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NEW TECHNOLOGIES FOR MILITARY TRACK BUSHING ACCELERATED TESTING AND EVALUATION

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ABSTRACT

This paper identifies the failure modes of military track bushings during lab testing and looks at correlation of lab tests failure modes with those found in field testing failures. In an effort to understand and duplicate the failures seen in the field, a track shoe was modified to measure the displacement (magnitude and direction) of the bushing pin relative to the inside diameter of the track shoe bore. Utilizing Hall Effect Technology and a small data acquisition system, test course data was recorded and analyzed. A specially designed bushing test machine, capable of testing the entire track pitch, was also designed and built in order to duplicate the field failure in a laboratory environment.

INTRODUCTION

The failure mechanism of most military track is due to the deterioration of the bushings. Although the ground pads normally fail first, they are a field replaceable item. Bushings on the other hand are not field replaceable and the entire track needs to be returned to the depot for rebuild if applicable. Given this fact, the importance of obtaining a quality bushing is paramount. This work compares previous lab test failure modes in different bushing test machines with field failure modes and looks at the first measurements ever taken of bushing deflections inside a tracked vehicle while performing the Training and Doctrine Command (TRADOC) Operational Mode (Opmode) testing at Yuma Proving Ground in Yuma, Arizona.

BACKGROUND

For decades the US Army's method to determine a quality bushing has been a test specified in MIL-DTL-11891. This test is required for all track systems ***except*** for the M1 Abrams which requires a field test on an M1 during the hot months at Yuma Proving Ground. Although not required for the M1 test qualification, most M1 compounds are also tested in the laboratory before they are considered for a field test. The MIL-DTL-11891 Test, designed by Tank Automotive Research, Development and Engineering Center (TARDEC), requires T130 long bushings to be tested with whatever compound a manufacturer is trying to get qualified. The test consists of a simultaneous radial deflection of 0 – 5200 lbs (minimum) at 64 ± 1 cpm with a torsional deflection of +15° to -15° at 256 ± 4cpm (Approx. 4.2 Hz) at 75°F ambient temperature. The 1 to 4 ratio is based on the 1 major radial tensile load the track experiences as it enters the sprocket and the 4 torsional inputs are based on the 4 major angle changes the track experiences per revolution (sprocket, idler, first and last road wheel). To become a qualified compound, the 8 lowest of the 9 samples tested must have an average life of 130,000 radial cycles and none of the 9 samples can have less than 110,000 radial cycles before failure. Failure is defined by reaching a radial deflection of .145 inches[1].

BUSHING COMPARISONS

The T130 Bushing, used for compound qualification, is the bushing originally used in the T130 Track system on the M113A3 Armored Personnel Carrier (APC). It is single pin, drive-on-shoe designed track with a 3/2 lattice as shown in Figure 1[2]. This track system has been replaced by the T150 track system on the M113A3 APC, which is a double pin, drive-on-end connector designed track. The T150 shoe is shown in Figure 2.

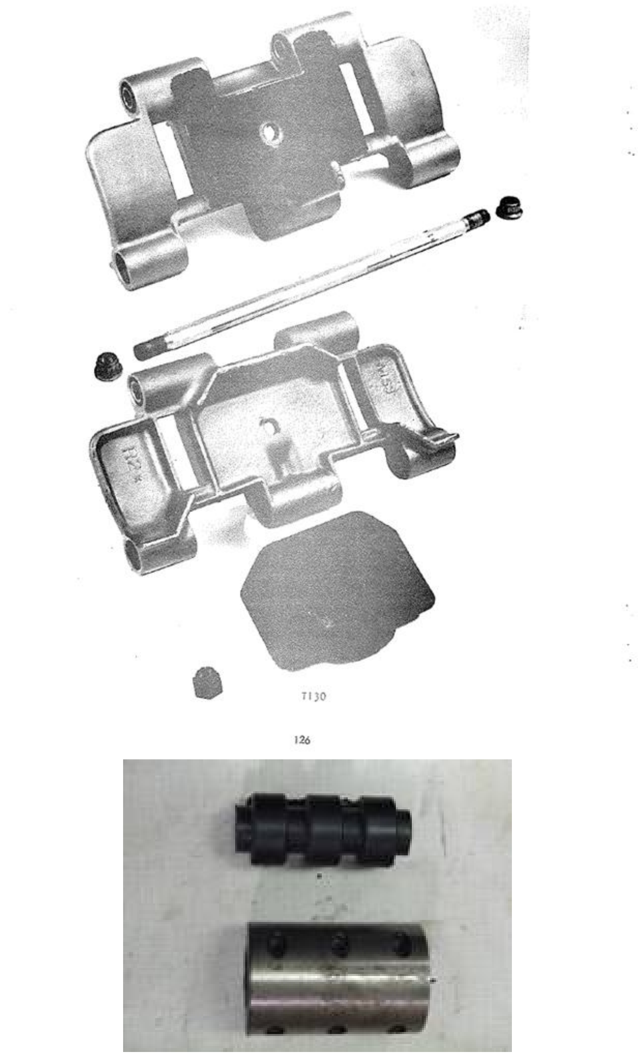

Figure 1: T130 Track (above) and T130 Track Bushing and MIL-DTL-11891 Test Bore (below).

