MEMORANDUM REPORT VRTC-DCD-6099
EA06-002
Investigation of Rear Tire Puncture Due to Coil Spring Fracture on 2000 – 2001 Ford Taurus Vehicles

1.0 Introduction

This program was performed at the Vehicle Research and Test Center (VRTC) at the request of the Office of Defects Investigation (ODI) of the National Highway Traffic Safety Administration. ODI opened an Engineering Analysis (EA06-002) on 2000 – 2001 Ford Taurus and Mercury Sable vehicles, manufactured by Ford Motor Company, to investigate consumer complaints to ODI alleging that fractured rear coil springs were puncturing the adjacent tire and causing rapid air loss.

Two rear complaint springs from the same vehicle (one fractured, one intact) were provided to VRTC by ODI for analysis and testing. Additionally, one new exemplar spring was purchased by VRTC and examined in order to provide a comparison to the complaint springs. The exemplar spring was also used for the instrumented testing described later in this report.

2.0 Objective

The objectives of this program were to assess the risk of tire puncture from a rear coil spring fracture; to conduct a survey of consumers' experiences with rear spring fracture; to assess the time from spring fracture and tire contact to tire loss of air; and to assess high stress regions of the spring by conducting strain gauge testing.

3.0 Visual Evaluation of Taurus Springs

When mounted in the vehicle, the subject spring compressed and the fracture area bore directly on the coil below it. Figure 1 (taken through a mirror) shows a non-fractured subject spring mounted in a subject vehicle at curb weight. Contact exists between the bottom coil and second coil. The contact area became greater as the load in the vehicle was increased.

Figure 2 shows the lower end of the two complaint springs that were received. It is evident that the first ~90 degrees of both springs have been in contact with the coil immediately above it. This contact has caused the protective coating to wear away and corrosion to begin on the first two coils of the fractured spring but only on the first coil of the non-fractured spring.

Figure 1
Coil Contact at Curb Weight

Figure 2
Lower End of Complaint Springs

Figure 3 shows that not only did the protective coating wear away, but the remaining coating acted as a pocket to gather debris and moisture. This condition was evident on both springs.

Figure 3
Cupping and Corrosion of Lower Coil

4.0 Driving Tests

A fractured spring was installed on a subject vehicle. The vehicle was then driven with the spring rubbing against the inner sidewall of the tire. A small hole was created in the sidewall, which resulted in air loss, after driving 3.8 miles. No loss of vehicle control was experienced. After installing the space-saver spare tire, there was no contact between the broken spring and the tire. Driving the vehicle in this manner would only be limited to the capability and limitations of the spare tire. Figure 4 shows the orientation of the spring at the conclusion of the test. Figure 5 shows rubber that was abraded from the tire and deposited on the front of the wheel well.

Figure 4
Spring at End of Test

Figure 5
Rubber on Wheel Well

5.0 Owner Questionnaire and Survey

A questionnaire was generated and sent to owners of subject vehicles who live in the six counties immediately surrounding VRTC. Owners were asked to respond to questions regarding their experience with rear spring failures. A total of 306 questionnaires were sent out. To date, 99 responses have been received by VRTC. Of these responses, 85 owners still own the vehicle. Of these 85 respondents, 68 (80%) have not had a problem with the rear springs on their vehicle while 17 (20%) have already replaced the rear springs on their vehicle. Of these, 10 (12%) have experienced tire damage and 4 (5%) have experienced air loss. There were no reports of loss of vehicle control or crashes. The average current mileage reported by owners was 78,896. The average mileage where rear springs required replacement was 92,328. The average age of vehicles where rear springs required replacement was 67 months. These data are tabulated below.

Taurus Spring Ohio Questionnaire									
Questionnaires sent:			306		Valid Responses:			99	32%
No Longer Own	Repair not Reqd.	Already Repaired	Tire Damage	Air Loss	Loss of Control	Crash	Avg. Current Mileage	Avg. Mileage at Repair	Avg. Age @ Repair (Months)
14	68	17	10	4	0	0	78,896	92,328	67
	80%	20%	12%	5%	percentages of total responses				
		100%	59%	24%	percentages of repaired vehicles				

6.0 Strain Gage Testing

A total of nine strain gages were mounted to a new spring[1] to measure both torsional and straight strain in two regions of the spring. Gages 1 – 7 measured straight strain in the spring. Gages 8 and 9 measured torsional strain in the spring. Gages 1 – 5 were located one rotation above the lower end of the spring. Gage 3 was mounted directly over the end of the spring, gages 1 and 2 were mounted approximately 2" and 1", respectively, before gage 3, and gages 4 and 5 were mounted approximately 1" and 2", respectively, beyond gage 3. These gages were all in the area where fractures have been documented. The upper gages (6 & 7) were located more or less in the center of the spring (top to bottom) at a point where there was no coil bind. These were used as reference. The lower torsional gage (gage 8) was mounted perpendicular to gage 3. The upper torsional gage (gage 9) was mounted between gages 6 and 7. Figure 6 shows the location of the lower strain gages, consisting of five straight strain gages (1 – 5) and one torsional strain gage (8). Figure 7 shows the upper strain gages, consisting of two straight strain gages (6 and 7) and one torsional strain gage (9).

