A SIMPLE PERFORMANCE TEST FOR EVALUATING END HOSE SUPPORT STRAPS FOR RAILROAD FREIGHT CARS

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ABSTRACT

A study has been performed to simulate the impact experienced on hose support straps during end hose separations on railroad freight cars. Analysis and comparison of test results of different hose straps show that the elasticity of the hose strap determines the reaction force generated by a certain impact. Under the same impact, a stiffer hose strap sustains a larger reaction force. Unlike the current requirement of AAR S-4006, the relation between the elasticity of the hose strap and its reaction force is not linear. Additionally, for a certain impact, the reaction force of the hose strap is only related to its mechanical properties, which reflects the real application. This study concludes that a simple drop test is adequate as an alternative method for performance testing of hose straps.

INTRODUCTION

Hose straps, which are used to support railroad freight cars' end hose assemblies, are usually connected between the gladhands of end hose assemblies and the bottom of the car couplers. As AAR Specification S-4006 [1] requires, hose straps are designed to be length adjustable so that they can be properly installed to meet the requirements of different End-of-Car (EOC) arrangements and different coupler heights.

The AAR updated S-4006 in 2003 [2] and required that a qualified hose strap must be able to lift 300 pounds with a maximum stretch of five inches. It also required that the stretch be less than one inch for a 25-pound weight [2], since usually the force applied to the hose strap is less than 25 pounds under normal train operations. However, when the end hose assembly is separated while pressurized, a force generated by the jet stream of air escaping from the gladhands will produce an impact on the hose straps. The reaction force may cause failures of the hose straps. Failed hose straps may cause problems such as hitting angle cocks, elbows, features on the car, etc.

This situation had been investigated by Strato, Inc. requested and sponsored by the AAR in 2005. Five different EOC arrangements and four different hose straps were studied and tested by L Hua et al [3]. The research found that in addition to the EOC arrangement types, the elasticity of the hose strap was another key factor contributing to the reaction force. More flexible hose straps generate less reaction forces for the same EOC arrangement. The research results were considered to be a positive input that led to a revision of S-4006 and a new revision of this specification was released in 2008 which took into account the elasticity of hose straps. As Figure 1 shows, the new specification raised the requirement for a rigid strap to 600 pounds while flexible straps are required to support a minimum of 300 pounds [1].

Based on the research conducted by L Hua et al, a new hose trap was designed by Strato, Inc. and approved by the AAR in 2009. The elastic end hose support strap design took a unique approach to improve strength without significantly changing size, weight or other physical properties. A technical paper discussing this design was presented at the ASME Joint Rail Conference in 2010[4].

This paper presents a study of a simple drop test for hose straps. In this study, three types of end hose support straps with different elasticity were tested. The test results showed that, under the same impact, a stiffer hose strap sustained a larger reaction force. This finding is the same as that found in the hose separation simulation research conducted by L Hua et al in 2006 [3], meaning that a simple drop test can be used to simulate the impact experienced on hose support straps during end hose separations. Since, unlike the current requirement of AAR S-4006-2008 [1], the relation between the elasticity of the hose strap and its reaction force is not linear, the drop test may be considered as an alternative method for performance testing of hose support straps.

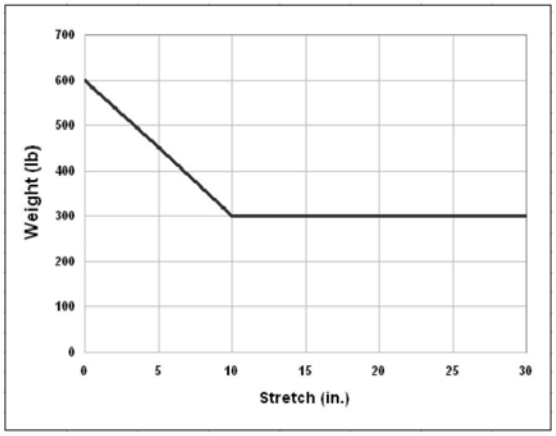

Figure 1: Minimal Tensile Strength of Hose Strap. Per AAR S-4006-2008 [1]

DROP TEST

Setup

A sample drop test setup is shown as Figure 2 (A, B, C). A hose support strap is hung vertically, and a mass with a certain weight is attached to the lower end of the hose support strap via a stiff chain or cable, and then the weight is raised to a certain height and released it to fall free. The dropping weight creates kinematic energy and generates an impact as the hose support strap is stretched to absorb the energy. On the top end of the hose support strap, a load cell measures the reaction force of the strap during this impact.

Test Results

Drop tests were performed on a steel chain and three different types of hose straps with different stiffnesses. Figure 3 shows the test results for a 30-pound weight dropped from a 3-foot height. The impact energy created by the dropping weight was 1080 lb·in.

From Figure 3, the test results show that a stiffer hose strap sustains a greater reaction force under the same impact. For the rigid steel chain, the reaction force was more than 1,500 pounds.

