

## Engineering Analysis Closing Report

**SUBJECT:** Intermediate Steering Shaft Binding

**EA No.:** EA08-024

**OPENED DATE:** 28-Oct-2008

**CLOSED DATE:** 16-Jul-2009

**SUBJECT VEHICLES:** Model year (MY) 2004 through 2006 Toyota Sienna minivans.



Figure 1. MY 2004 Toyota Sienna

**BASIS:** On July 9, 2008, the Office of Defects Investigation (ODI) opened Preliminary Evaluation PE08-041 to investigate complaints of steering binding in MY 2004 through 2006 Toyota Sienna minivans. At the conclusion of PE08-041 the complaint rate per 100,000 vehicles was 81.0 and a warranty rate for replacement of the steering intermediate shaft (SIS) was 3.0 percent, with the majority indicating “noise” as the main concern and containing little other detail. Based on this information, ODI upgraded the investigation to an Engineering Analysis (EA08-024).

**DESCRIPTION OF COMPONENT:** The steering intermediate shaft (SIS) allows for connection of the primary steering column/shaft and the power steering rack input shaft. Because of the change in angle required, the SIS is equipped with a universal joint (Figure 2). This universal joint allows for off-axis rotation and allows steering wheel hand forces to smoothly apply torque to the steering rack input shaft.

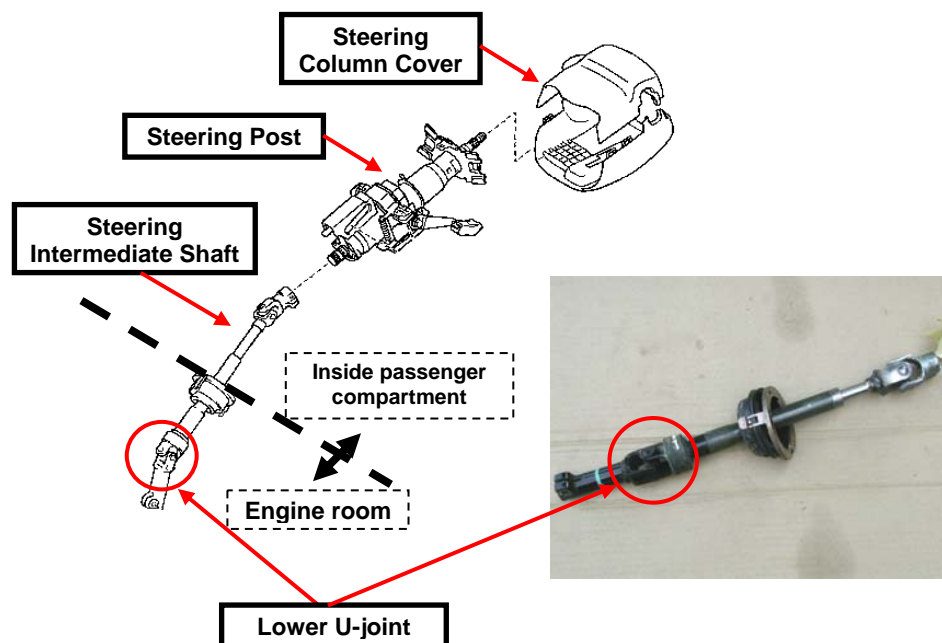
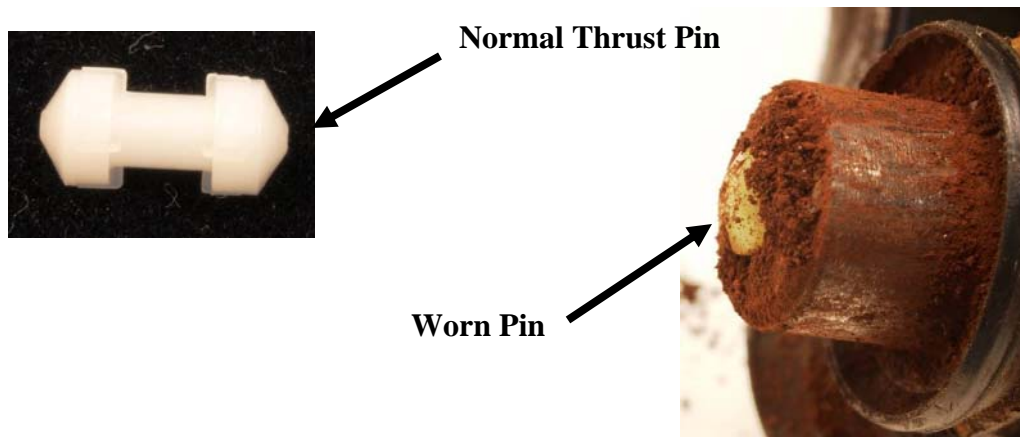


