Proceedings of JRC2006
2006 ASME Joint Rail Conference
April 4-6, 2006, Atlanta, Georgia USA

JRC2006-94010

HOSE STRAP REACTION FORCES IN RAILROAD FREIGHT CARS

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ABSTRACT

This paper investigates the reaction forces on hose straps when end hoses are separated while in the charged condition, *i.e.*, the gladhands are uncoupled. Five different End-Of-Car (EOC) arrangements and four most widely used hose straps are studied and tested. It is found that the load on hose straps is related to EOC arrangement types on the two connected cars. More rigid arrangements give less reaction forces on the hose straps. It is also found that the elasticity of the hose straps is another key factor contributing to the reaction force. More flexible hose straps generate less reaction forces for the same EOC arrangement setup. Simulation details are given, as well as the test results and the explanation of the results. Final discussions and conclusions are presented in the last part of this paper.

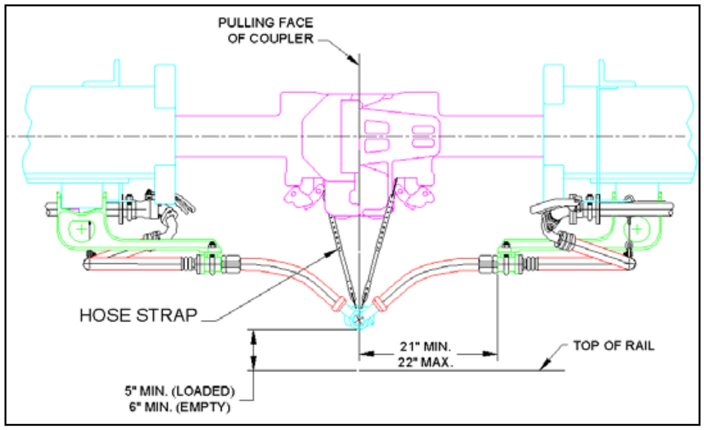

Figure 1: Typical Installation of Hose Straps and End Hoses

1. INTRODUCTION

Hose straps are used to support gladhands on end hoses of railroad freight cars. They are usually connected between the gladhands on end hoses and the bottom of the car couplers. The straps are adjustable to control the height of the gladhands to meet the requirements of the Association of American Railroads (AAR) specifications. After the strap is correctly installed, the lowest point of the gladhand should be 5 inches minimum above the top of the rail when the car is loaded or 6 inches minimum when the car is empty. By AAR Specification S-4006, qualified hose straps shall be capable of lifting a 300-lb weight or stretching 5 inches [1]. One typical installation of hose straps and end hoses is shown in Fig. 1.

When end hoses are coupled and pressurized, most of their weight is distributed to supports on the end opposite of the gladhand, in most cases, trainline castings and brackets. The load on the hose straps is then relatively small compared with their strength. When the end hoses are being separated under pressure, however, the load on the hose straps will greatly increase, along with the reaction force, because of the impact of the compressed air and the dynamic motion of hoses. This increase may lead to the breakage or other types of failures of hose straps. If the hose straps do not function correctly, the distance from the top of rail to the lowest point of gladhand may be smaller than the AAR requirement. Gladhands will then have a greater possibility to hit obstacles on the rail or tracks when the train is moving and finally be uncoupled because of the impact. Once they are uncoupled, the lost of air pressure will result in an emergency application of the train brakes. This situation may cause problems of train delays or even derailments.

This issue is therefore brought to the attention of the industry and the AAR. Further investigation is needed to study the principles, reaction forces, and dynamic motions of hose straps during and after the period of separations. In addition, their relationship with different design of hose straps, different

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End-Of-Car (EOC) arrangement types and different separation speeds are also needed to be taken into consideration and studied.

The objective of this paper is to investigate reaction forces on different hose straps in different conditions when end hoses are separated while they are charged with air. It is found that the load on hose straps is related to EOC arrangement types on the two connected cars because of their various dimensional and non-dimensional requirements, such as the end hose mounting method, for example.

Five most widely used EOC arrangements are studied. Their dimensional and non-dimensional requirements are followed in the tests and test results are provided. It is found that more fixed arrangements give less reaction forces on the hose straps. In this paper, it is also found that the elasticity of the hose straps is another key factor contributing to the reaction force. More rigid hose straps generate higher reaction forces for the same EOC arrangement setup. This relationship is discovered and supported by the test results.

