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Analysis of End Hose Elasticity

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ABSTRACT

This paper investigates the relationship between end hose elasticity and the potential amount of energy coupled railroad cars can absorb in charged condition before pull a part force separation occurs.

One of the most significant issues with the existing end hose is that it will uncouple after enough force is applied causing a loss of pressure in the brake system. Our initiative to evolve the end hose into a more durable wire braided rubber material from the standard hand wrapped construction has decreased this potential for separation in the field.

Simulation testing using end hoses from three manufacturers is studied and compared. Charged hose assemblies were coupled and pulled apart. The results showed one end hose stretched nearly double the distance of the other hoses. Analysis of the resulting data will show that a more elastic hose will allow a train brake system to absorb more energy thus reducing the opportunity for a disconnect while in service.

INTRODUCTION

The railroad industry end hose is the facilitating component in the train air brake system. The end hose is positioned under the coupler at each end of the train car. When end hoses are coupled and pressurized, they circulate compressed air between train cars that maintains the uniform distribution of air braking throughout the train. Attached to the end of the hose is a gladhand with an installed rubber gasket that couples the hoses between connecting cars. The air pressure seal is created from the gaskets of each end hose's gladhand being coupled together in opposing positions as the hoses hang beneath the car coupler.

The ability to apply brakes to multiple cars allows for longer more reliable train arrangements but also comes with potential risks. Identifying these risks led us to focus on the force created from the train cars as they travel at high speed along the tracks. These violent forces can cause the hose gladhands to uncouple, releasing the air pressure in the brake system which can lead to train delays or even derailment. Our goal became the prevention of pull-apart force separation, so we explored the features of the end hose that could be improved.

Investigating the construction of the end hose, the Association of American Railroads (AAR) regulations state it is to be a suitable chloroprene material with polyester fabric reinforcement. The traditional end hose is manufactured by a series of hand wrapped layers of plies bonded together between the outer cover and inner tube. This method must be a well-controlled process as insufficient bonding can cause layer separation and reduce the strength of the hose. Other concerns with the wrapped hose are that during pressurization, it can twist up to 35 degrees and expand nearly ½” causing multiple points of undesirable stress. Based on our research, we took the initiative to evolve the standard wrapped hose to a braided wire hose. The braided hose manufacturing process not only eliminates the potential risk of bonding ply layers but will also demonstrate significantly less twisting, expanding, and stress on the hose while pressurized.

The current AAR M-601 specification states a wrapped air brake hose must withstand physical requirements and tests that include tension, elongation, friction, cold testing and others. The braided hose consistently exceeds all the testing benchmarks displaying its strength of construction and quality of connection with its fittings. The fact that the current M-601 specification does not identify a standard for hose elasticity is what sparked the idea to test wrapped and braided hoses.

Figure 1 illustrates an end hose arrangement between train cars. The end hoses sit exposed at five inches above the rail which can leave them vulnerable to the elements and the forces created from the train cars moving back and forth during operation. The gladhands couple the end hoses and the coupler locks the train cars together.

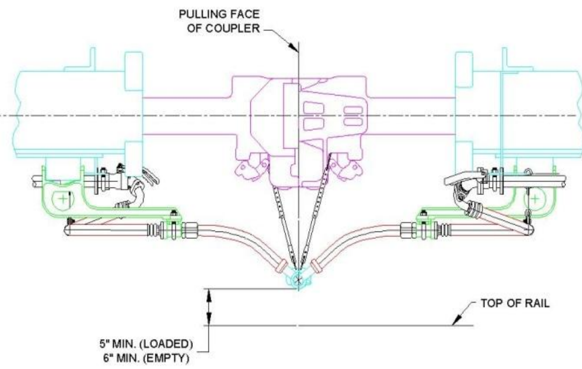

Figure 1. End Hose Arrangement

The objective of this paper is to investigate the relationship between the elasticity of different end hose constructions and the forces generated from the trains that rely on them.

TEST DESIGN

Our theory of the relationship between the energy created in a system and an objects ability to absorb the force generated began with the equation:

$$E = \int_0^X F(x)dX \quad (1)$$

E is the potential energy absorbed by the end hose, *F* is the force of the train cars shifting while in service, and X is the displacement of the end hose when this force is applied. Implementing an elasticity coefficient *K*, the equation can be manipulated to show a linear relationship between force and elasticity.

If we consider *F(x)* linear with the displacement *x*, then:

$$F(x) = Kx \quad (2)$$

Where *K* is the elasticity coefficient of the hose, which is a constant. From Eq. (1) and (2), we know:

$$E = \frac{1}{2}KX^2 = \frac{1}{2}FX \qquad (3)$$

$$\text{and } E = F^2/2K \qquad (4)$$

Eq. (3) explained that, to absorb certain potential energy *E* generated by the railcar movement, the longer the hose can be extended, the lower the reaction force on the hose will be. A similar conclusion can be drawn from Eq. (4). "Softer" hoses will create less force on the hose which will contribute to longer hose life and more reliable End-Of-Car (EOC) arrangement.

To test our theory that a more elastic end hose will absorb more energy and force, a hydraulic simulation apparatus was developed and is displayed in figures 2 and 3. The purpose of the tension experiment was to determine if there was a significant difference in elasticity between the braided end hose and hand-wrapped design. The test was performed twice under 2 different sets of conditions in accordance with existing AAR specifications for end hose testing.

Figure 2. End Hose Hydraulic Test Fixture.

