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An Experimental Investigation of Damaged Arresting Gear Tapes for the Langley Aircraft Landing Dynamics Facility

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ABSTRACT

An experimental investigation was performed on damaged arresting gear tapes at the Langley Aircraft Landing Dynamics Facility. The arrestment system uses five pairs of tapes to bring the test carriage to a halt. The procedure used to determine when to replace the tapes consists of a close evaluation of each of the 10 tapes after each run. During this evaluation, each tape is examined thoroughly and any damage observed on the tape is recorded. If the damaged tape does not pass the inspection, the tape is replaced with a new one. For the past 13 years, the most commonly seen damage types are edge fray damage and transverse damage. Tests were conducted to determine the maximum tensile strength of a damaged arresting gear tape specimen. The data indicate that tapes exhibiting transverse damage can withstand higher loads than tapes with edge fray damage.

INTRODUCTION

The objectives of this study were (a) to develop a methodology for testing aging tapes, (b) to determine the tensile load strength of damaged arresting gear tape specimens, and (c) to develop recommendations to improve the procedure for replacing damaged arresting gear tape at the Langley Aircraft Landing Dynamics Facility (ALDF). An overview of the ALDF is pictured in figure 1. This paper presents data showing the effects of transverse damage and edge fray damage on the tensile load capability of the tapes.

The arrestment system is a key component of the ALDF. This system is designed to stop a 58-ton sled traveling at speeds of 220 knots. No failures of the arrestment system have occurred to stop the test carriage, but damage has occurred to the system tapes and the test carriage. Although the incident rate is less than 0.1 percent, tape failure could result in extensive damage to the arrestment system and the carriage. Repairs to any component of the facility can be costly and time-consuming and affect the schedule of planned tests. The arrestment system makes use of five sets of steel cable pendants with a nylon tape attached to each end of the pendant for a total of 10 tapes. Although the system consist of five assemblies, three of the five are adequate to stop the test carriage in approximately 600 ft. Figure 2 shows an arrestment of the test carriage during a typical run.

The facility uses an inspection procedure after each test run to determine the condition of each tape. This evaluation involves intense screening of the tapes to detect and report

damage. The damaged areas are further examined to ensure that the tapes meet the minimum strength requirements before proceeding with the test. When a tape fails the inspection, it is replaced with a new tape. Several types of damage that can cause a tape to fail are noted in the Inspection and Replacement Procedure for the ALDF. The tests performed for this study were on specimens exhibiting edge fray damage and transverse damage. The edge fray damage manifests itself as a loss in tape integrity near the tape edges as transverse weaving material fails; thus loose axial fibers will fray. Then the damaged edges need to be cut off, which makes the tape more narrow (fig. 3(a)). This damage linearly decreases the tensile load capacity as tape width decreases. Transverse damage occurs when the transverse weave of the tape material unravels. This damage indicates internal failure of the tensile weave. Transverse damage manifests itself by worn spots or cuts through the outer weave of the tape (fig. 3(b)). When the transverse weave unravels, the tensile load capacity decreases. A test was conducted on one of the specimens exhibiting simulated damage. Simulated damage involved taking a specimen in fairly good condition and manually applying damage to the specimen using tools to put several cuts and bruises on the material in various sections of the specimen.

FACILITY

The Langley Aircraft Landing Dynamics Facility is a unique national test facility at the NASA Langley Research Center and is located in Hampton, Virginia. This facility has the ability to evaluate aircraft landing gear systems including new and advanced concepts. Tests can be performed on full-size aircraft landing gear systems. These tests can be conducted under closely controlled conditions on runway surfaces to simulate landing and takeoff operations of aircraft under many different simulated weather conditions. Research is performed on phenomena such as hydroplaning, tire friction, tire braking, slush drag, cornering, steering, tire performance, and runway grooving. The accomplishments of tests at the ALDF have made significant impacts on aircraft progress.

The main features of the ALDF include a water jet propulsion system, the test carriage, and the arrestment system. The high-pressure water jet propulsion system propels the test carriage along the 2800-ft runway. The components of this system are an L-shaped vessel that holds 26 000 gal of water, three air storage tanks pressurized to a maximum of 3150 psi, and a high-speed shutter valve which controls the flow of the water. The test carriage is constructed of tubular steel members and weighs 58 tons. Located near the center of the carriage is a 20-ft-wide and 40-ft-long open bay. The open bay is part of the test section area used for mounting landing gear systems and other various test articles. A hydraulic

system is used to position the drop carriage, apply loads, and obtain sink speeds up to 20 ft/sec on tires. Positioned on the front of the carriage is a nose block that has five V-grooves, which is used to capture the five arresting gear cables on the arrestment system. Reference 1 gives a more detailed description of the ALDF.

ARRESTMENT SYSTEM

The arrestment system (fig. 4), located 1800 feet down the track, is used to bring the test carriage to a halt. A typical test can include speeds up to 220 knots. The main components of this system include five independent sets of energy absorbers, a water cooling system, a pendant support gantry tower, and 10 arresting gear tapes. Connected to each energy absorber is the cable-tape assembly in which a tape is attached to each end of the five cables. Each cable assembly consists of a steel wire pendant that is 1.25 in. in diameter and 100 ft long. The system is capable of absorbing 167 000 000 ft-lb of energy by raising the temperature of water contained in five sets of tubs. Each energy-absorber assembly contains a tub, rotation shaft, and a spool. If any two sets of the energy absorbers fail, this system still has sufficient energy absorbing capability to arrest the carriage successfully. The gantry tower supports the arresting gear cables, is used to elevate the cables when towing the carriage down the track, and supports the five cable assemblies to the precise nose block position for the test carriage and arrestment system engagement. (See fig. 5.)

ARRESTING GEAR TAPE

The arresting gear tape is made of woven nylon and is extremely stiff. To accommodate wear and abrasion on the tape, the top and bottom edges of each tape are reinforced with extra nylon. The tape is also treated with a black resin polymer to help prevent deterioration because of weather conditions.

The test specimens used for the experiment were selected from aged arresting gear tapes that had been replaced from the arrestment system by new tapes. The aged tapes were closely examined to identify the various types of tape damage. New tapes are initially 8 in. wide, 0.344 in. thick, and 483 ft. long. For the test, aging arresting gear tape was cut into specimens 26 in. and 30 in. long and grouped into two damage categories, edge fray damage and transverse damage. Figure 6 shows an example of typical arresting gear tape.