Figure 6
Lower Strain Gages

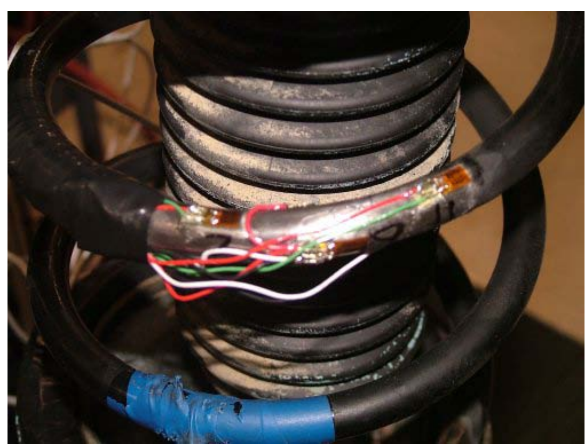

Figure 7
Upper Strain Gages

[1] A new spring was used instead of a used spring because the pitting due to corrosion on used springs prevented adequate surface preparation for mounting the strain gages.

With the spring installed in a strut and the strut installed in VRTC's United Tensile Test (UTS) machine, the spring was loaded to 1,200 lb[2] and a rate of approximately 0.5 in/sec. Upon reaching the set load, the UTS machine automatically stopped and reversed and the spring was then unloaded at the same rate.

Shown below are several data plots that illustrate the strains recorded during testing. Because of the constant application rate, the strain data are plotted vs. time[3] rather than load. The peak strain in the center of the plots represents the 1,200 lb load where the UTS machine automatically stopped and then unloaded. Figure 8 shows that the torsional strains for both the upper and lower strain gages are similar.