In this arrangement, the bottom end of the structure is fixed, while the top moves upward with the help of a hydraulic piston. A sealed pipe with fixed gladhand is attached to the piston and coupled with the test end hose. The test hose is then screwed into frame mount and pressurized to 90 psi to simulate charged condition on a train car. For this experiment, a pin was placed around the gaskets of the coupled gladhands to prevent them from compressing and causing a pull a part force before reaching the desired test force.

In creating a sample pool, three end hose assemblies were selected from three manufacturer (the Braided Hose, Hose A, and B). Each hose assembly was fitted with an F-type gladhand and pressurized for the entire testing. After installation and pressurization, the initial length was recorded using a fixed needle and measuring tape. Using the hydraulic cylinder and an integrated load cell, the hose was stretched at intervals of 100lbs, to a maximum weight of 800lbs. The length of hose at each interval was recorded. The maximum weight of 800lbs was chosen because the braided hose combined with a double wide gasket can reach almost 700lbs before pull a part force separation. Hoses A and B do not provide a double wide gasket with their hose assembly so will not be exposed to this amount of force in field applications.

Figure 3. Hydraulic Test Fixture Closer look

After completing the tension test on all nine hose samples, they were placed into a -50 degrees Celsius freezer overnight. Once the hoses were chilled overnight, the tension test was repeated the following day. The hose was taken from the freezer, and placed onto the H-frame. The temperature was recorded along with the initial length. The hose was loaded, and the length was recorded at intervals of 100 lbs up to 800lbs again. Once the test was completed, the final temperature of the hose was measured and recorded using a Milwaukee laser temperature gun thermometer.

TEST RESULT AND ANALYSIS

The results below represent the average values for three hose types comparing elongation to increasing tensile force. The first graph shows the results of the testing of the original 9 hoses at room temperature. Wrapped hoses A and B provide similar performance while the braided hose shows a higher amount of elasticity. The dotted lines mark at what force typically a pull a part separation occurs. Standard gladhands and gaskets can separate at 300lbs while the double wide gasket can reach 700lbs before separation. As you can see, the braided hose stretched over 6 inches while hose A and B stayed under 3 inches. Combined with a double wide gasket, the braided hose will provide a train car system with nearly 6 inches of stretch before separating. The wrapped hoses do not provide a double wide gasket so their elasticity values would expand only 2 inches before pull a part separation.

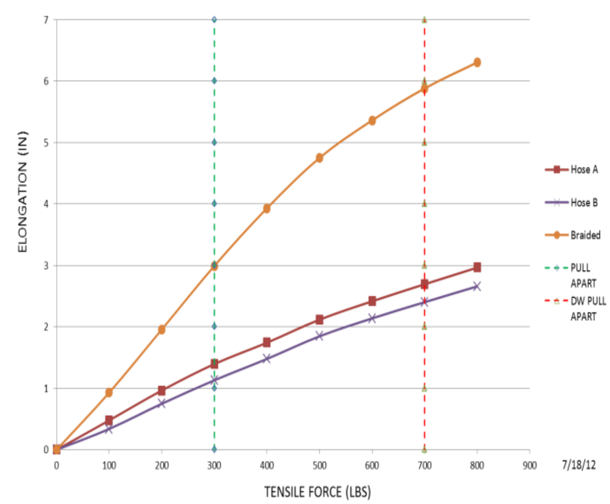

Figure 3: Room Temperature Testing Results

The next graph shows the results of hoses tested after being left overnight in a -50 degrees Celsius freezer. The hoses defrosted to approximately -20 degrees Celsius while being set up in the test fixture. The results are comparable to the room temperature testing with the expected overall drop in elongation from the hoses still being stiff. The braided hose stretched more than double the other hoses and providing a train car with roughly 4.5 inches of stretch before separation when using a double wide gasket.

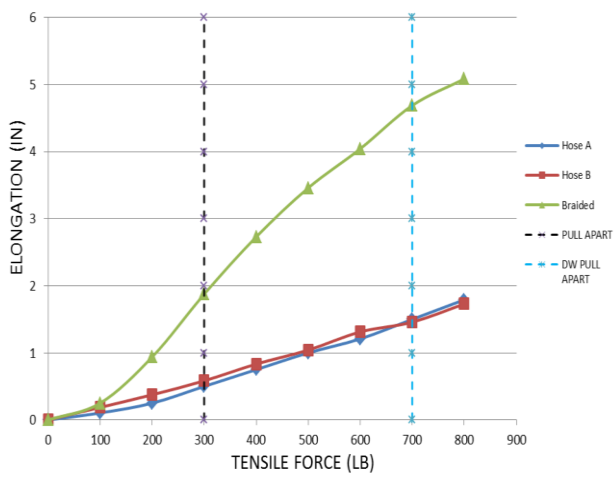

Figure 4: Cold Temperature Testing Results

The results of this study show the wire braided end hose has an elongation value that doubles the standard wrapped hose. In regards to its application, the wire braided hose can provide a train car with double the force absorption than a hand wrapped hose. This greatly diminishes the opportunity for an unwanted end hose separation while in service. Coupling two double wide braided hoses together will double the absorption ability again. Lastly, to see the hose perform almost identically when exposed to cold temperature adds merit to its survivability in the field.

CONCLUSION

From the research in this paper, it is clear that the machine braided hose provides benefits beyond our original expectations. Not only does it exceed AAR performance requirements but it provides an added elasticity element that helps reduce a significant brake failure mode on train cars. These benefits are maximized in combination with the double wide gasket.

In closing, the braided end hose allows for double the absorption of force generated by train car compared to standard hand wrapped end hoses. Even in cold weather conditions the construction of the braided hose maintains its integrity. This leads to a longer life of the hose and increased proficiency of the trains that use them.

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