U.S. Department of Transportation
National Highway Traffic Safety Administration

ODI RESUME

Investigation: EA 05-017
Prompted By: PE04-080
Date Opened: 10/28/2005 Date Closed: 04/30/2007
Principal Investigator: Peter Kivett
Subject: Hummer H2 Steering Knuckle Failures

Manufacturer: General Motors Corp.
Products: General Motors Model Years 2003 - 2006 Hummer H2
Population: 138,194

Problem Description: The steering knuckle fails resulting in a collapse of the front suspension system and/or wheel separation.

FAILURE REPORT SUMMARY

	ODI	Manufacturer	Total
Complaints:	6	20	24
Crashes/Fires:	6	9	15
Injury Incidents:	1	1	1
# Injuries:	1	1	1
Fatality Incidents:	0	0	0
# Fatalities:	0	0	0
Other*:	0	0	0

*Description of Other:

Action: This investigation is closed. A safety related defect trend has not been discovered. See attached report for complete details.

Engineer: *Peter Kivett* PHK Date: *04/30/2007*
Div. Chief: *Richard Boyd* Date: *04/30/2007*
Office Dir.: *Kathleen C. DeMeter* Date: *04/30/2007*

Summary: ODI upgraded this investigation at the conclusion of PE04-080. The alleged defect involves the failure of the steering knuckle at the lower ball joint boss, resulting in a separation of the lower ball joint from the knuckle. A lower ball joint separation could result in a loss of steering and/or a disabled vehicle.

It appears that the fractures of H2 steering knuckles can be attributed to wheel/tire collision forces being transferred directly to the steering knuckle. The original knuckle design appears to be sufficient for the H2 application. Evidence from inspected vehicles, photographs, police reports and EDR data indicates collision impact events placed stress on the steering knuckle causing it to fracture.

Further use of agency resources does not appear to be warranted. The closing of this investigation does not constitute a finding by NHTSA that no safety-related defect exists with regard to the subject component. The agency reserves the right to take further action on this issue if warranted

PHK

[redacted]

ENGINEERING ANALYSIS CLOSING REPORT

SUBJECT: STEERING KNUCKLE FAILURES

EA No: EA05-017 **Date Opened:** 28-Oct-2005 **Date Closed:** 30-April-07

BASIS: ODI opened a Preliminary Evaluation (PE04-080) on December 2, 2004 to investigate allegations of four steering knuckle failures involving model year (MY) 2003 – 2004 Hummer H2 vehicles manufactured by General Motors (GM). On October 28, 2005, the investigation was upgraded to an Engineering Analysis (EA) and expanded to cover all H2 vehicles ranging from MY 2003 - 2006.

SUBJECT VEHICLES: (MY) 2003 – 2006 Hummer H2 vehicles manufactured by GM. During the investigation, ODI also obtained peer data on similar types of vehicles.

ALLEGED DEFECT: The alleged defect involves the failure of the steering knuckle at the lower ball joint boss, resulting in a separation of the lower ball joint. A lower ball joint separation would ordinarily result in a loss of steering, a disabled vehicle and, in some cases, a wheel/tire separation.