TEST APPARATUS

The tests of the arresting gear tapes were conducted on a 120 000-lb load-testing machine (fig. 7). The setup consisted of the 120 000-lb load-testing machine and a digital data acquisition system, which was used to capture the data during each test with a recording rate of 10 samples/sec. The testing machine consists of a hydraulic press and a sensitive load measurement system. The critical component to the success of the test was the grip fixture, which had to fit into each of the 3- by 4-in. top and bottom open slots of the testing machine as well as grip the tape specimen. Two identical grip fixtures were designed, one for the top mount of the testing machine and the other for the bottom mount. One end of the grip fixture was designed to fit into the open slots of the testing machine, and the opposite end was designed to fit the 8-in -wide arresting gear tape specimen. (See fig. 8.)

The tape grip fixture shown in figure 9 consisted of a center plate and two side plates. The plates were mounted together at an angle by 1-in. bolts. When the tensile load increased, the clamping force of the side plates increased. The assembly of the specimen between the side plates consisted of two wedges that fit between the inside of the side plates and each side of the specimen. Sandpaper was used between the inside of the side plate and the wedge. Doublers made out of Union Carbide Bakelite material were attached to the specimen prior to testing to help reinforce the tape edges.

TEST PROCEDURE

The test procedure involved three main steps. The first step involved preparing the specimen for testing. The preparation consisted of making doublers out of Union Carbide Bakelite material. The process involved bonding the doublers to the tape by applying epoxy to the edges of the tape specimen and curing the epoxy for at least 6 hr prior to testing. Step two was the assembly of the grip fixture and the tape. The tape specimen was assembled to the grip with wedges and sandpaper, fitting the specimen between the wedges and the side plates and bolting together with 1-in. bolts on each side of the specimen. Two bolts on each side of the specimen were tightened to clamp the specimen in the grip fixture. The grip fixture clamped each end of the specimen using up 2 in. of specimen. Step three involved attaching the grip fixture to the testing machine. The narrow end of the grip fixture was placed in the open slots of the top and bottom mounts and held together by 2-in. bolts. (See figs. 7 and 8.)

The testing machine was set to the maximum load capacity of 120 000 lb and a displacement transducer was mounted on the machine to measure deformation. A digital data acquisition system was used to collect data during each test. Loads were applied increasingly until failure occurred or the maximum travel length on the testing machine was reached. Most of the specimens failed at the grip fixture. A challenge was developing a fixture that did not cause the specimen to slip or fail at the fixture ends. The failure loads varied from 40 206 lb to 93 083 lb. Figure 10 displays a typical failed specimen.

RESULTS

Fifteen arresting gear tape specimens were tested. The condition of the specimens ranged from transverse damage, simulated damage, and edge fray damage. The specimens were 0.344 in. thick and 8 in. wide with the exception of specimen 1 that was 7 in. wide, and the length was 26 in. for 13 of the specimens and 30 in. for the remaining 2. The geometry for each of the specimens tested can be found in table 1, but due to grip failure problems, only 3 tests showed tape failure and are discussed in the following paragraphs.

Specimens 12, 14, and 15, which exemplified tape failure, are now discussed. Figure 11 displays a load-displacement plot for specimen 12. The damage type for this specimen is transverse damage with minor edge fray. Specimen 12 failed at a maximum load of 69 048 lb. The minor discontinuity observed in the curve is possibly caused by internal fiber breakage of the specimen. Popping sounds were heard when the loads were approaching 20 000 lb.

A load-displacement plot of specimen 15 is shown in figure 12. Specimen 15 exhibited transverse damage as well and failed at a maximum load of 74 634 lb. The curve in the figure shows some minor discontinuity approaching 25 000 lb. During the test, popping sounds were heard near these loads.

A plot showing load displacement of a tape with edge fray damage, specimen 14, is in figure 13. This specimen failed at a maximum load of 40 206 lb. Popping sounds were also heard during this test. The specimen with edge fray damage failed at a much lower load than that of the specimen with transverse damage. Based on this observation, further tests should be performed because it is probable that the tapes with edge fray damage should be replaced sooner than the ones with transverse damage.

CONCLUDING REMARKS

An experimental study was performed on damaged arresting gear tape specimens to determine their maximum tensile load strength capability. After several modifications to the grip fixture, a grip design was developed that was adequate to grip the 8-in. specimens and fit properly into the slots on the 120 000-lb load-testing machine. A methodology was established to perform continued evaluations of the aging arresting gear tapes in the future.

The specimens tested were characterized as exhibiting transverse damage and edge fray damage. The specimens with transverse damage failed at higher loads than the specimen with edge fray damage. This result suggests that if the arresting gear tape shows edge fray during the inspection procedure, consideration should be given to replacing the tape sooner than one with transverse damage. However, further tests should be conducted on specimens with both transverse damage and edge fray damage to acquire a larger data set before consideration is given to altering the inspection and replacement procedure.

One recommendation is if edge fray damage is detected and the damaged edges are trimmed, the trimmed edges should be treated with a polymer solution to help hold the fibers together to increase the tensile strength of the tape.

REFERENCE

1. Davis, Pamela A.; Stubbs, Sandy M.; and Tanner, John A.: *Langley Aircraft Landing Dynamics Facility*. NASA RP-1189, 1987.

TABLE 1. TEST SPECIMEN GEOMETRY

SPECIMEN ID	SPECIMEN CONDITION	LENGTH (in.)	WIDTH (in.)	TEST SECTION LENGTH (in.)	COMMENTS
1	Good Condition	30	7	26	Out of travel
2	Transverse Damage	26	8	22	Grip failure
3	Transverse Damage	26	8	22	Grip failure
4	Transverse Damage	26	8	22	Grip failure
5	Simulated Bone-shape	26		22	Insufficient data
6	Transverse Damage	26	8	22	Grip failure
7	Transverse Damage	26	8	22	Grip failure
8	Transverse Damage	26	8	22	Grip failure
9	Good Condition	26	8	22	Grip failure
10	Good Condition	26	8	22	Grip failure
11	Simulated Damage	26	8	22	Grip failure
12	Transverse Damage (some minor edge fray)	26	8	22	Tape failure
13	Transverse Damage	30	8	26	Out of travel
14	Edge Fray Damage	26	8	22	Tape failure
15	Transverse Damage	26	8	22	Failure at weak damaged areas

