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Static and Dynamic Testing of Serpentine Belt Drive Tensioners

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ABSTRACT

Serpentine belt drive tensioners are used in virtually every model of automobile produced today. Limited testing has been done to see how the tensioner performs under certain situations. In each case outside influences were either not accounted for or considered not to influence the way the tensioner performed in a given situation. By developing new ways of testing tensioners for static and dynamic characteristics separately, the influence each trait has on the performance of the tensioner can be exactly gauged.

INTRODUCTION

The days of automotive engines with multiple belts are gone. Today virtually all of the new automobiles produced in the world use a single polyrib belt to drive the peripheral engine components (i.e. fan, water pump, alternator, etc.). With the change in the belt drive system came a change in the way tension was kept in the belt. In the multiple belt system, tension in each individual belt was set by the adjustment of the position of the specific component that was being driven by the belt. With the advent of the single belt drive, also called the serpentine belt drive, a new component was introduced: the serpentine belt drive tensioner. Tensioners consist of a belt pulley mounted on one end of an arm with a very stiff torsional spring attached to the pivot end of the arm. Tension is kept in the belt, by the tensioner, by moving the arm and thus loading the spring and allowing the pulley to push on the belt between the pulleys of two of the peripheral engine components.

Since the tensioner is used to supply a force to the belt which induces tension, the tensioner exhibits a dependance on static load. Also, due to the fact that an automotive engine is a large source of vibration and the main forcing component in the tensioner is a spring, the effect of vibrations on the tensioner is of great concern.

Experimental Background and Scope

Limited testing of the tensioners has been done by the research and development division of Dayco Industries in Springfield, Missouri. Dayco is the major manufacturer of tensioners for the Ford Motor Company. At Dayco the dynamic characteristics of the tensioners were tested on a stationary engine. Testing the dynamic response in this manner may have introduced the elastic characteristics of the belt and thus the dynamic characteristics of just the tensioner may not have been tested. The static load response was tested by directly attaching an air cylinder to the arm of the tensioner. By testing static characteristics this way the effects on the tensioner due to the tension in the belt and the placement of the surrounding components were totally neglected.

The goal of this research is to test the static and dynamic characteristics of only the tensioner in a typical application. This can be easily done by using a steel strapping material in place of the polyrib belt to eliminate any elasticity effects the belt would introduce. Also, by simulating nearby components both the dynamic and static characteristics of the tensioner can be measured in an environment that imitates an actual application. To develop overall characteristics many different tensioners from numerous production runs will be tested.

Fixture design

Using information which described the position of the engine components in relation to the center of the crankshaft pulley, the positions of the required components were laid out, see figure 1. An attachment was added to the lower portion of the main fixture that would allow the fixture to be elevated off the floor such that the free end of the steel strap could be attached to a weight hanger or a vibration source. Since static forces of up to 200 pounds and vibration forces are used in the experiment the fixture had to be quite strong so that it would not introduce any unwanted effects. Therefore, the fixture box was made out of half inch steel plate and the components were braced well to make the entire setup rigid.

The steel used in the fixture parts that were built in the Mechanical Engineering shop was paid for with the money provided by the OURE. All other parts were provided by Dayco, free of charge, or built in my home shop using scrap materials. Instrumentation was built from used parts and therefore cost nothing also.

STATIC CHARACTERISTICS

By using a weight hanger suspended from the free end of the steel strap the static response of a tensioner was tested. Large weights averaging about fifteen pounds and small weights of exactly five pounds were added until the tensioner reached full displacement. Then the weights were removed to see if the tensioner exhibited the same sort of static response in this setup as it did in the setup used by Dayco.

Results

The tensioner shown in figure 2 was used on an engine by Dayco during testing, thus, it contained some amount of wear. In the figure each line represents