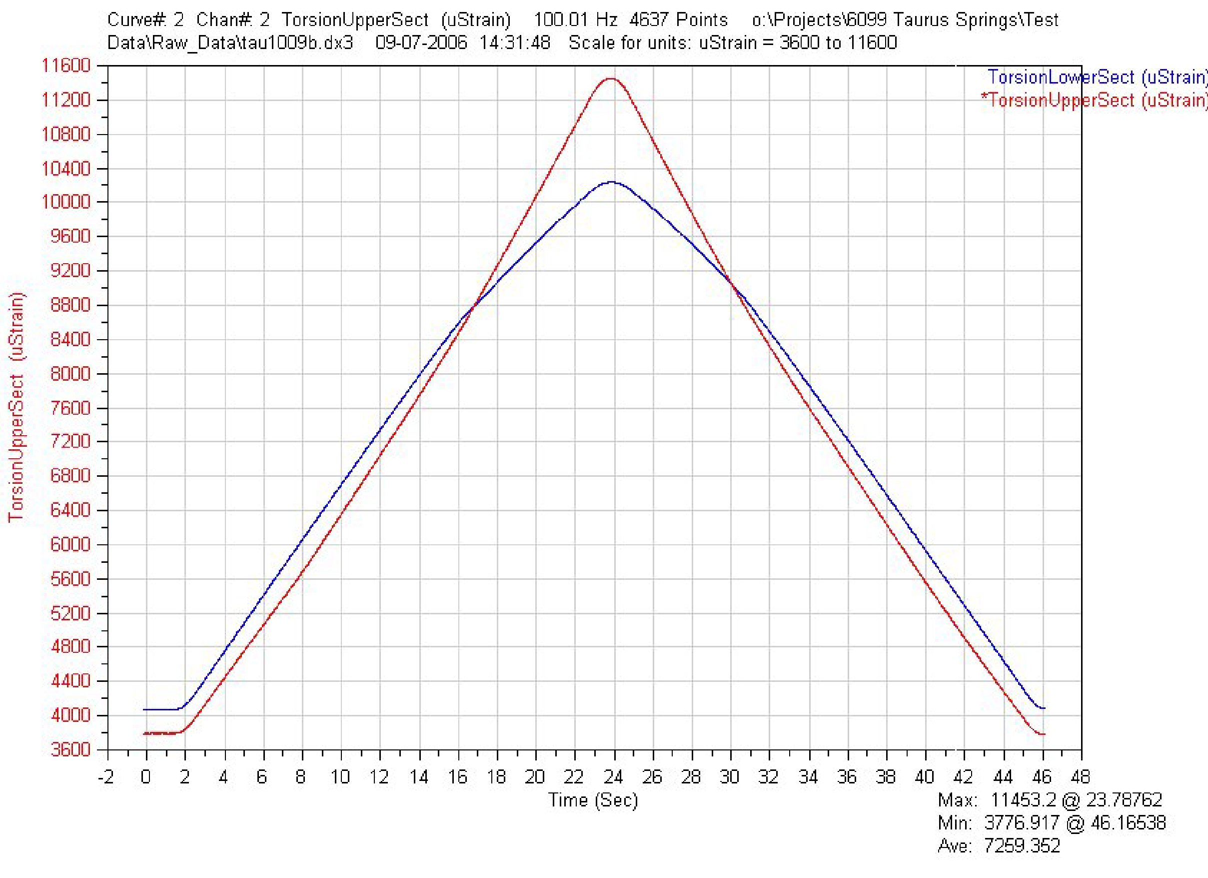

Figure 8
Upper and Lower Torsional Strain

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[2] The load of 1,200 lbs was chosen because it represents a wheel loading that slightly exceeds half of the GAWR of the rear axle.
[3] Time, rather than load, was used for purposes of clarity. When the strain readings are plotted vs. load, the data plot tends to overwrite itself as the load is reduced, thus making the plots more difficult to interpret.

Figure 9 shows the straight strain for both upper gages measuring straight strain. Like the torque values, they are similar, rise more or less gently to a peak, and then decrease as the load is reduced.