Other experiments have been performed to simulate end hose separations under different volumes of compressed air (shown in Figure 4) [4]. Three tanks with different volumes were used to simulate different numbers of cars in front of, or behind the separation. The reaction force of the rubber hose strap was fairly constant no matter what the tank size was. That


2.A

2.B

2.C

Figure 2: Sample Setup of Drop Test

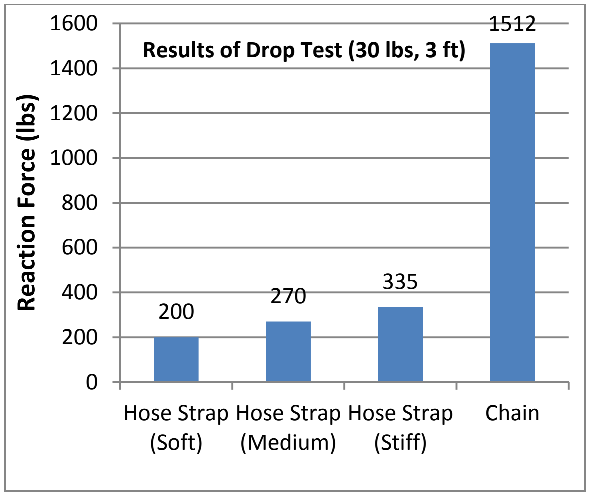

Figure 3: Maximal Reaction Force Created by 1080 lb·in Impact Energy

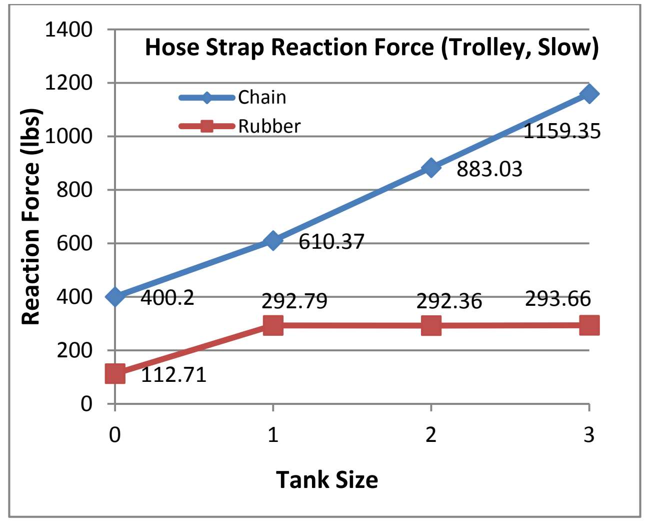

Figure 4: Reaction Force Created by Hose Separation under Different Air Volumes.

made it easy to simulate the separation impact applied to the hose strap by adjusting the weight and drop distance.

The Science Behind the Test

As shown in Figure 5, when a mass weight, W, makes a free fall through a distance, h, and stretches the strap, the total energy generated is

$$E_v = W(h + x) \quad (1)$$

where x is the stretch distance. The energy absorbed by the hose strap is

$$E_p = \int_0^x F dx \quad (2)$$

where F is the reaction force. Assume the stretch distance is within the hose strap's elasticity range, Eq. (2) can be integrated as

$$E_p = \int_0^x F dx = \int_0^x kx dx = \frac{1}{2}kx^2 \quad (3)$$

where k is the elasticity coefficient of the hose strap. The law of energy conversation gives

$$E_p = E_v \quad (4)$$

Substitute Eq. (1) and Eq. (3) into Eq. (4), giving

$$\frac{1}{2}kx^2 = W(h + x) \quad (5)$$

Since

$$F_m = kx \Rightarrow x = \frac{F_m}{k} \quad (6)$$

where F_m is the maximal reaction force of the hose strap, substituting into Eq. (5), we solve

$$F_m = W + \sqrt{W^2 + 2Wkh} \quad (7)$$

From Eq. (7) it can be seen that the maximum reaction force of the hose strap in the drop test is only related to the mass weight, W, free fall distance, h, and its elastic coefficient, k. For a given impact (W, h), the stiffness of the hose strap (k) is the only factor to determine reaction force.

The actual elasticity coefficient of the medium soft hose strap shown in Figure 3 is approximately 28 lb/inch [4]. From Eq. (7), the maximum reaction force applied on the hose support strap is

$$F_m = 30 + \sqrt{30^2 + 2 \times 30 \times 28 \times 36} = 277.7\ lbs \quad (8)$$

Figure 6 shows the comparison of the maximum reaction forces of the drop test and its theoretical values under different impacts. The theoretical predictions match the test results very well.