2. SYSTEM DESCRIPTION

To read the reaction forces of hose straps, a simulation system is built and shown in Fig. 2.

Figure 2: Simulation System

In this system, the fixed frame on the left is used to simulate one car and the moving mechanism on the right is installed to simulate the other car. One hydraulic cylinder and one air cylinder are applied to offer the power to drive the moving part at two different separation speeds to simulate the process of separation of the two coupled cars. At the bottom part of system, two aluminum channels are installed as rail tracks. The height of gladhands and other related dimensions are measured from the top surface of the channels. The end hose on the left is installed on the fixed frame and the end hose on the right is installed on the moving mechanism to simulate the structure of the EOC arrangement. The top ends of hose straps are connected to load cells through ball joints to assure the reaction forces on hose straps are always collinear with the longitudinal direction of load cells so that the data can be read accurately (Fig. 3). The positions and dimensions of all parts are designed and installed to follow AAR requirements S-107, S-154, S-163, etc. [2-4] Also, a linear encoder is installed between the fixed frame and the moving mechanism to record the distance traveled which will be used to calculate the instant speed of separation (Fig. 4).

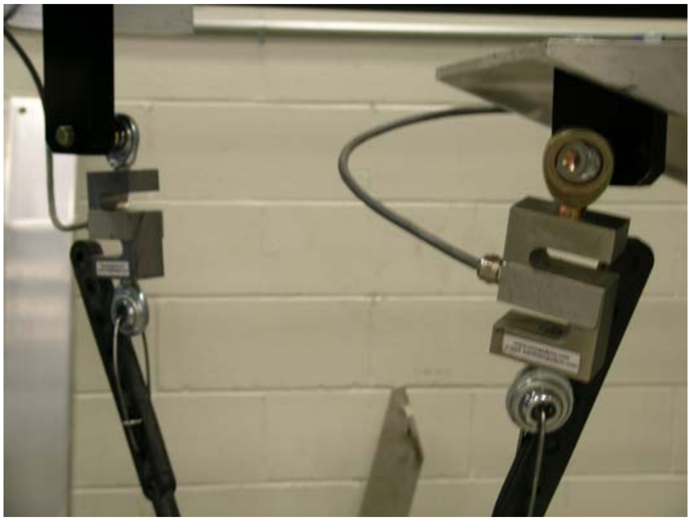

Figure 3: Load Cells with Ball Joints

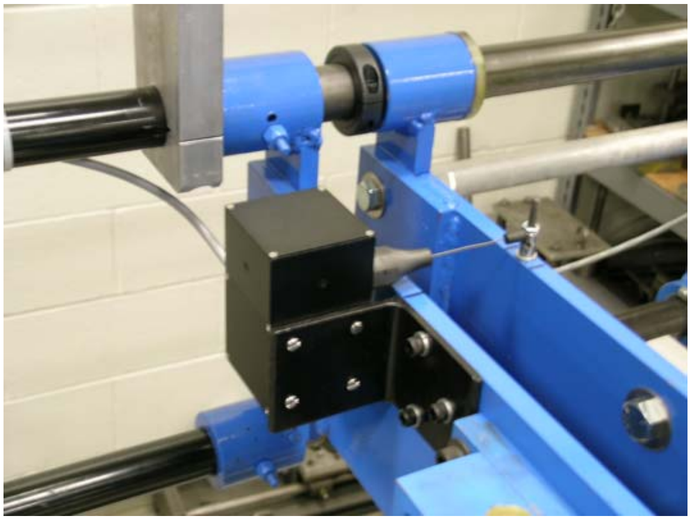

Figure 4: Linear Encoder

During the separation process, analog and digital signals generated from the load cells and the linear encoder are sent to a Data Acquisition (DAQ) system through the cables. With an internal integrated high accuracy clock, reaction forces and instant separation speed are calculated and recorded by a computer program. All records will be saved to data files for analysis. The process is shown in Fig. 5.