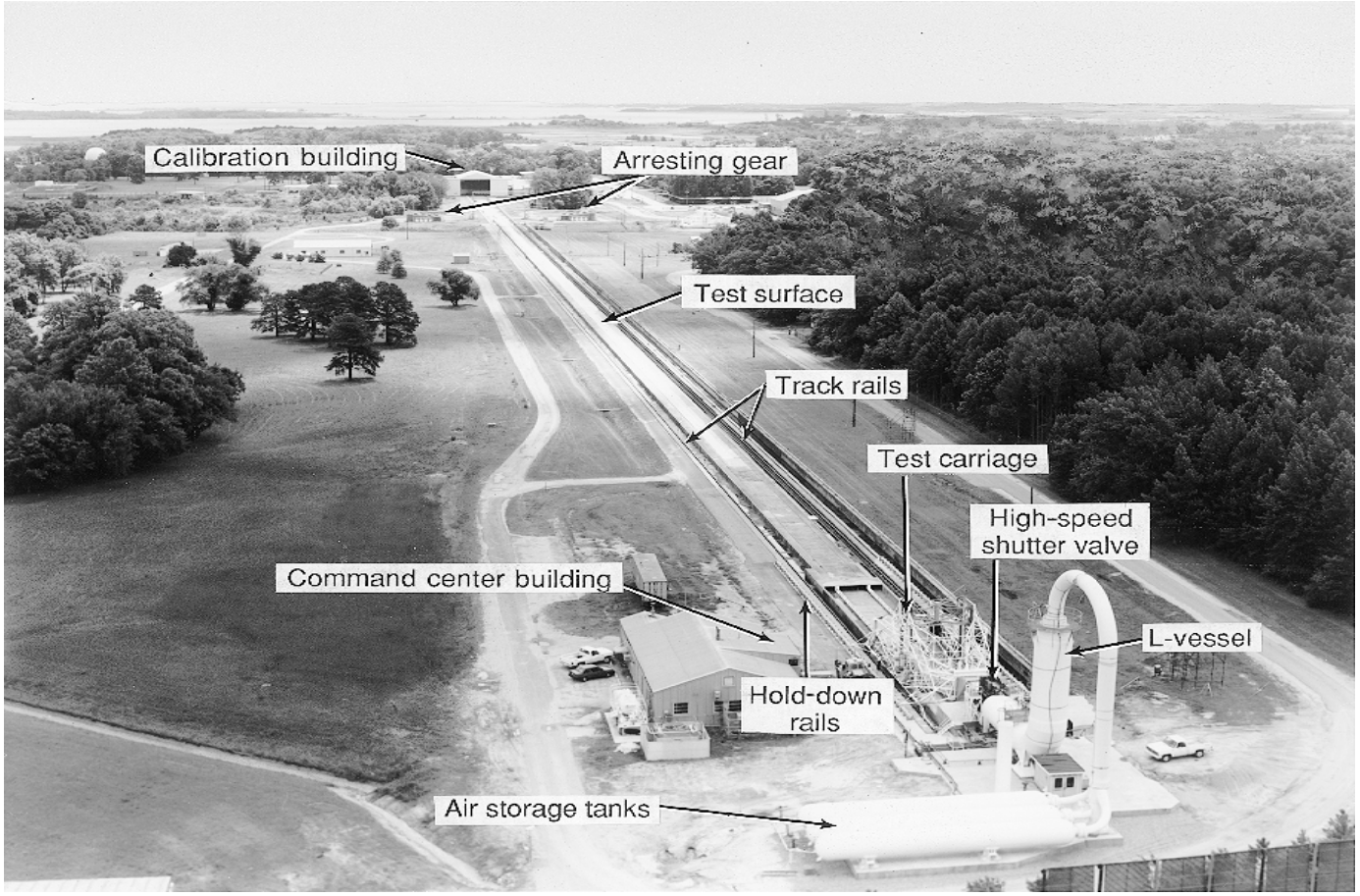

Figure 1. Langley Aircraft Landing Dynamics Facility.