Single Versus Double Pin Track Loads

Single and double pin track bushings experience a different type of load case as they rotate around the drive system due to many factors. One of the primary factors is the location of the drive sprocket load. On most single pin track systems the drive load is applied into the track shoe itself. On most double pin track systems the drive load is applied on the end connectors. Another factor is the single pin shoes have one half or less of the elastomer volume to carry the loads as a double pin so the stress on the bushing is greater.

Figure 2: T150 Track.

The M2/3 Bradley is the last major US Army vehicle to convert from a single pin (T157I) to a double pin (T161) track system. The life has more than doubled with the new track. The type of track failures has also changed with the introduction of the T161 double pin system. Pin migration failures in the T157I track are non-existent in the double pin track. Also since the track is reversible, the bushings see different load cases. Finally, the double pin track bushings experience a pin bending load not seen in a single pin design.

Single Pin Track Bushing Test Machine Results

As mentioned previously, the MIL-DTL-11891 is based on the bushing of a single pin track system. Figure 3 shows the test machines used to test to this specification and the insert shows the test bore (see Figure 1) in the machine. Figure 4 shows the type of failure or failure mode of the T130 bushings on this test machine. The image shows an elastomer failure and not a bonding failure. Bonding failures are also experienced by this test however that type of failure will not be addressed in this paper since it is a manufacturing/quality control issue.

As can be seen in Figure 4, the elastomer in this bushing has failed in a relatively small area in a purely radial direction. The side opposite the radial load application looks almost new as can be seen in the view shown in the top of the figure.

Figure 3: MIL-DTL-11891 Bushing Test Machine.

Figure 4: MIL-DTL-11891 T130 Bushing Failure

Double Pin Track Bushing Field Test Results

In order to monitor and document the progression and failure mode of a double pin track, T158LL shoes were dissected at mileage intervals during a M1 Abrams Track test. Figure 5 shows the progression of bushing failures in 250 mile increments. As can be seen in this figure the bushing failures progress from the outside of the shoe toward the inside (Bushing 1, 7, 8, and 14). Figure 6 shows an individual bushing failure mode. As can be seen, the failure mode here not only has a radial component but also has a torsional component.

Figure 5: Progression of Bushing Failures (Top new bushings, bottom worn bushings, 250 mile increments between samples)

Figure 6: T158LL Bushing Failures

The failure mode in the field testing of the double pin track does not match the failure mode in the lab test of the single pin track.

FULL PITCH BUSHING TEST MACHINE

The Full Pitch Bushing Test Machine is shown in Figure 7. This second generation design will handle testing from T130 qualification bores up to and including T107 Track shoes. It was designed with fully programmable Servo-Hydraulic radial and torsional actuation. It is capable of measuring load, displacement, angle, torque, and block temperatures from both the right and left blocks. External heating is also available if needed.

The advantages of testing full pitches on this machine are numerous. First, being able to test the full pitch allows the capability to monitor production. This is useful in determining quality control, process control, operator differences, site or company variations, etc.

Second, being able to test full pitch allows the bushings to experience similar thermal gradients and insulation properties that would be experienced due to shoe geometry and rubberization of other parts of the shoe.

Third, the use of the entire pitch allows the pins to deform as they would under in-field conditions. The short test section of the pins used in the MIL-DTL-11891 type testing does not have the same boundary conditions of those in a track pitch. The MIL-DTL-11891 testing bores also do not exhibit the same end conditions since they are designed for "infinite" length.

Fourth, variations in the relationship between the radial and torsional loads can be varied between tests or varied during a single test.