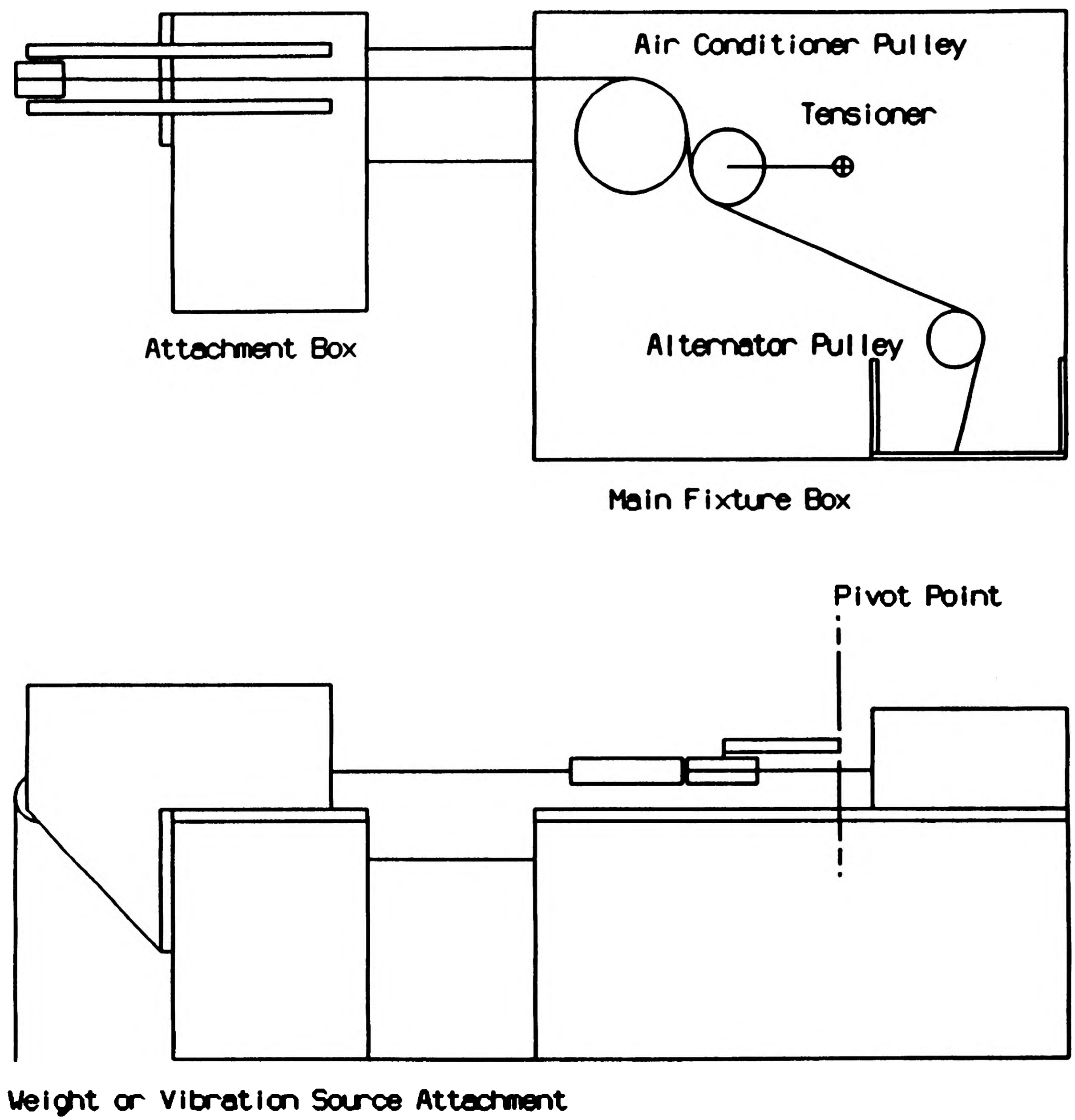

Figure 1: Schematic Layout of the Test Fixture

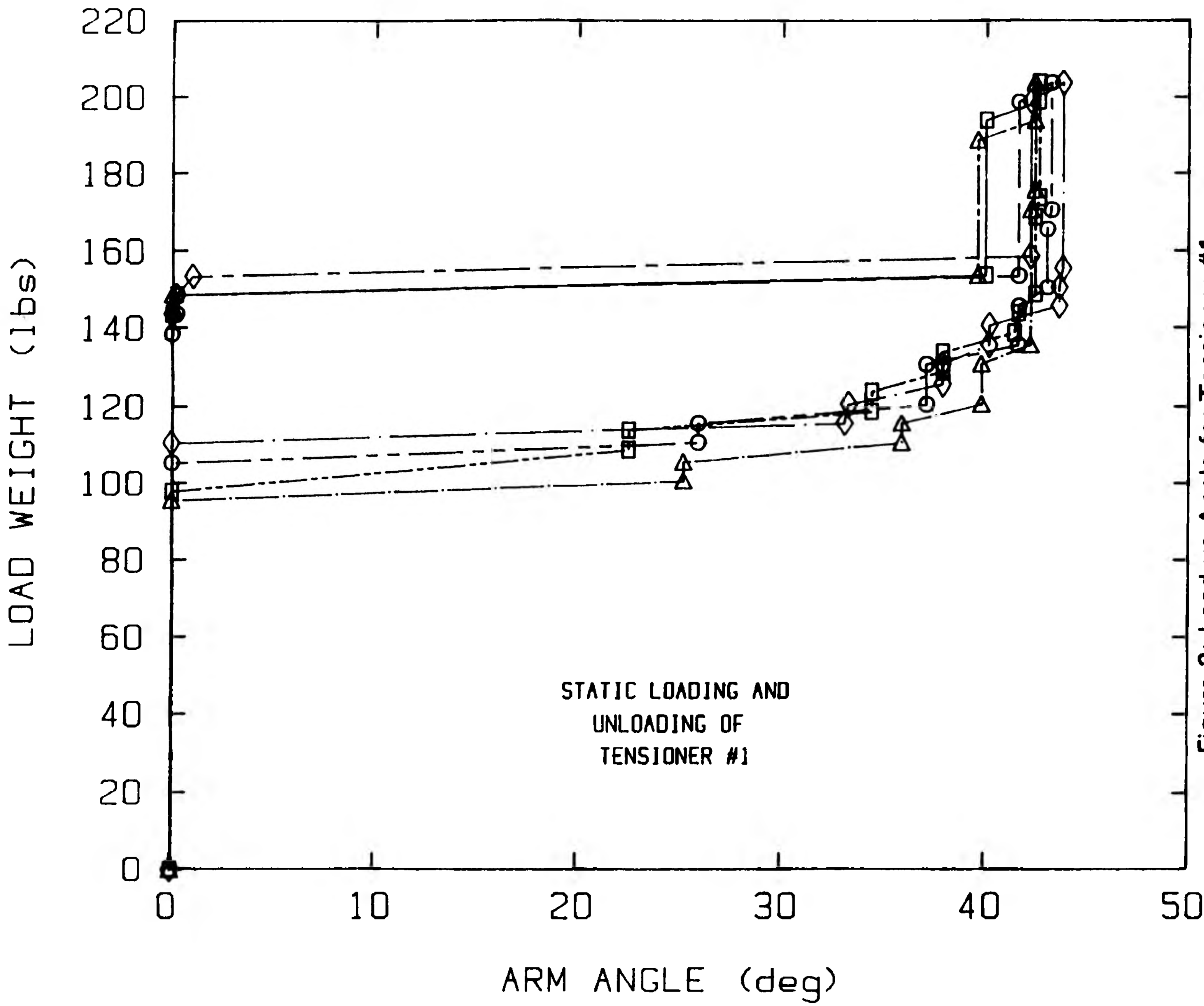

Figure 2: Load vs Angle for Tensioner #1

a loading and unloading of the tensioner. From the figure it is easy to see that the tensioner arm does not move until a large amount of weight is contained upon the weight hanger and with the addition of only five pounds the tensioner goes to virtually full displacement. This is nothing like the smooth loading curve that Dayco produced when loading a tensioner by their method [1]. However, the part of the graph that corresponds to the unloading of the tensioner is approximately equivalent to the unloading curve found by Dayco. The only difference in the unloading portion is that in the setup used by Dayco the tensioner gradually reached zero displacement whereas here the tensioner quickly moves to zero displacement after a certain amount of weight is removed.

In figures 3, 4, and 5 new tensioners directly from the production plant were tested. These tensioners were given an initial displacement to see if a change in the way the tensioner loaded was evident. Each tensioner loaded without moving until a certain weight was reached and then displaced to its full displacement. Unloading each tensioner proceeded in the same fashion as tensioner one.

Conclusions

Due to the way that the tensioner loaded, it is easy to see that the way a tensioner loads is highly dependent on the environment in which it is loaded. Also, the load at which the tensioner will displace depends on the age of the tensioner. Tensioner one displaces at a much lower load than either of the other three tensioners. However, looking at all four figures the unloading lines are virtually the same for all four tensioners and the maximum displacement angles are also relatively the same. Thus, if the tension in the belt close to the point where the addition of a small amount of load would cause full displacement and the tension were to be somehow increased, due to the addition of a load (i.e. turning on the automobile's air conditioner) or by increasing the speed of the engine, momentary loss of tension would occur causing belt squall.