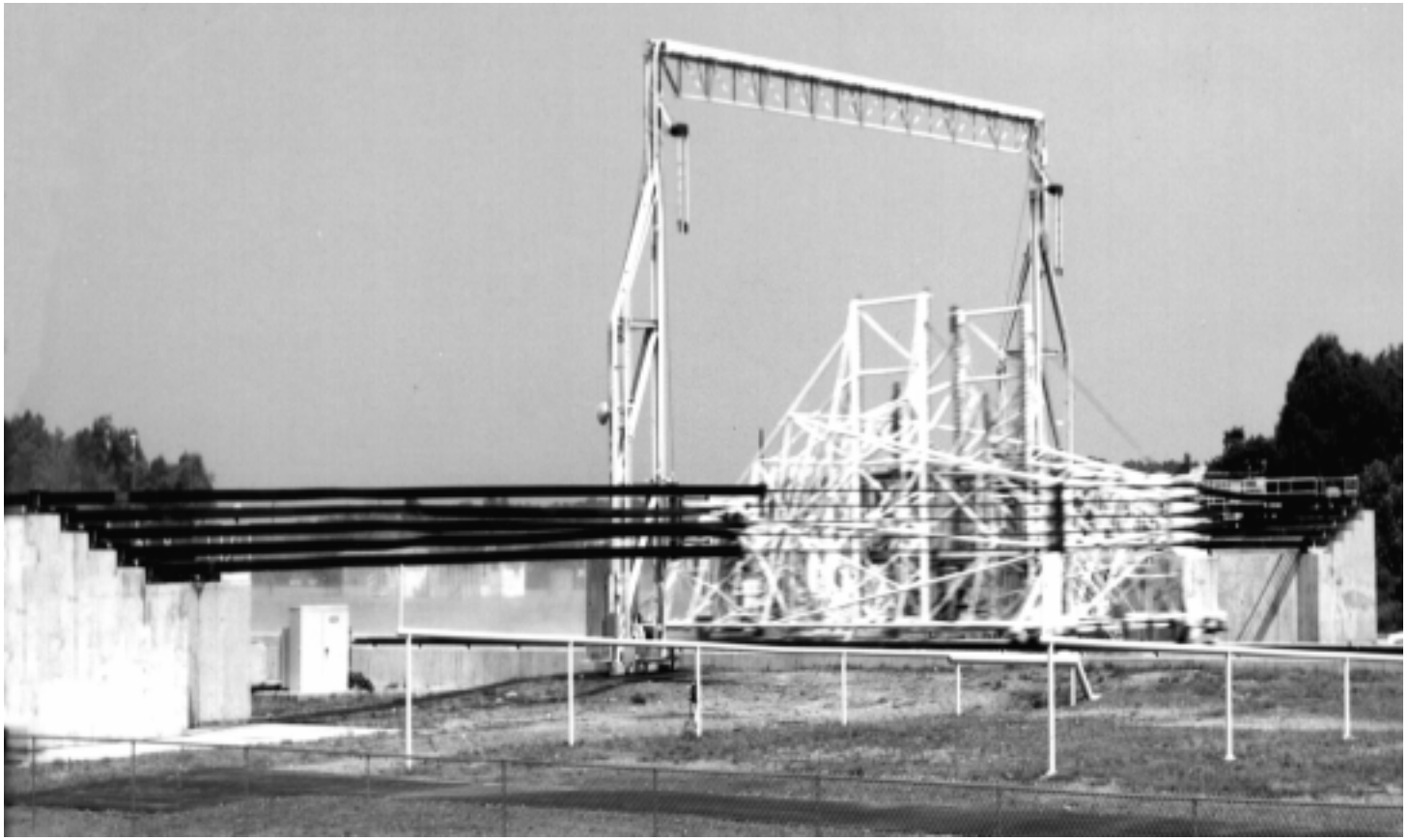

Figure 2. Arrestment of test carriage during a typical test run.

(a) Edge fray

(b) Transverse

Figure 3. Types of damage.

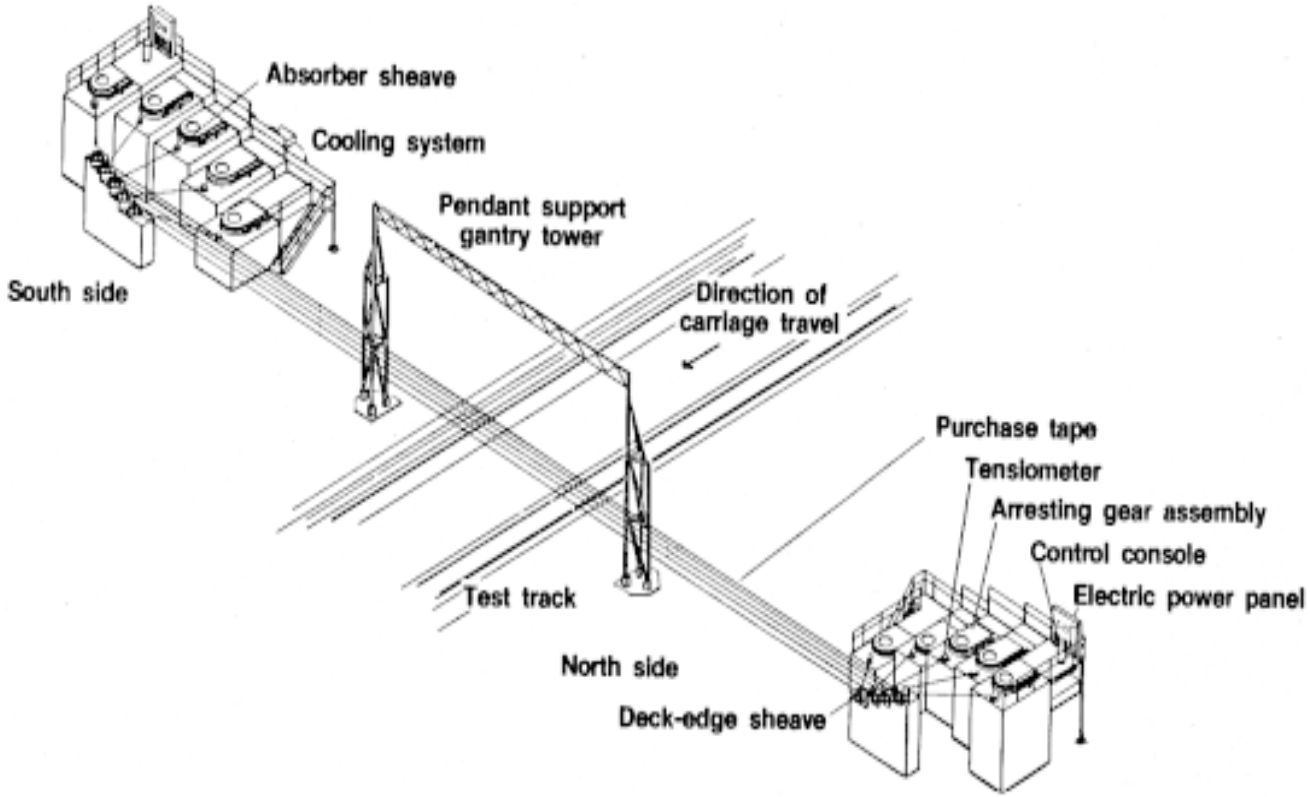

Figure 4. Schematic of arrestment system for the Langley Aircraft Landing Dynamics Facility.

Figure 5. Arrestment system elevated for towing of test carriage.