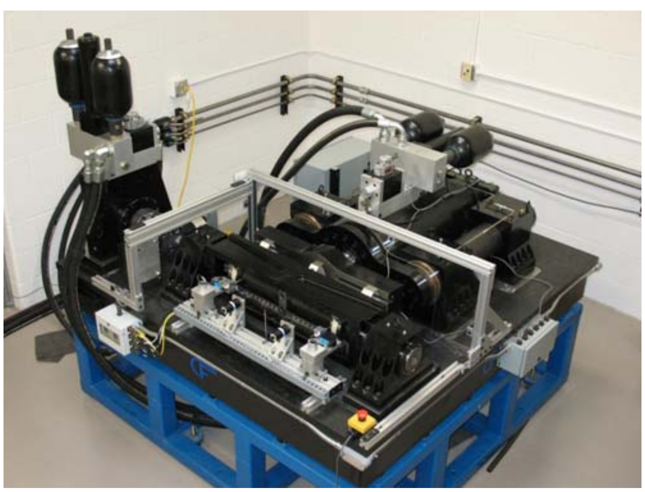

Figure 7: Full Pitch Test Machine

Comparing the failure mode between in-field T158LL bushing and those from a Full Pitch Machine test clearly shows a better comparison than that found in the MIL-DTL-11891 test shown in Figure 4. Figure 8 shows a comparison of the edge effect crack initiation between the field and lab test samples. As can be seen, the two compare closely.

Figure 8: Crack Initiation from Field Test (left) and Lab Test (right)

Figure 9 shows the final failure of the bushings from the field test (top) and the lab test (bottom) of the T158 track. Although difficult to see in the photographs, the 2 failures both experience the same mode. Both have a radial crushed zone of similar size and a torsional tearing of the bushing around the circumference of the pin. The field tested pin shows a polishing area not seen in the lab test most probably due to sand and dirt getting into the bore. Rust is also seen in the field tested part due to the migration of water into the bore as the bushings fail from the outboard sides of the track blocks.

Figure 9: Radial and Torsional Failure from Field (top) and Lab Test (bottom)

Similar samples of pulverized rubber were also seen in both samples indicating a similar failure mode.

Ideally the laboratory testing would mimic the field test with more than just the failure mode criteria. One of the other parameters that would provide a higher confidence level in the lab testing would be to be able to get a one to one correlation between mileage on the vehicle and cycles on the test machine. In order to do this, a more complete picture of the bushing displacement was needed. This required the development of a new technology.

HALL EFFECT INSTRUMENTED TRACK SHOE

The original assumption of 1 radial load to 4 torsional inputs has been the standard for testing most of the bushings up to this point. Only variations in load and angle had been explored. Bushing failure is a complex problem and it was known that the test conditions probably did not mimic field conditions. However, up until recently there was no way to actually record bushing data in the field. For example, laboratory tests run continuously in an ambient temperature of 75°F. Lab tests do not include the introduction of sand, gravel, water, or other environmental variables seen in the field. In an effort to determine what the bushing actually experiences on a TRADOC Opmode test, the Hall Effect Technology was developed and employed on the newly developed T161 double pin track used on a M2/3 Bradley.

The Hall Effect Transducers were mounted on the track shoe and the corresponding magnets were mounted to the bushing pin. Once the pins were rubberized they were inserted into the track bore and the shoe was assembled into the strand. A small data acquisition computer was added into one block and the power supply was added into the other block of the pitch. Figure 10 shows the computer and acquisition boards along with the locations of the number 2 and 4 transducers.

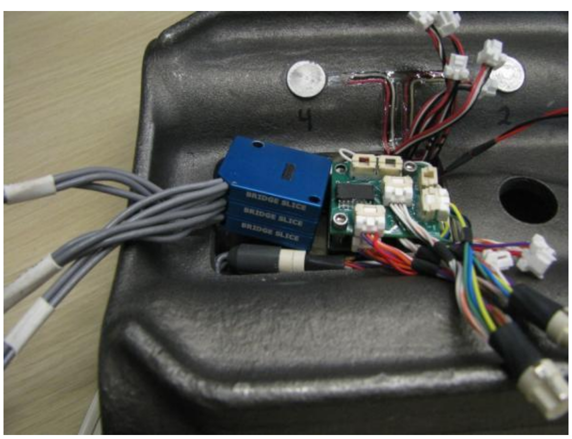

Figure 10: T161 Modified Shoe with Data Acquisition and Hall Effect Transducer Locations

Four bushings were instrumented. These were bushing number 2, 4, 7, and 9 of the 10 bushing on the T161 pin. The transducers were located in such a way that the data, once post processed, revealed the magnitude and direction of the pin displacement at the 4 locations.

Once installed on the vehicle, the driver proceeded to run all of the Paved, Secondary, Hilly and Cross Country courses at YPG that make up the TRADOC Opmode. Figure 11 shows a section of data recorded on the Paved Course. Shown is one revolution of the track. As can be seen in the figure, the signal starts at the Sprocket, traverses under the 6 Bradley road wheels, through the idler and across the support rollers and finally re-engaging the sprocket. Trace A is the outboard most transducer and Trace D is the inboard most transducer. Magnitude of the displacement in inches is shown on the top plot and Angle of the pin deflection in degrees is shown in the bottom plot.