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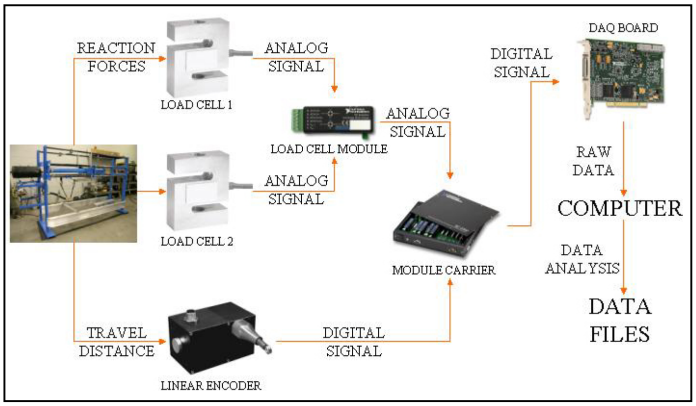

Figure 5: Data Processing and DAQ System

3. TEST SETUP AND RESULTS

3.1 TEST SETUP AND RESULTS OF DIFFERENT HOSE STRAPS FOR SAME EOC ARRANGEMENT

This section is to illustrate the reaction forces of different hose straps for the same EOC arrangement. Four most widely used hose straps are selected in the tests and shown in Fig. 6.

Figure 6: Four Most Widely Used Hose Straps

To test the reaction forces for these four different types of hose straps, dimensions and requirements of AAR Specification S-4021 arrangement [5] are followed on both sides of the simulator. The air pressure is adjusted to 90 Psi. Two separation speeds are considered and tested. They are 5-10 MPH, thereafter called "fast motion", and less than 1 MPH, thereafter called "slow motion". Test duration is 5 sec. for fast motion driven by the air cylinder and 10 sec. for slow motion driven by the hydraulic cylinder. Sampling frequency of DAQ system is set to 6000 Hz. Every setup will be tested 3 times and average values will be taken.

Test results for all brands are given in Table 1. From the listed data, it is clear that different hose straps have significant different reaction forces for the same setup. The results for the same hose strap, however, do not show noticeable difference for different separation speeds.

Brand	A	B	C	D
Reaction Force (Lb) (Slow Motion)	79.1	122.5	231.7	340.6
Reaction Force (Lb) (Fast Motion)	82.8	130.8	216.9	315.0
Separation Speed (MPH) (Slow Motion)	0.91	0.65	0.91	0.71
Separation Speed (MPH) (Fast Motion)	7.1	7.1	7.3	7.1

Table 1: Test Result of Different Hose Straps for Same EOC Arrangement

3.2 THE ANALYSIS OF TEST RESULT OF DIFFERENT HOSE STRAPS FOR SAME EOC ARRANGEMENT

This section is to investigate the reason of the difference of reaction forces of different hose straps in Table 1.

When two railcars are coupled and end hoses are pressurized, some potential energy is stored in the compressed air in the hoses. When the two cars are separated, end hoses and other parts of EOC mechanisms are pulled and stretched by the separation forces that introduce more potential energy. The energy will be released during the separation and converted to kinematic energy in the form of violent motions of end hoses and other parts. A portion of the energy will be absorbed by the elastic hose straps as described by Eq. 1:

$$E_P = \int_0^{X_{\max}} F dX \qquad (1)$$

where E_p is the potential energy absorbed by the hose straps, F is the force applied on the hose straps and X is the displacement of hose straps when the force is applied. If the displacement is within the hose straps' elasticity range, Eq. 1 can be rephrased to:

$$E_P = \int_0^{X_{\max}} F dX = \int_0^{X_{\max}} KX dX = \frac{1}{2} K X_{\max}^2 \qquad (2)$$

where K is the elasticity coefficient of hose straps. Since:

$$X_{\max} = F_{\max} / K \qquad (3)$$

the relationship between E_p, F_{max} and K can be described as:

$$E_p = \frac{F_{\max}^2}{2K} \qquad (4)$$

For same EOC arrangement, the potential energy E_p is a constant. From Eq. 4, it can be found that F^2_{max} and K have a linear relationship if E_p is a constant. So, more flexible hose straps will generate less reaction forces for the same EOC arrangement. The elasticity coefficients K of all four brands are tested by measuring the applied force and their deformation.

