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Strength Test for Pre-ROPS Tractor Axle Housings

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SUMMARY. Tractor rollovers are a major cause of farm-related deaths. A rollover protective structure (ROPS) dramatically reduces fatalities during tractor overturns. However, pre-ROPS (before ROPS were available) tractor axle housings were not designed to support the ROPS. This paper presents the strength test investigating pre-ROPS tractor axle housings, evaluating their suitability for accepting reliable ROPS. The factor of safety between longitudinal yield torque of the axle housing and the maximum torque subjected during ASAE S519 longitudinal static test is determined. The relationship between twisting angle and torque of the axle housing is established. The results show that a particular pre-ROPS axle housing can successfully support the ROPS with a safety factor of about two. The test was conducted in accordance to ASAE Standard S519 on a single axle housing. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: getinfo@haworth.com]*

KEYWORDS. Rollover protective structure (ROPS), pre-ROPS tractor, strength test, tractor safety, axle housing

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INTRODUCTION

Tractor rollovers are a major cause of agricultural worker deaths. One out of five agricultural work fatalities is caused by a tractor overturn.[1] A rollover protective structure (ROPS) is a structural frame designed for protection of the operator in the event of a vehicle overturn. Most new tractors since 1986 are manufactured with ROPS, but many tractors produced prior to 1970 did not have ROPS as an option (pre-ROPS tractors) and their axle housings were not designed to structurally support ROPS during overturns.

Retrofit ROPS are available for some pre-ROPS tractors.[2] However, pre-ROPS tractor axle housings which were not designed to support ROPS may be subject to loading beyond the design range when tractors turn over. It is imperative that the ROPS is properly designed and manufactured, and the axle housing successfully supports ROPS.

ASAE (American Society of Agricultural Engineers) S519 Standard defines the test procedure and performance criteria for ROPS to minimize the frequency and severity of tractor operator injuries during a wheeled tractor overturn.[3] However, the Standard focuses mainly on the performance of the ROPS itself, not on the ROPS/axle housing combination; it does not take into account the ultimate strength of the tractor axle housing. Therefore, there is a concern that a ROPS/axle housing combination passing the static test may not be representative of the total population of ROPS/axle housing performance. The structural integrity of pre-ROPS tractor axle housings to support ROPS safely is questionable.

The tractor rear rollover is considered more critical than the side rollover in terms of axle housing failures. Failures during a rear rollover are more dangerous to the tractor operator compared to a side rollover as the axle housing may rotate with respect to the axle crushing the operator. Structural support by the axle may result in some operator protection if it fails during a side rollover.

The focus of this study is to present the longitudinal strength test investigating popular pre-ROPS tractor axle housings to determine the safety factor between longitudinal yield torque of the axle housing and the maximum torque subjected during ASAE S519 longitudinal static test. This safety factor indicates how well the pre-ROPS tractor axle housings can successfully support ROPS.

METHOD

The axle housing strength test was similar to the longitudinal static test in ASAE S519 and the same testing apparatus was used. The apparatus measured both the loading force and displacement during testing. One side of the pre-ROPS tractor axle housing was mounted to the test apparatus to prevent movement of the housing relative to the testing frame. An I-beam (8 inch × 31 lb/ft) was attached to the axle housing using a typical ROPS mounting technique, and the loading force was applied at the point two meters above the housing using a hydraulic cylinder. A data logger was utilized to collect force and I-beam displacement measurement at one second intervals.

The test was conducted by pushing the I-beam to twist the axle housing until it failed or the cylinder was out of range. The displacement of the I-beam increased linearly with time during testing.

RESULTS

The twisting angle of the axle housing was calculated from the dimension of the testing apparatus. Meanwhile, the twisting torque of the axle housing was calculated in terms of the loading force and the distance between loading point and the axle housing. For instance, when the loading force was 13,450 Newtons, the twisting torque was 26,900 Newton-meters.