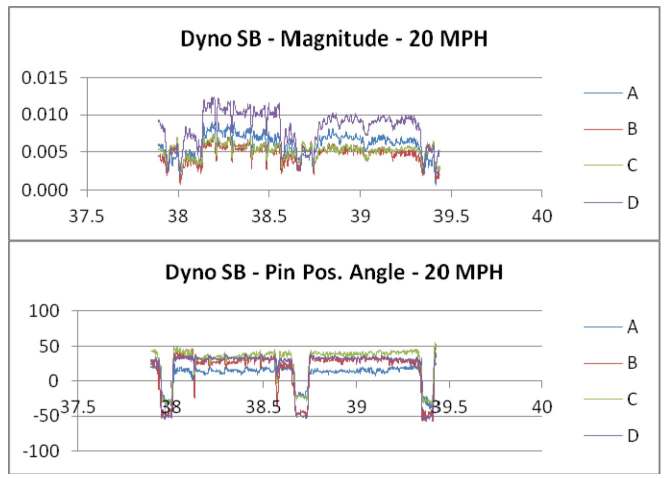

Figure 11: Magnitude and Deflection of the Track Pin Laguna Paved, South Bound 20 mph

The data shows a much more complex bushing load case with more radial and torsional inputs than the simple 1 to 4 ratio of previous tests. Pulling data from a single point in time reveals what the pin is actually doing relative to the track blocks. Figure 12 shows a point in time when the shoe is engaged in the sprocket. The deflection data shows that pin bending does exist in the double pin track design as some theorized.

Another theory that was shown to be true was that the radial loading of the pin occurs in a larger vector than was reflected in the laboratory tests as can be seen in the lower trace of Figure 11.

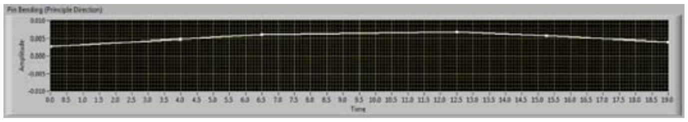

Figure 12: Track Pin Bending, Laguna Paved, South Bound 20 mph

PATH FORWARD

With the successful development of the technology and methodology to characterize the test courses at YPG from the bushings perspective on the M2/3 Bradley, the T158LL shoe was developed as shown in Figure 13. A pair of these shoes was recently completed and is currently awaiting field testing on the M1 Abrams. Once testing is completed the damaging components of the data from the different courses can be reduced and a test load profile can be developed for the Full Pitch Test Machine.

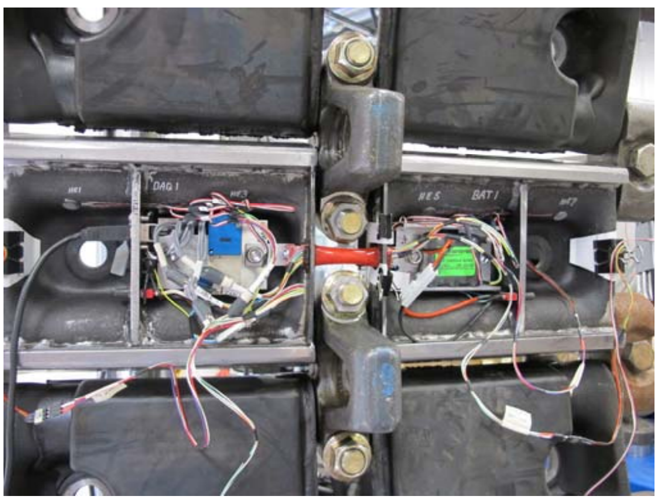

Figure 13: T158LL Shoe During Checkout

CONCLUSIONS

As was shown, the failure modes of elastomers between the single pin MIL-DTL-11891 qualification test and the T158LL field failure do not match. The Full Pitch Test Machine does closely match the field failure mode however the cycle count relationship to test mileage has not been established. With the addition of load history information gathered from the T158LL Hall Effect Track shoe incorporated into the new Servo-Hydraulic controlled software, closer correlation to vehicle life should be possible.

REFERENCES

[1] Track Shoe Sets, Track Shoe Assemblies, Track Shoe Pads and Track Shoe Bushings, Vehicular: Elastomer, MIL-DTL-11891G(AT), Appendix A, page 49-51.

[2] Track Data Book, 1971 Edition, US Army Tank-Automotive Command, Page 126.