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Based on these data, the values are linearized using Least Square Method (LSM) except Brand D, which is a very rigid steel cable. The results are shown in Table 2 and Fig. 7.

Brand	A	B	C	D
K (Lb/in)	10.94	24.56	76.22	N/A

Table 2: Elasticity Coefficient *K* of Different Hose Straps

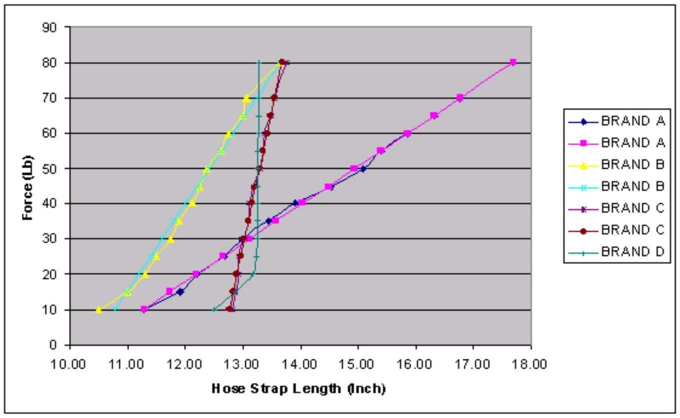

Figure 7: Elasticity Coefficients *K* of Different Hose Straps

By taking the average values of reaction forces of each brand in Table 1, the potential energy E_p of S-4021 arrangement is calculated and listed in Table 3. It can be seen that the results calculated from different hose straps are fairly close (Maximum Error 6.0%). It proves that the previous assumptions and Eq. 4 are accurate.

Brand	A	B	C
F (Lb)	80.95	126.65	224.30
K (Lb/in)	10.94	24.56	76.22
E_p (Lb-in)	299.49	326.55	330.03
Average E_p		318.69	
Error	-6.0%	2.5%	3.6%

Table 3: Potential Energy Calculation from Different Hose Straps

3.3 TEST SETUP AND RESULTS OF DIFFERENT EOC ARRANGEMENTS FOR SAME HOSE STRAP

This section is to investigate the relationship between the reaction forces of hose straps and different EOC arrangements for the same hose strap. In this section, hose strap brand A is selected to apply on both fixed and moving sides for all tests. Five most widely used arrangements for cushion cars are selected and installed on the moving side for simulation. They are S-4021, S-428, S-4003, Former S-4003 and S-427 [5-9]. Detail dimensions and layouts can be found in corresponding reference documents. S-4021 arrangement is installed on the fixed side for all tests. Their dimensional and non-dimensional requirements are followed during installation. Some photos of the setups are shown in Fig. 8. And their test results are listed in Table 4.