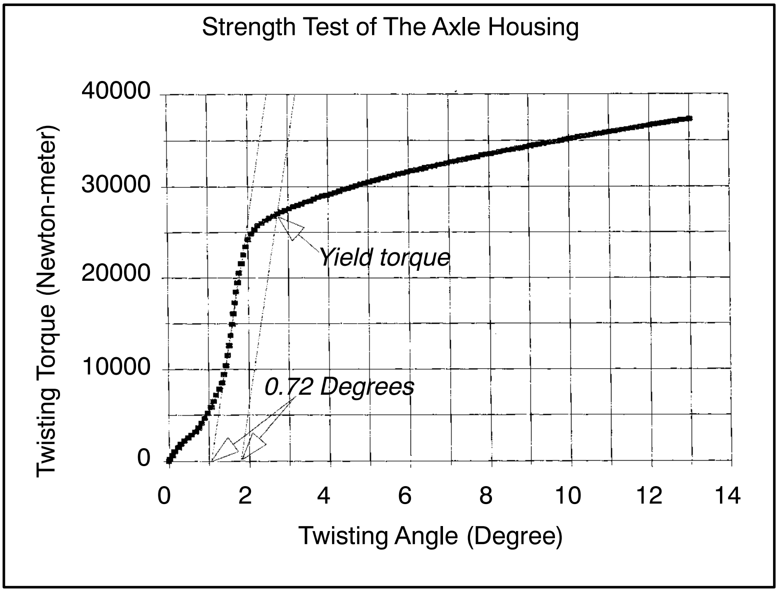
Based on the twisting angle and torque of the axle housing, the relationship between them was established (Figure 1). The curve was initially linear but deviates from linearity as the torque increased. It showed that when the twisting torque was less than 23,000 Newton-meters, the relationship between twisting angle and torque was approximately linear with a steep slope. This was referred to as the elastic deformation stage. When the torque reached 27,000 Newton-meters, the slope of the curve became flat where large deformation was obtained with relatively slight torque increases. This was referred to as the plastic deformation stage.

The axle housing went from the elastic to plastic stage (or was partly plastic) when the twisting torque was between 23,000 and 27,000 Newton-meters. The cylinder was out of range when the axle housing was twisted to 13 degrees. The beginning of the curve showed some adjustment of the system when the initial load was applied. This part was small and negligible.

The axle housing is expected to work properly in the elastic deformation stage, and the operator is safe as long as the axle housing does not go into the plastic deformation stage. However, although the axle housing is not fractured during the plastic deformation period, the large twist of the axle housing in this phase may cause the ROPS to intrude significantly into the clearance zone, resulting in operator injury.

The twisting torque where the axle housing yields appreciably with

FIGURE 1. Laboratory Test Results



little change in torque is defined as the yield torque of the axle housing. In engineering practice, the 0.2% proof torque is used to estimate the yield torque.[4] A line is constructed parallel and 0.72 degrees right to the elastic loading line, which 0.72 degrees is 0.2% of circularity, 360 degrees. The intersection of this line and the angle-torque curve is the point where the yield torque is defined (Figure 1). In this case, the yield torque is 26,900 Newton-meters.

In the ASAE S519 static longitudinal test, the ROPS/axle housing combination was tested under similar conditions.[2] In the static test, the deflection was mainly caused by ROPS and the plastic deformation of the axle housing was not found.[2] The maximum torque of the entire axle housing subjected to the ASAE S519 is 27,000 Newton-meters.[2] Since the entire axle housing was tested, the maximum torque of one side of the housing is estimated as half that for the entire housing which is 13,500 Newton-meters.

The safety factor between longitudinal yield torque of the axle housing and maximum torque subjected during ASAE standard longitudinal static test is determined as:

$$\textit{Safety Factor} = \frac{\textit{Yield Torque}}{\textit{Maximum Torque Applied During ASAE S519 Static Test}}$$

$$= \frac{26900}{13500} = 1.99$$

The test results indicate that this particular axle housing has a quite large safety margin and can successfully support the ROPS.

DISCUSSION

In this investigation, one axle housing was tested and the safety factor 1.99 was determined.

Further study is needed to repeat testing several similar axle housings to determine the confidence interval of the safety factor. The safety factors of other common pre-ROPS tractor axle housings should also be determined.

The axle housing tested appeared to have an adequate safety factor to support ROPS. However, the axle housing strength should be an important consideration when designing ROPS for pre-ROPS tractors.

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