Figure 2. Component detail – steering intermediate shaft.

**ALLEGED DEFECT:** Failure of the SIS universal joint bearings (Figure 3), which can result in binding or resistance to vehicle steering.



**Figure 3. Corroded/worn thrust pin, SIS/ universal bearing.**

**FAILURE EFFECTS:** Drivers may experience increased resistance to steering efforts, particularly at low speeds. Over a period of time the condition may also be associated with some noise, such as popping or clicking when steering that indicates the need for service. In extreme cases steering response can be slow to return to neutral or exhibit increased steering effort when driving slow or making a sharp turn.

**FAILURE MECHANISM / CONTRIBUTING FACTORS:** The primary contributing factor to the alleged defect is the degradation due to thermal degradation and friction of the SIS bearing thrust pins, which leads to poor universal bearing cap seal. The failure of the seals allows water to intrude into the bearings, which then corrode, resulting in increased steering effort over time. Exposure to deicing materials (road salt) will cause the bearings to degrade faster.

**VEHICLE POPULATION:**

MODEL YEAR			Grand Total
2004	2005	2006	
216,015	170,784	198,429	585,228

**Table 1. Subject vehicle sales by model year.**

**FAILURE REPORT SUMMARY:** ODI has identified 149 complaints and 1,164 Toyota warranty claims for SIS repairs with no crash incidents. The current complaint rates by regions are 53.0 and 9.0 per 100,000 vehicles for salt vs. non-salt States.

Problem Experience	EA Opened			EA Closed		
	ODI	Toyota	Total	ODI	Toyota	Total
Owner Reports / Field Reports	16	67	80	43	109	149
Claims/Lawsuits	-	-	-	-	-	-
Crashes/Injury	-	-	-	-	-	-
Fatal Incidents	-	-	-	-	-	-
Warranty Claims	-	914	914	-	1,164	1,164

**Table 2. Problem Experience.**

**WARRANTY:** ODI’s analysis of warranty claim data provided by Toyota show that the alleged defect has occurred predominantly in salt-belt<sup>1</sup> states, which account for 38.9 percent of the subject vehicles sales and 75.3 percent of warranty claims. Based on the available technician or owner comments associated with the warranty claims, the most frequent owner complaints were for noisy steering or stiff steering when parking or turning at low speeds.

**DESIGN CHANGES:** In it’s response to ODI’s information request, Toyota indicated that concerns with binding of the steering intermediate shaft were first identified and investigated in October 2005. In September 2006, Toyota implemented changes to the universal joint bearing thrust pin and seal material. The new material has a higher heat resistance which reduces the potential for deformation of the thrust pin and bearing seals.