DYNAMIC CHARACTERISTICS

Due to the trouble in getting tensioners and other parts no dynamic testing was done at this point in the experimentation. Testing of the dynamic characteristics will be done at some point by applying a vibrating force to the steel strap with a tensioner in its normal running angle, approximately 18.5 degrees, by either the use of a vibration exciter or other vibration source. The vibration testing will seek out any resonance characteristics or other parameters associated with vibrating systems.

FUTURE TESTING

At the present time static testing on six more tensioners is in progress. At the conclusion of this round of static testing, some dynamic testing will be done in order

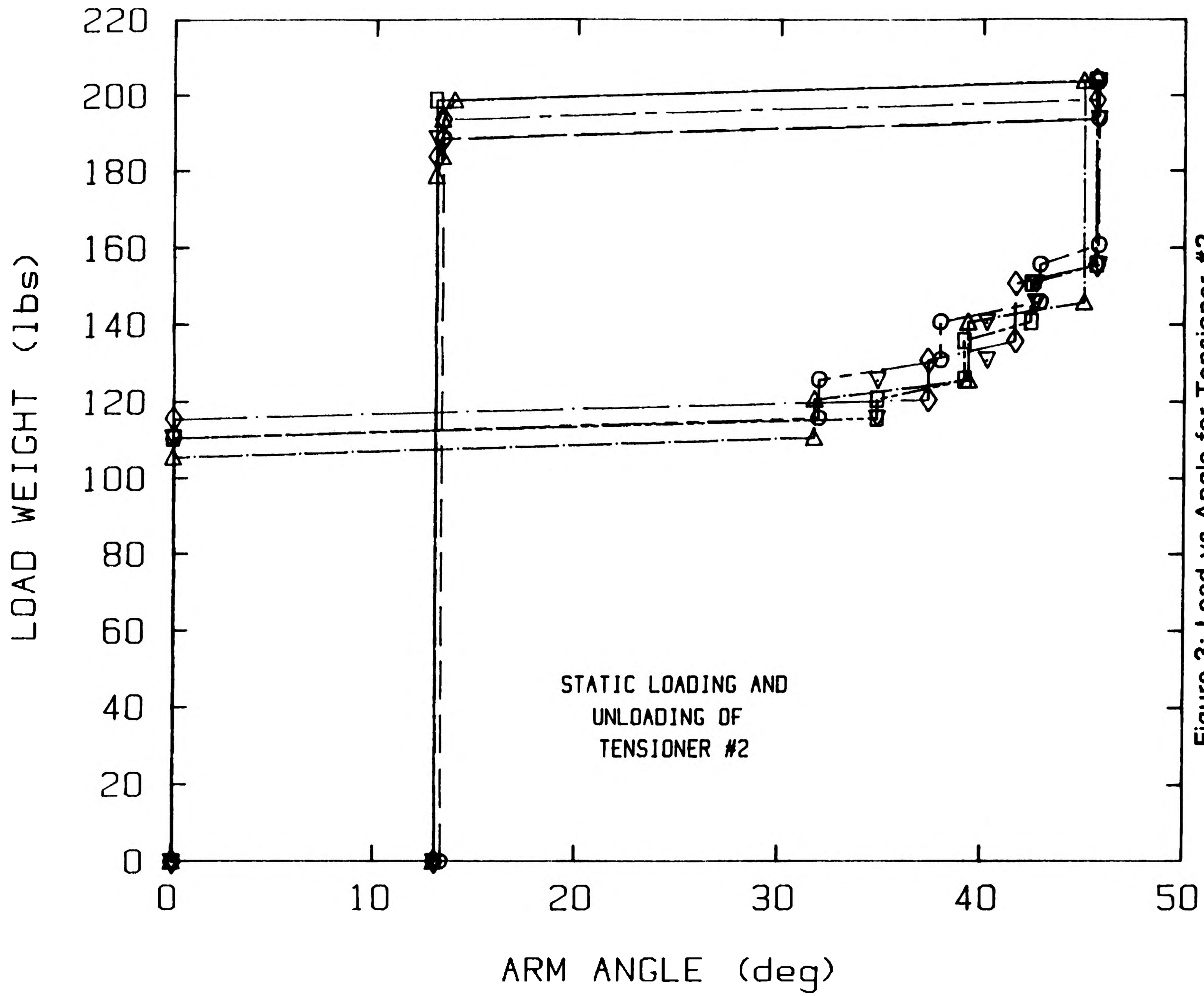

Figure 3: Load vs Angle for Tensioner #2

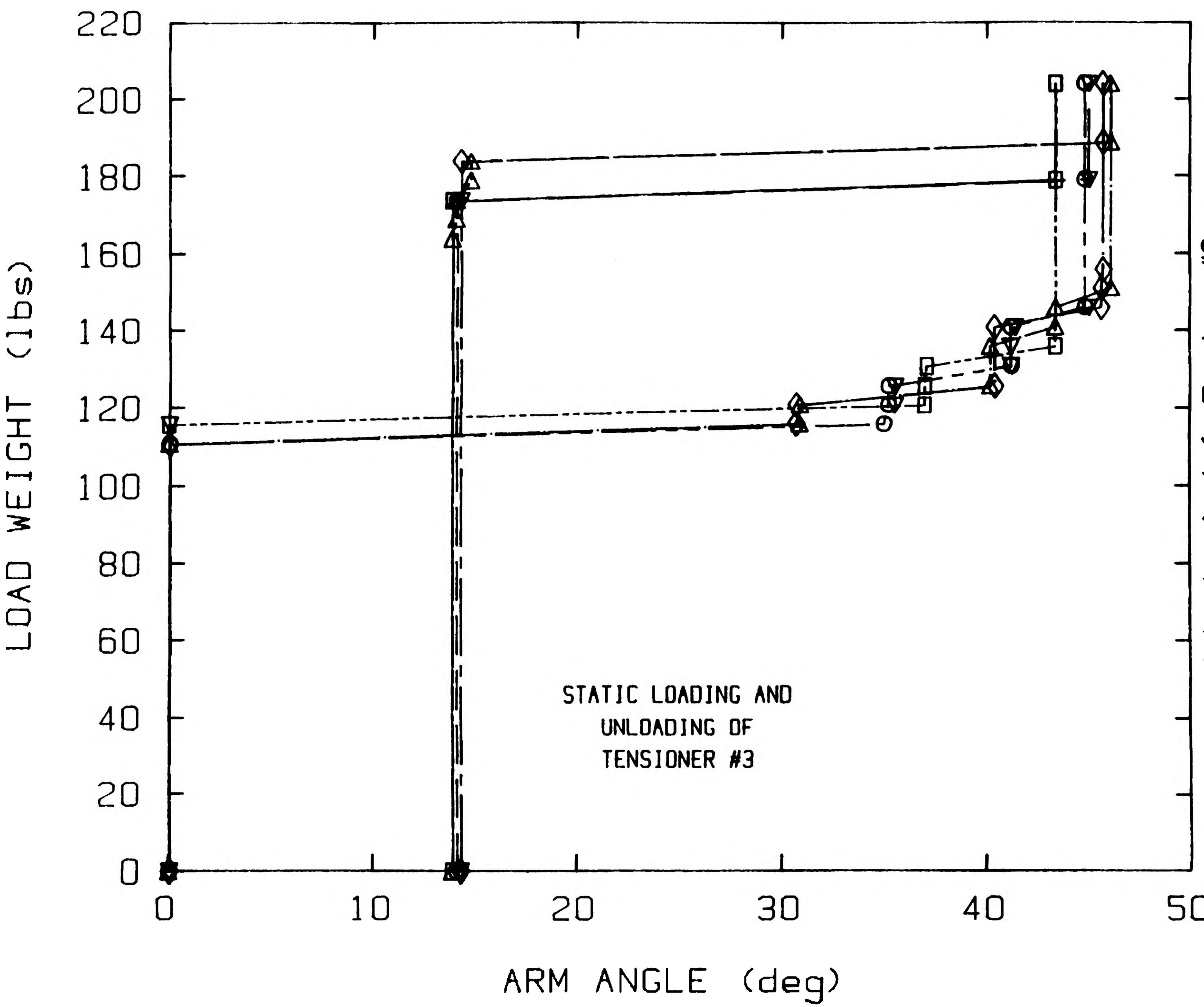

Figure 4: Load vs Angle for Tensioner #3

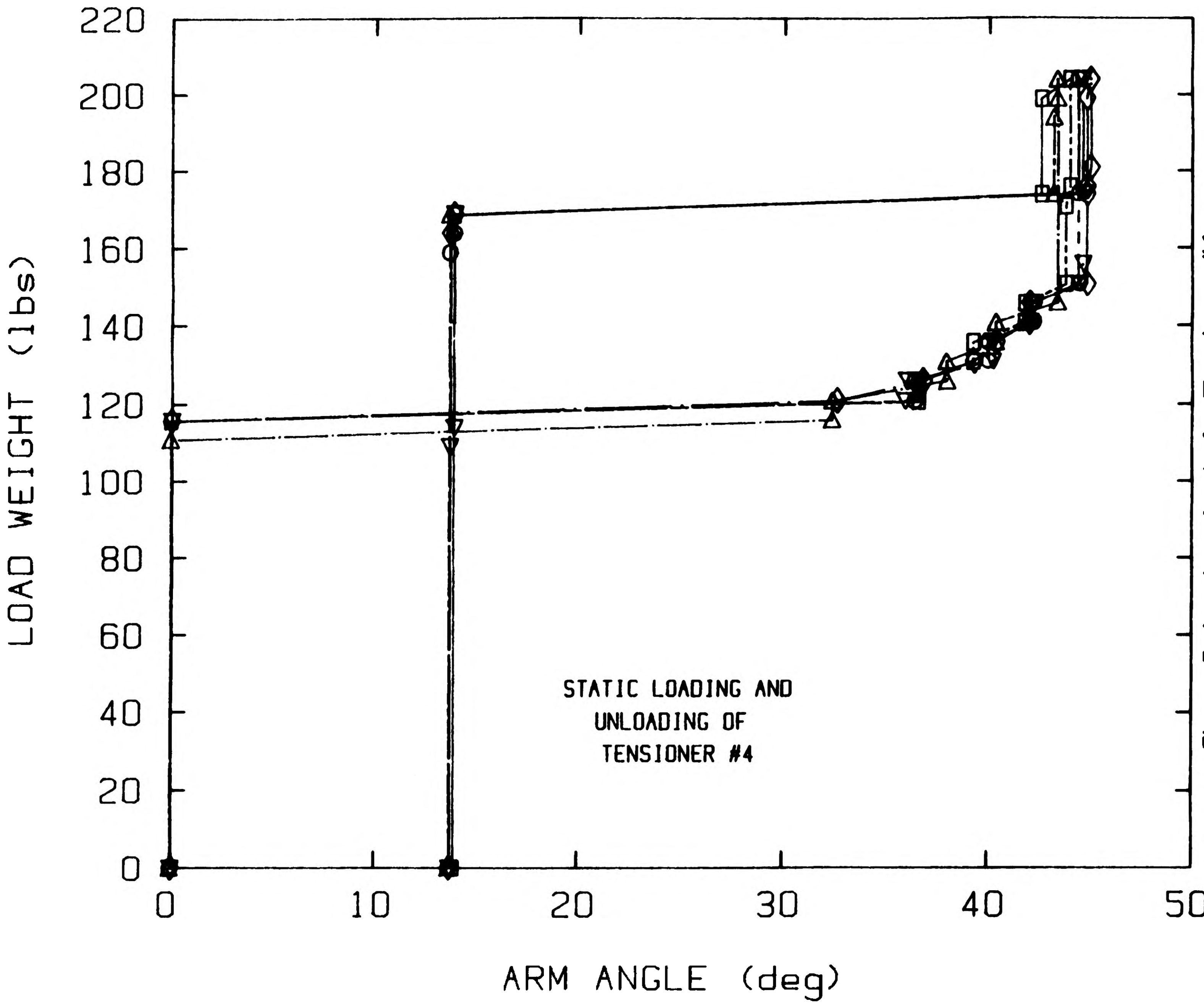

Figure 5: Load vs Angle for Tensioner #4

to come up with a basis for later testing of the dynamic characteristics of the tensioners. Work will continue until the end of the semester as part of my honors research in the Department of Mechanical Engineering. Also, due to the constant changing of tensioner design, more research on this topic could be done by others in coming semesters.

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REFERENCES

1. Barker, C. R., Oliver, L. R., and Breig, W. F., "Dynamic Analysis of Belt Drive Tension Forces During Rapid Engine Acceleration", SAE Technical Paper 910687, February, 1991.