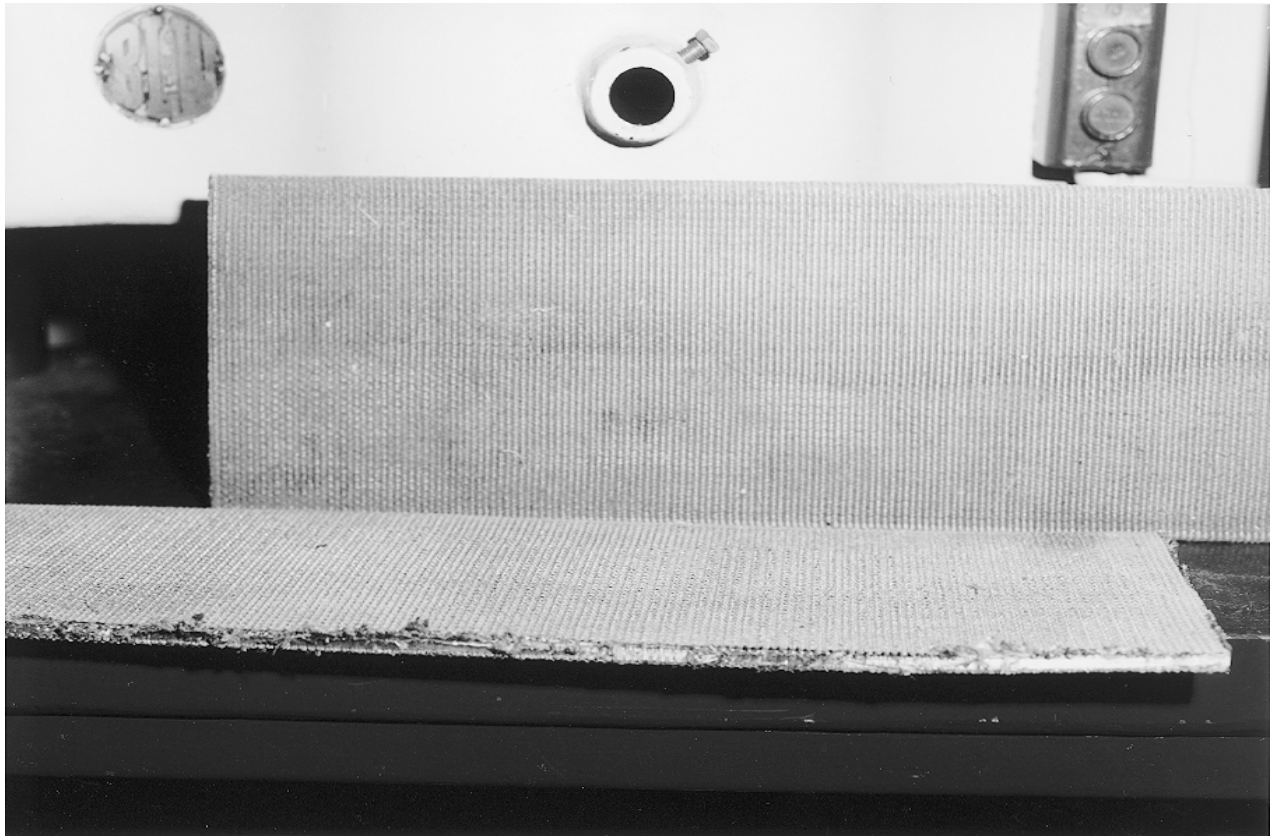

Figure 6. Arresting gear tape material.

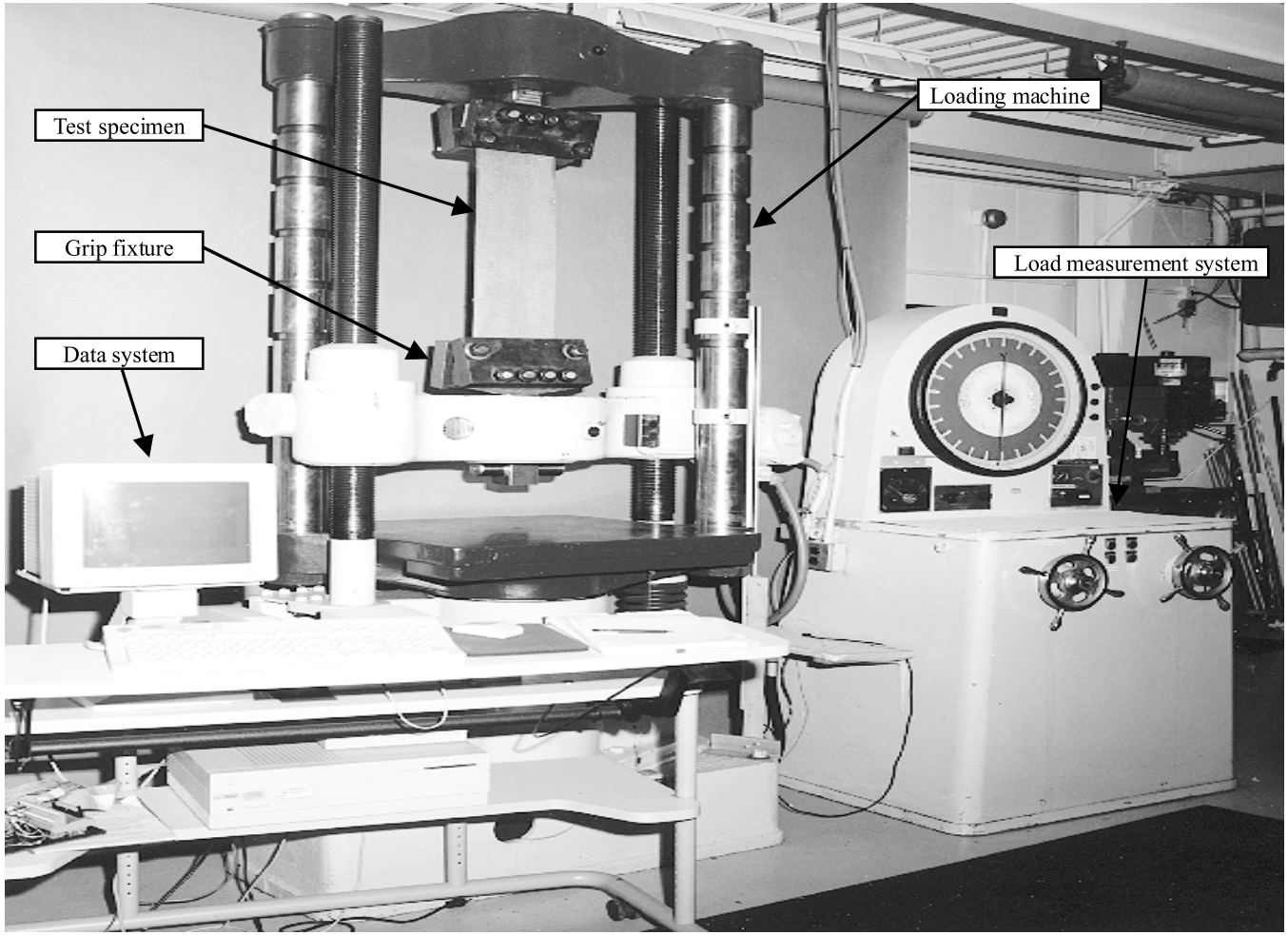

Figure 7. Test setup: data system, load-testing machine and measurement system.