**TESTING:** NHTSA’s Vehicle Research Test Center (VRTC) conducted testing to assess the effects of the alleged defect on steering effort when nearly stopped (parking lot maneuvers) and during dynamic turning/cornering<sup>2</sup>. The testing consisted of a series of static steering tests to determine the baseline hand wheel forces required for a NEW vs. BAD steering shaft and several on road driving tests including the “worst case” engine off, no power steering assist operating. The dynamic tests were conducted using a MY 2004 Sienna instrumented and continuously monitored for hand wheel forces, speed and lateral acceleration. The tests were conducted by driving a simulated mix of daily conditions and a slalom course used to measure hand wheel force as a function of lateral acceleration (turning speed). For the first test, the simulated mix road driving with the normal steering shaft hand wheel forces for all conditions varied from 1.0 to 3.0 lbf, and with the bad steering shaft forces varied from 1.0 to 11.0 lbf. In a second test, after remaining at rest for several days, the vehicle was driven through the same slalom course as the previous test. With the engine off, considered the “worst case” condition, transmission in neutral and coasting down from a straight-line speed of 40 mph the vehicle hand wheel forces were measured. For this case, engine off, no steering assist the maximum gain (percent increase in effort) occurred at 0.1 lateral g and steering the force increase was 11 lbf to 12 lbf (8.3% change). The results for all conditions are shown in Table 3.

<b>VRTC Dynamic Steering test</b>			
Lateral acceleration (g’s)	Hand wheel force (lbf)		Gain (%)
	New Shaft	Bad Shaft	
0.1	11	12	8.3
0.2	22	22	0.0
0.3	31	32	3.0
0.4	37	38	2.6

**Table 3. Dynamic steering gain forces.**

**MANUFACTURERS TESTING AND EVALUATION:** In response to ODI’s information request letter in PE08-041, Toyota provided test data showing the effects of the alleged defect on dynamic steering efforts using the European Union ECE regulation 79, “Steering Effort Test” procedures. No regulation governing steering efforts is required in the United States. The ECE 79

<sup>1</sup> For purposes of this investigation the “Salt Belt” includes Connecticut, Delaware, the District of Columbia, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia and Wisconsin.

<sup>2</sup> Refer to the VRTC final report in the document file for EA08-024.

regulation requires vehicles sold in countries requiring compliance with ECE79 must meet minimum steering efforts when power steering assist is lost. The European standard specifies that steering efforts not exceed 15 daN (34 lbf) for intact systems and 30 daN (68 lbf) for systems with a failure for the vehicle category applicable to the Sienna (4-wheel passenger vehicles with no more than 8 seat positions), when turned through radii of 12 m (39 ft) for intact systems and 20 m (49 ft) for systems with a failure at a constant speed of 10 km/h (6 mph). The test conditions used by Toyota to assess the alleged defect in the subject vehicles were slightly more stringent than those required by ECE 79. Toyota's testing of several exemplar Sienna vehicles showed that the maximum steering effort required while turning in a 10 m (33 ft) radius curve at the ECE 79 specified speeds was 3.3 daN (7.4 lbf) for the worst corroded SIS part used.

**TECHNICAL SERVICE BULLETIN:** In February 2004, Toyota issued a technical service bulletin (TSB-ST003-004, "Steering Intermediate Shaft Noise"), providing dealers with information to diagnose and repair complaints associated with the alleged defect in the subject vehicles. In January 2007, Toyota released a second bulletin (TSB-ST001-07, "Steering Intermediate Shaft In High Road Salt Areas") with additional instructions for diagnosing and repairing the subject condition.

**REASON FOR CLOSING:** ODI's analysis of the warranty data shows that the alleged defect has occurred in 0.2 percent of the subject vehicle population. When the analysis is limited to salt-belt states, the rate is still well below one percent of the population (0.4 percent). In addition, tests conducted by ODI and Toyota have shown that the alleged defect has a minimal effect on steering efforts. ODI interviews of owners who experienced the alleged defect indicated that in most cases the problem was preceded for some time by odd noises while steering or a gradual increase in steering efforts when the vehicle was cold and first started. The subject vehicles have been in service for 4 to 5 years with no crashes or injuries associated with the alleged defect. Toyota's technical service bulletin provides assistance to service technicians in the early diagnosis and repair of the alleged defect condition.

Accordingly, this investigation is closed. The closing of this investigation does not constitute a finding by NHTSA that a safety-related defect does not exist. The agency will continue to monitor complaints and other information relating to the alleged defect in the subject vehicles and take further action in the future if warranted.

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