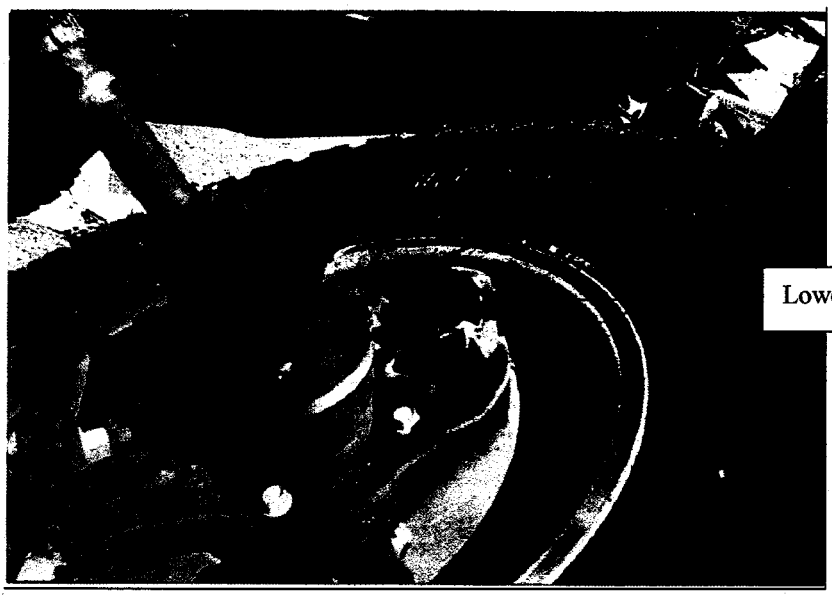

Figure 1. Front suspension steering knuckle failure-
MY 2003 Hummer H2

SUBJECT COMPONENT DESCRIPTION: The steering knuckle is attached to the chassis by an upper and lower control arm. The weight of the vehicle is supported by a stabilizer shaft link attached to the lower control arm, shock absorber and torsion bars. The steering knuckle material specification is and remains SAE standard J434 as Grade D4512. Grede Foundries produces the knuckle in two plants located in Reedsburg, Wisconsin and St. Cloud, Wisconsin.

SUBJECT VEHICLE COMPLAINT SUMMARY: ODI focused on three H2 populations that are separated by build dates. Build dates were demarcated by material part changes and torque specification changes. The first population covered H2 vehicles manufactured from March 12, 2002 (First Production H2) to June 9, 2003. From this first population, ODI learned of 24 allegations of fractured knuckles. These allegations came from ODI and GM complaints and GM warranty claims. Of these 24 knuckle fracture allegations, 15 of these alleged that a crash occurred that resulted in minor property damage. ODI is aware of three minor injuries stemming from these alleged knuckle failures. A majority of owners state the vehicles were not subject to abusive conditions and knuckles failed during routine driving. However, the available evidence does not include any knuckle failures that occurred prior to any accident.

The second population ODI examined were those H2 vehicles built from June 9, 2003 – June 1, 2005. Within this population, ODI is aware of 8 allegations of knuckle fractures, including 5 crashes. There was one injury to a consumer's wrist.

The third population involved H2 vehicles built since June 1, 2005. ODI is unaware of any knuckle fractures occurring within this population. The relevant complaint data are summarized in Table 1 below:

Table 1

Build Dates	Population	Knuckle failures	Rate per 100/K	Crash allegation
March 2002 to June 2003	41,518	24	57.8	15
June 2003 – June 2005	71,546	8	11.2	5
June 2005 – Nov 2006	25,130	0	0	0

PEER DATA COMPLAINT SUMMARY: As part of a peer review, ODI requested complaint and warranty information from other manufacturers concerning failed knuckles. ODI classified "failed" knuckles as those that the manufacturer coded as "cracked" or "broken." Table 2 shows the complaint and warranty rates for these peer manufacturers.

Table 2

MFR	MY-s	Total Pop	Applicable Warranty	Applicable Complaints	Total	Rate per 100K vehicles
Ford	2003-04	335,222	0	4	4	1.2
DaimlerChrysler	2003-07	126,181	0	2	2	1.5
Chrysler	2003-07	827,616	20	3	23	2.8
*GMT 400	1996-99	69,569	4	0	4	5.7
Pre *GMT 800	2000-June 9 2003	994,986	85	0	85	8.5
Post *GMT 800	June 9 2003	697,309	9	0	9	1.3

(* GMT: peer GM vehicles that use the same steering knuckle)

DESIGN CHANGES AND SERVICE LAUNCH DATES FOR THE SUBJECT COMPONENT: During the production of the H2, GM incorporated a number of evolutionary changes that affected the design of the knuckle and its assembly process. Table 3 below provides the process and design changes for the H2 and the date of introduction of each.