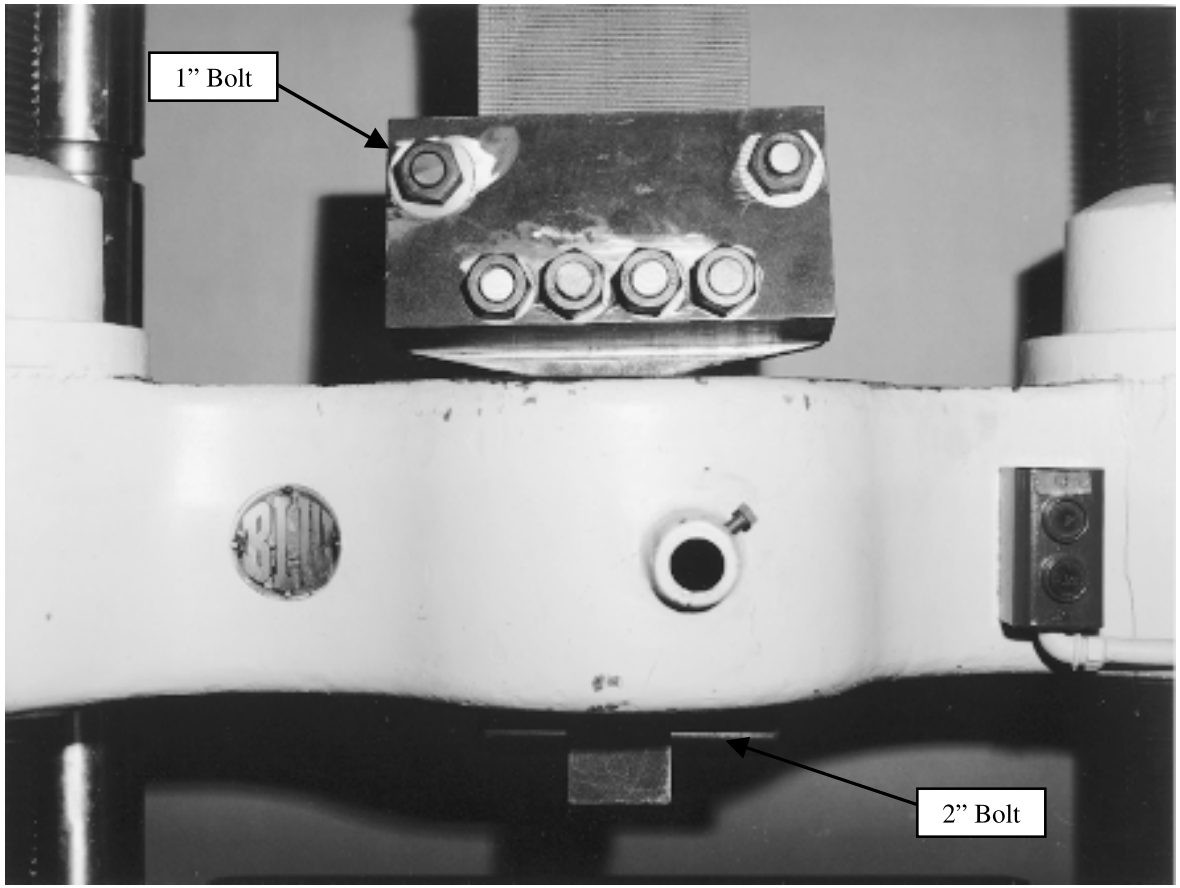

Figure 8. Arresting gear tape specimen grip fixture.