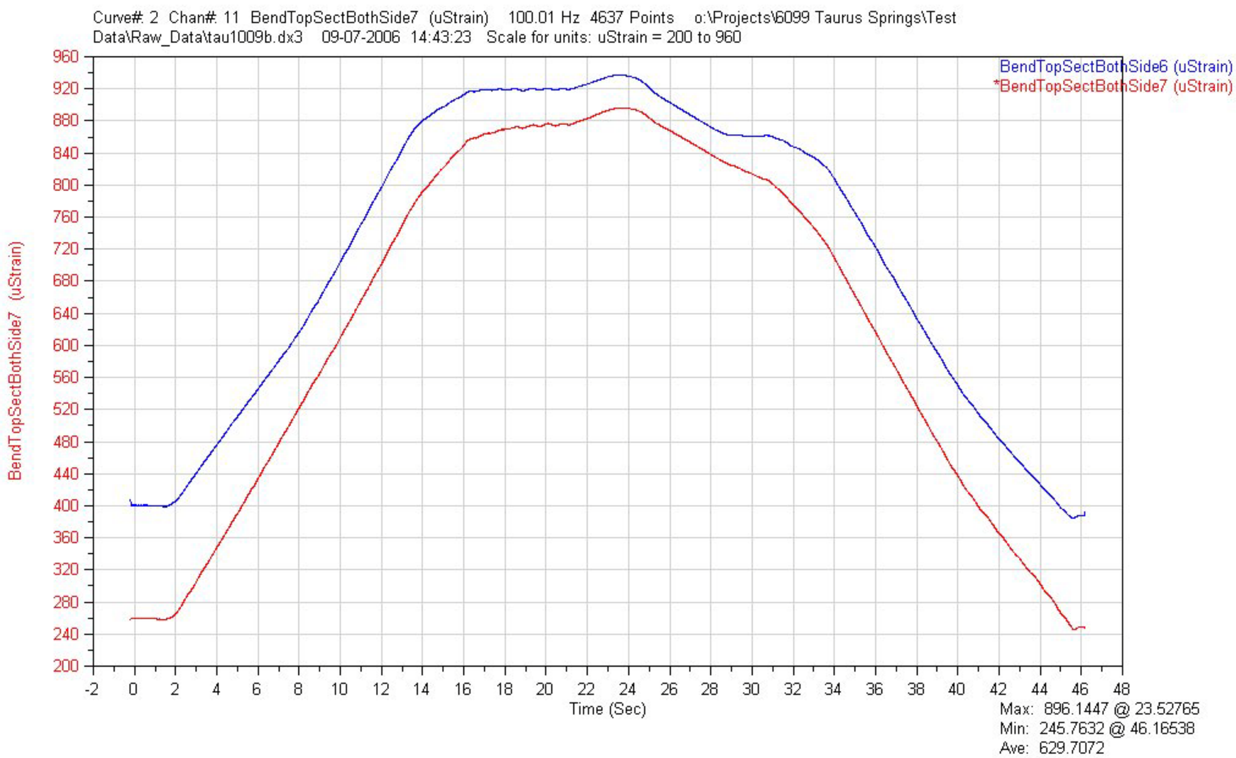

Figure 9
Straight Strain in Middle of Spring

Figure 10 shows the straight strain measured on gages 1 – 5, located on the coil directly above the end of the spring, and gages 6 and 7, (same data but different scale as Fig. 4) located in the middle of the spring. Gages 1 – 4 initially measured a reduction in strain, then an increase. Gage 5, the furthest up the spring, measured strain that approximated that of gages 6 and 7. which were located in the middle of the spring. The strain measured at gages 1 and 3 reversed sharply and then increased to almost double that measured on the other gages. The strain measured on gages 2 and 4 reversed sharply a little later than gages 1 and 3 and then increased to a level similar to gages 5 – 7. The reversal of strain at 14 seconds coincides with the point at which coil contact begins. While each of these gages starts at a different value, the differences are due to the preloading of the spring that is created when it is installed in the strut. Before mounting the spring in the strut, the output from all seven strain gages read zero.

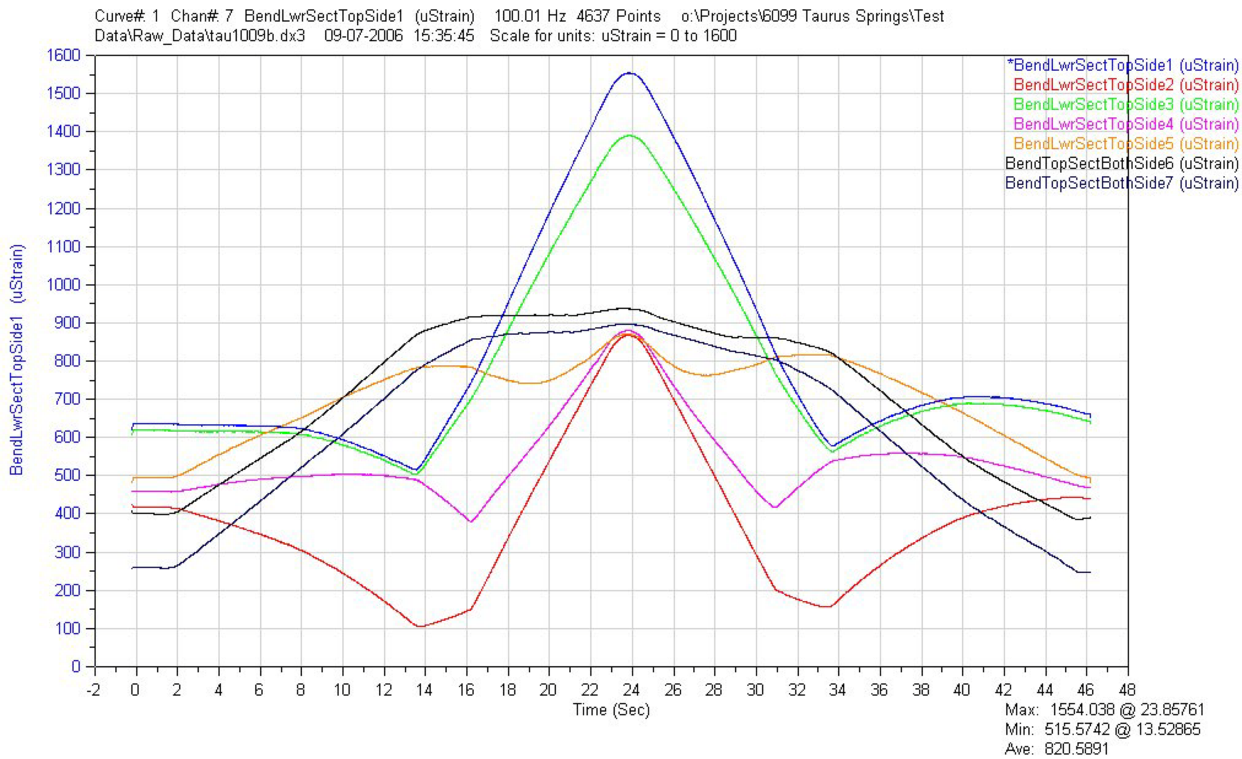

Figure 10
Straight Strain for All Seven Measured Locations

It was hypothesized that the coil-to-coil contact was causing the strain reversal that was being measured. In order to test this hypothesis, the spring was removed and inverted in the strut. This orientation placed the instrumented end at the flat upper spring mount and eliminated the coil bind at the instrumented end of the spring that was experienced in the standard mounting method. Figure 11 shows that while gage 1 still demonstrates almost double the strain of the other gages, the reversal of strain was eliminated with the spring in the inverted orientation.