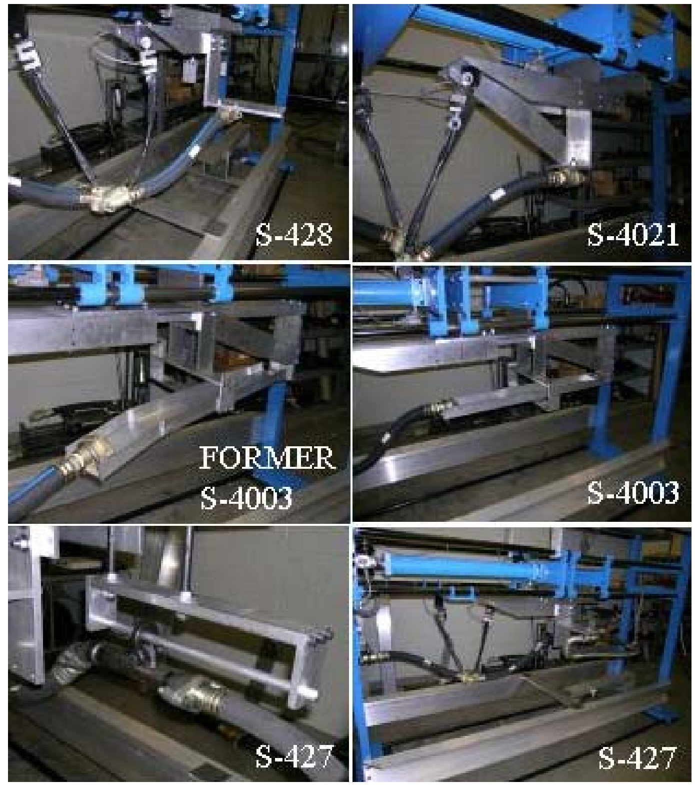

Figure 8: Setup for Different EOC Arrangements

EOC Arrangement	S-428	S-4021	S-4003	Former S-4003	S-427
Reaction Force (Lb) (Slow)	80.3	79.1	77.5	130.6	204.0
Reaction Force (Lb) (Fast)	73.7	82.8	83.7	116.5	181.4
Separation Speed (MPH) (Slow)	0.91	0.91	0.73	0.91	0.73
Separation Speed (MPH) (Fast)	6.4	7.1	6.2	6.5	6.5

Table 4: Test Result for Different EOC Arrangement for Same Hose Straps

From Table 4, it can be found again that the reaction forces for fast motions and slow motions do not show significant difference. The forces for different EOC arrangements, however, have a large variation. S-428, S-4021 and S-4003 have almost the same reaction forces. Their values are considerably smaller compared with the other two arrangements. Especially, the values of S-427 are much higher than any of other arrangements. It is believed that the difference is because of the dynamic motion of the unfixed parts in the mechanism during the uncoupling. The more unfixed parts in the arrangement, the higher reaction force of hose strap it will generate. In another word, more fixed

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arrangement gives less reaction force. Because the same brand hose strap is applied during the tests (*K* is constant), according to Eq. 4, the difference of the potential energy of these arrangements will be even larger because of the term F^2_{max}. The reaction forces on the hose straps, the rigidity of the arrangement and its potential energy are highly related to each other. So the reaction forces can indicate not only the status of the hose straps, but also the potential energy of the EOC arrangements installed on two connected cars. Equation 4 is applied again, as well as the data in Table 2 and 4, to calculate the potential energy of these EOC arrangements. The calculation result is shown in Fig. 9. Hose brand B and C for S-427 arrangement are also tested and their potential energy are calculated. The results are also shown in Fig.9. From the chart, it is clear that the potential energy for different EOC arrangements has large differences. But it is consistent for hose straps with different elasticity for the same arrangement.

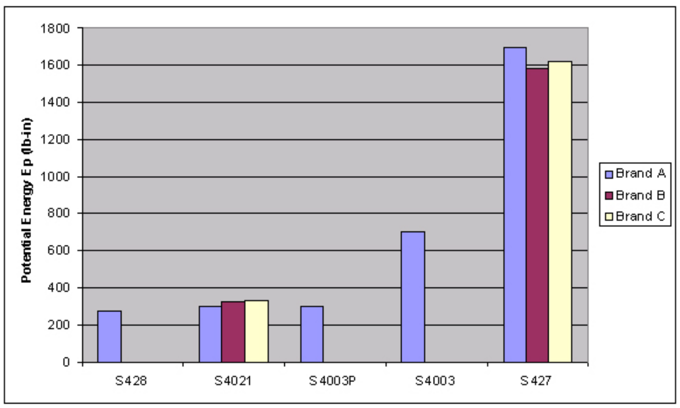

Figure 9: Potential Energy E_p of Different EOC Arrangements

4. DISCUSSIONS AND CONCLUSIONS

From the research in this paper, it is found that the load on hose straps during separation is decided by the EOC arrangement types on the two connected cars. More fixed arrangements contain less potential energy and so give less reaction forces on the hose straps. So the reaction force can be used to indicate not only the status of the hose straps, but also the potential energy of the EOC arrangements installed on two connected cars during end hose uncoupling. In this regard, S-428, S-4021 and S-4003 have more defined movements during end hose uncoupling than former S-4003 and S-427. Therefore, S-428, S-4021 and S-4003 are recommended to be followed for the installation of EOC arrangements rather than former S-4003 and S-427. Also, the elasticity of the hose straps is another key factor contributing to the reaction force. More flexible hose straps generate less reaction forces for the same EOC arrangement setup.

5. ACKNOWLEDGMENTS

This research is supported by the Association of American Railroads.

6. REFERENCES

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