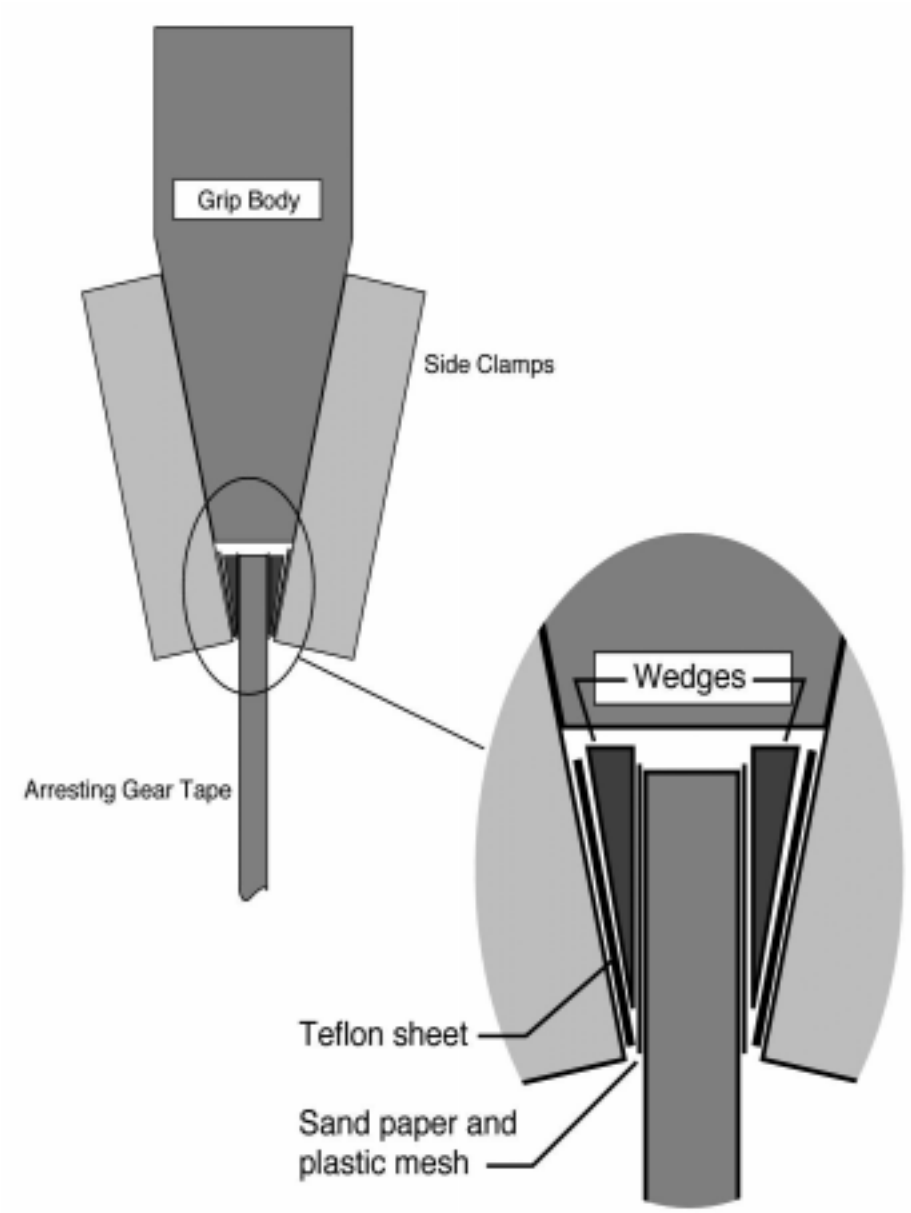

Figure 9. Schematic of tape grip fixture and arresting gear tape specimen assembly.

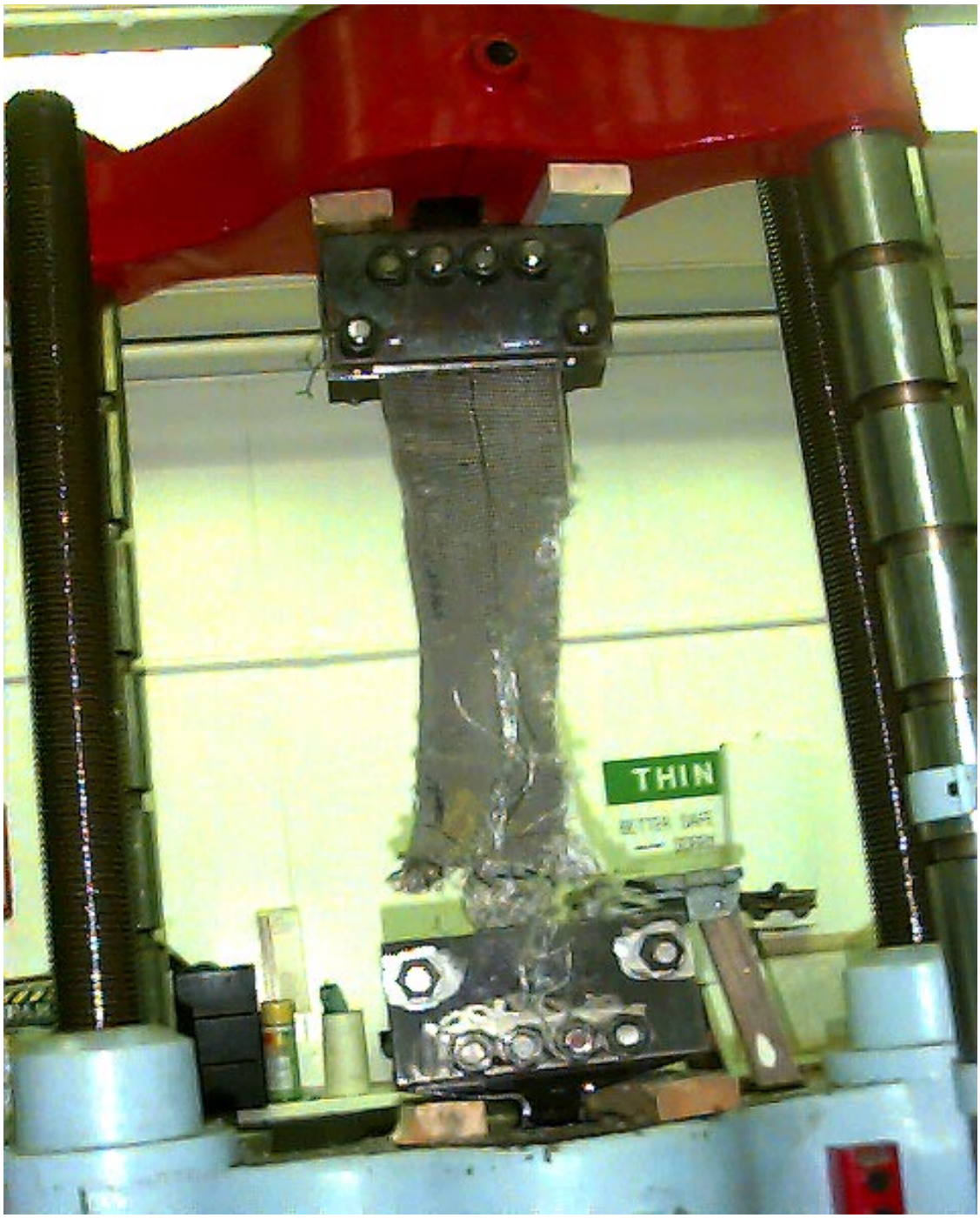

Figure 10. Arresting gear tape failure.