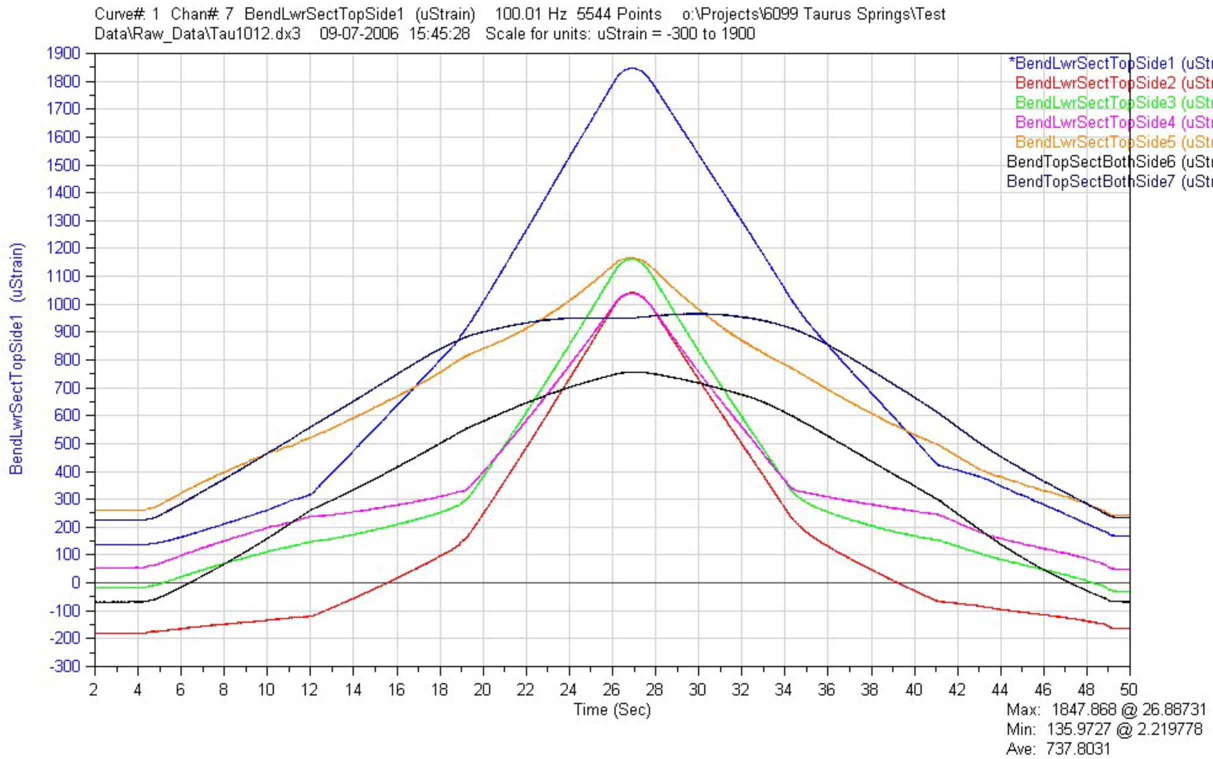

Figure 11
Strain with Spring Inverted

7.0 Summary:

Visual inspection of subject vehicles showed coil-to-coil contact between the first and second coils of the rear springs, even with the vehicle at curb weight. As vehicle loading increased, coil-to-coil contact became more pronounced and progressed further around the coil.

Visual inspections of fracture areas showed abrasion of the protective coating, and abrasion and corrosion of the spring steel.

When the fractured spring made contact with the adjacent tire, a hole was created in the tire sidewall and air pressure was lost after driving 3.8 miles. Installation of the space-saver spare tire did not result in spring/tire contact.

When compared to areas of the spring where abrasion and coil-to-coil contact do not occur, instrumented testing showed altered and increased strain patterns in the fracture region.

Consumer responses to questionnaires did not indicate that a vehicle control problem existed when a rear tire deflated due to spring contact. VRTC’s testing supported this finding when the vehicle was being driven in a straight line.