The theoretical relationship between the maximum reaction force of the medium soft hose strap and its elasticity coefficient under the same impact is shown in Figure 7. Unlike the current AAR specification S-4006-2008 [1] requirement, shown in

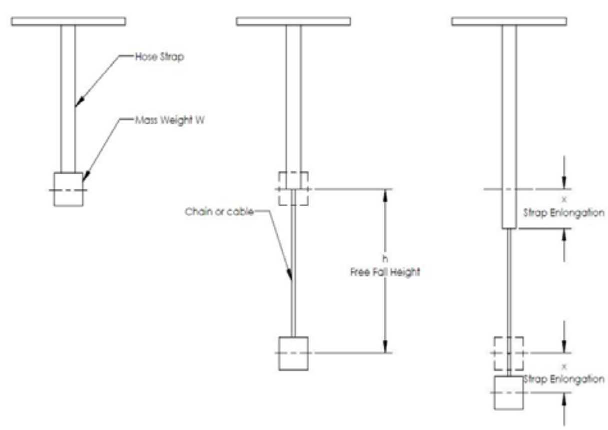

Figure 5: Scheme of Drop Test

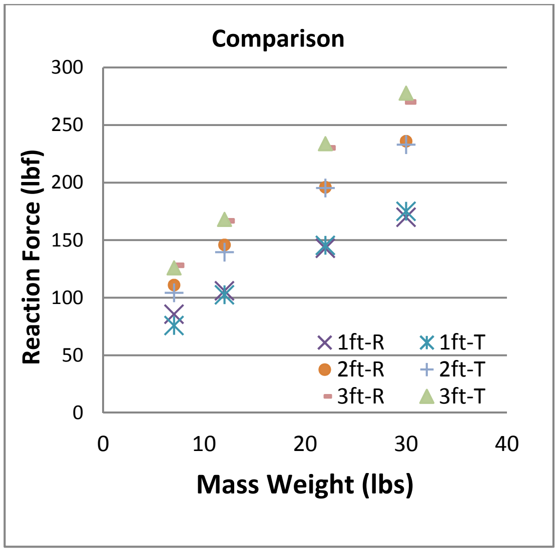

Figure 6: Comparison of the Maximum Reaction Forces of Drop Test and Its Theoretical Values under Different Impacts.

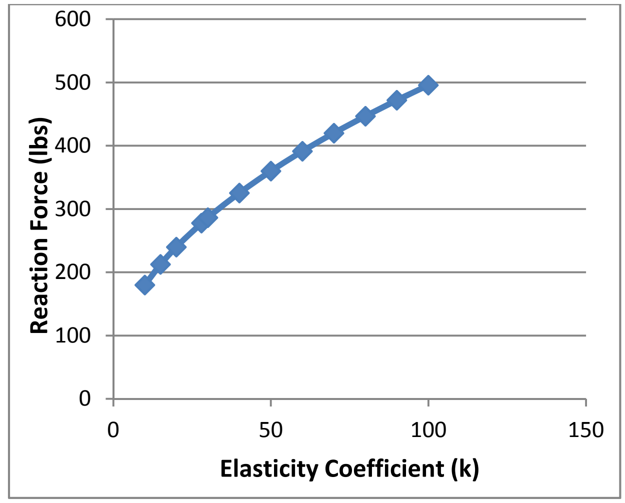

Figure 7: Maximum Reaction Force vs. Elasticity Coefficient under Same Impact (30lbs-3ft)

Figure 1, the relation is not linear.

CONCLUSION

In this study of a simple drop test, it was found that the stiffness of the hose support strap is a key factor for the reaction force created by the impact on the strap. Under the same impact, a stiffer hose strap sustains a larger reaction force. Although the current requirement of S-4006 takes into account the effect of the elasticity of the hose strap, the relation between the elasticity of the hose strap and its reaction force is considered linear, which doesn't reflect real applications. The impact generated by the end hose separation is fairly constant for a given EOC arrangement, and, for a certain impact, the reaction force of the hose strap is only related to its elasticity coefficient. These facts make the drop test adequate as an alternative method for the maximum load testing of hose straps.

The suggested test procedure and criterion is as follows: Hang the hose strap vertically, attach a 30-pound weight to the lower end of the hose strap, lift the weight and release it in a free fall. The length of the drop must be equal to or larger than 3 feet. The passing criteria can be set as 10 consecutive drops without the strap being cracked or damaged at each level of the adjusting increment, i.e., if a strap has multiple holes for adjustment, then the test must be repeated for each hole.

REFERENCES

[1] AAR Manual of Standards and Recommended practices, Section E Revision to the Standard S-4006, HOSE SUPPORTS-PERFORMANCE TESTING, Adopted: 1990, Revised: 2002, 2003, 2008. Section E [S-4006], pages 1- 4

[2] AAR Manual of Standards and Recommended practices, Section E, Standard S-4006, Adopted: 1990, Revised: 2002, 2003. Section E [S-4006], pages 557-558

[3] L. Hua, L. Hixon and G. Cobden of Strato, Inc.: Hose Strap Reaction Forces In Railroad Freight Cars, 2006 ASME Joint Rail Conference, April 4-6, 2006, Atlanta, Georgia, USA.

[4] X. Zhang, L. Hua of Strato, Inc.: Improved Design of End Hose Support for Freight Cars, 2010 ASME Joint Rail Conference, April 27-29, 2010, Urbana, IL, USA.