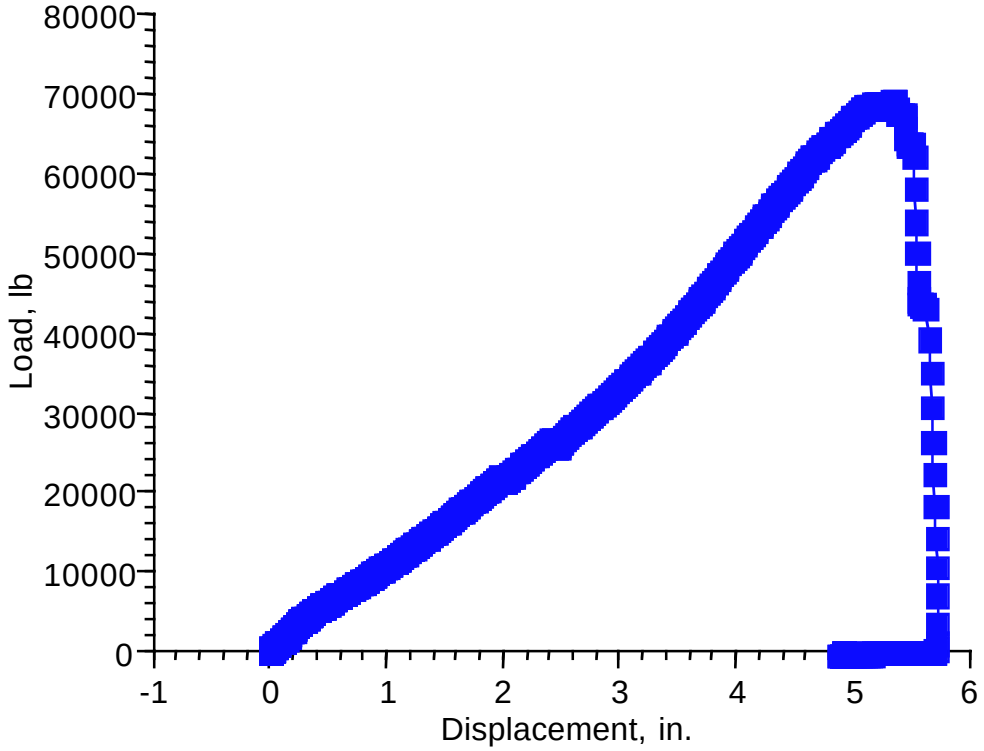

Figure 11. Load-displacement plot for specimen 12 with transverse damage and minor edge fray damage.

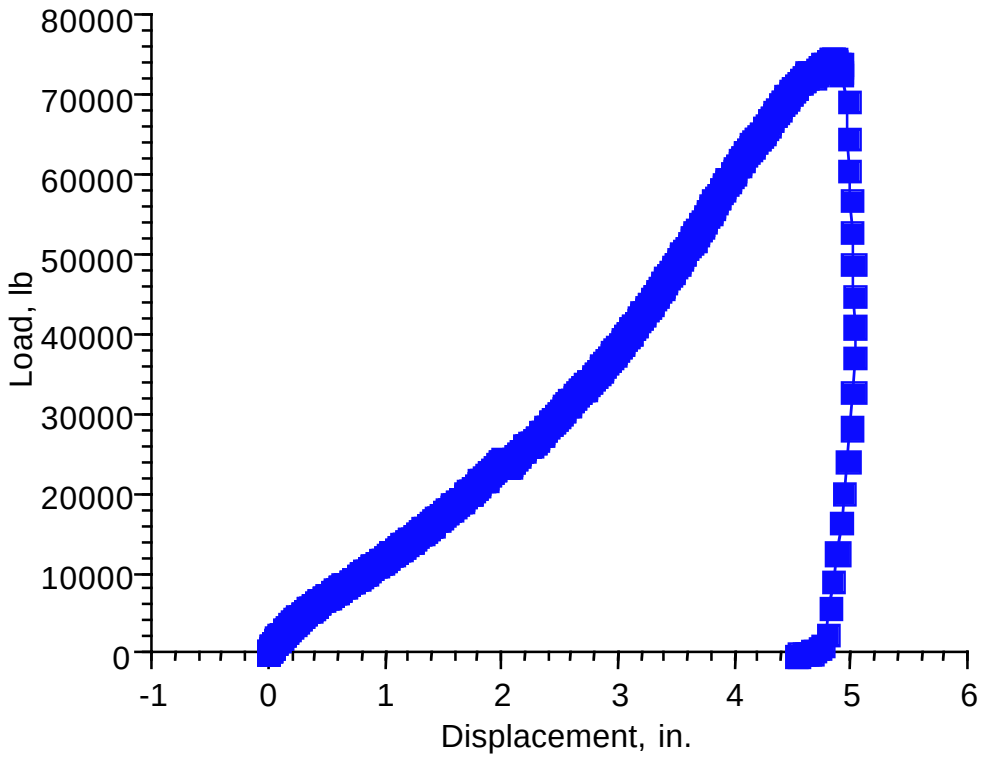

Figure 12. Load-displacement plot for specimen 15 with transverse damage.

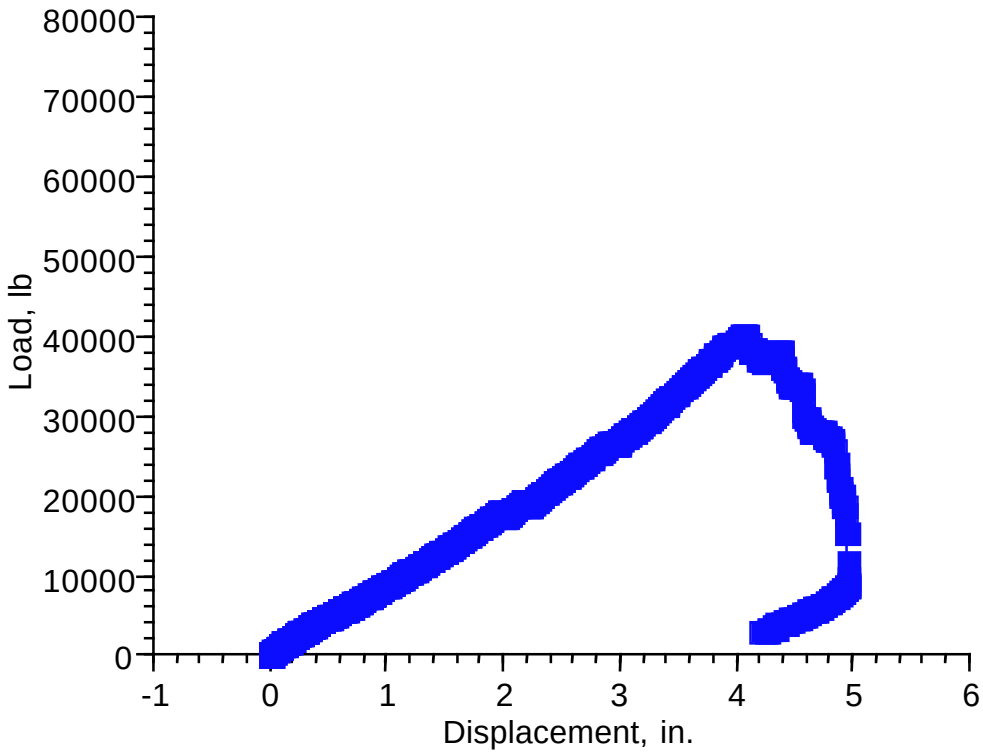

Figure 13. Load-displacement plot for specimen 14 with edge fray damage.

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