing vehicle without any energy absorbing elements was undertaken. Fig. 5 shows the variation in the amount of energy absorption with time for the vehicle nose during collision. The amount of absorbed energy is about 0.37 MJ.

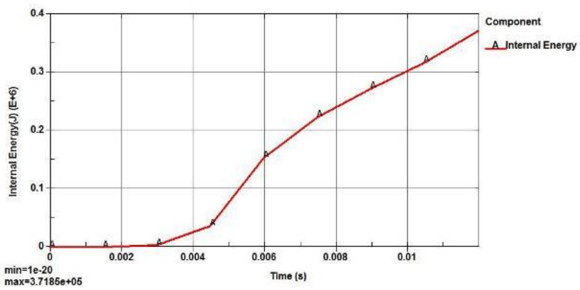

Fig. 5: Energy absorption vs. Time for existing structure

For improving the collision behaviour of the structure, five thin walled tubes are added to the front side of the vehicle model as shown in Fig. 6. The outcome of simulation for variation in tube thickness [12] between 2mm and 7mm is shown in Fig. 7. The addition of thin walled tubes has increased the amount of absorbed collision energy. Increase in the energy absorption is observed for an increase in tube wall thickness as expected. Installation of such thin walled tubes does not cause significant changes in the structure. It also reduces the maximum shock that can be applied to the structure as shown in Fig. 8.

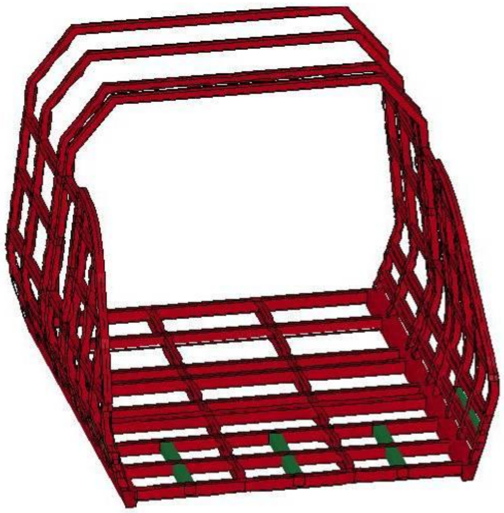

Fig. 6: Improved vehicle structure model

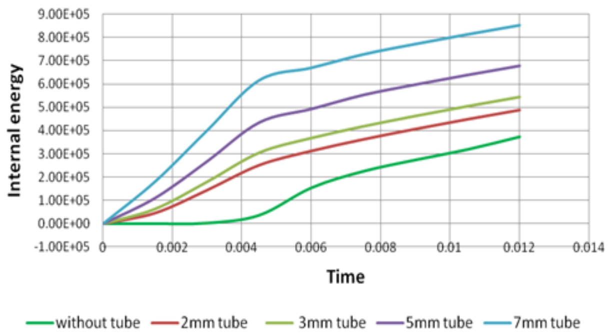

Fig. 7: Collision energy absorption for different tube thicknesses

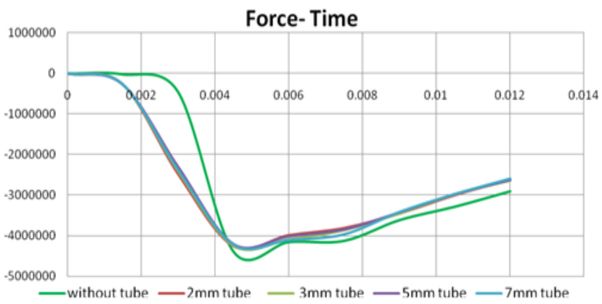

Fig. 8: Collision shock absorption for different tube thicknesses

Considering the accessible space in the chassis at the front of the vehicle, the possibility of mounting these thin walled tubes as part of the existing tubes in front of main structure was also investigated. This has resulted in delay and further reduction in the amount of the sustained shock by the structure. The collision energy absorption has also considerably increased. The corresponding results for the shock and energy absorptions are shown in Fig. 9 and Fig. 10 respectively.

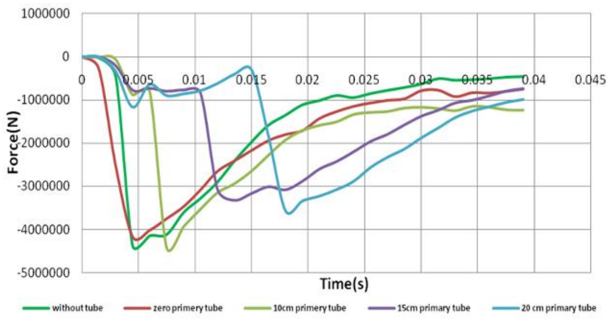

Fig. 9: Collision shock absorption for different tube thicknesses with extended thin walled tubes

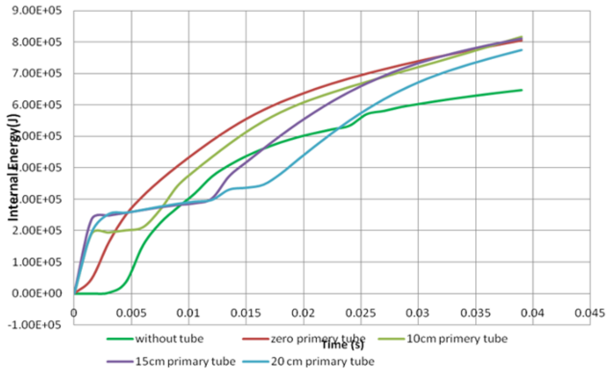

Fig. 10: Collision energy absorption for different tube thicknesses with extended thin walled tubes

4. Conclusions

Head on collision of Iran Pardis train set with 80 tons wagon is simulated with a view to improve its crashworthiness. The modeling procedure was verified by using ECE R 66 standard. Installation of thin walled energy absorbing tubes at the nose of vehicle is recommended to improve the crashworthiness of vehicle. The structure absorbed 0.37 MJ of energy during the collision. This elevated the energy absorption for the improved structure by twice as that of its original shape. Also this improved design has resulted in major reduction in the magnitude of shock loading to the structure. Extending the length of the thin walled tubes in the chassis of the vehicle considerably delayed and reduced the maximum shock applied to the structure.

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