Table 3

Date Modification went into Production	Detailed Description of the Modification or Change	GM's Reasons for the Modification or Change	Whether the original unmodified component was withdrawn from production and/or sale, and if so, when?
09 JUNE 2003 (Delphi Ship Date)	Change the H2 Knuckle (casting) to modify the lower ball stud boss by moving the locator pads 1.0 mm out from the knuckle centerline, add material to the outside diameter on the boss and blend with increased fillet radii.	Product Improvement	Yes. 09 June 2003 (Delphi Ship Date)
09 JUNE 2003	Lower ball joint torque spec increased from 100 +/- 10 Nm to 110 +/- 10 Nm	Product Improvement	Yes. 09 June 2003 (Delphi Ship Date)
DECEMBER 2003	Changed machining of lower ball stud from a two pass machining operation to a one pass machining operation.	Supplier Efficiency improvement	Not withdrawn from production. December 2003
01 JUNE 2005 (Production Implementation)	Modified LBJ torque spec from 110 +/- 10 Nm to 50 Nm + 90 Deg +/- 3 Deg	Product Improvement	N/A process change

As indicated above, GM redesigned the steering knuckle boss (see Figure 2), removed the old knuckle from production and/or sale, and began installing the redesigned knuckle on June 9, 2003. Assembly line torque applied to secure the ball joint stud to the knuckle was also increased from 100 to 110 Nm. GM made a subsequent change to the torque specifications in June 2005, changing it to 50 Nm + ¼ turn, which helps ensure proper draw-in of the stud and a tight joint. GM also increased the tire pressure from 35 to 44 psi. This change, allegedly based on fuel economy improvements, also diminishes friction at the road/tire interface and reduces stress on the steering system.

Figure 2, below, depicts both the MY 2003 (used until June 2003) and the post-June 2003 steering knuckles used on the H2. The MY 2003 knuckle on the left can be readily identified by the notches that form the smallest cross-sectional plane as denoted by the arrows. The post-June

2003 knuckle on the right has a thicker (2 mm) boss. These later knuckles use the increased 50 Nm + ¼ turn torque specification starting on June 1, 2005.

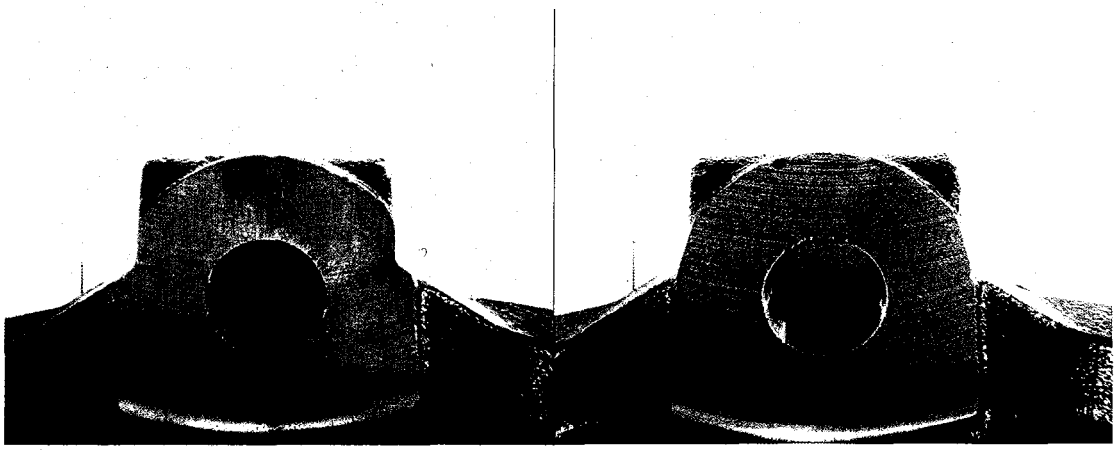

Figure 2

POTENTIAL FAILURE MODES: During the course of the investigation, ODI developed several interrelated theories concerning the failure mechanism of the H2 steering knuckle. ODI considered whether:

1. insufficient surface contact between the lower ball joint stud and lower ball joint hole resulting from variations in the machining process could increase stresses within the joint to a critical level;
2. the unusual occurrence of a highly pearlitic microstructure could reduce the fracture toughness of a steering knuckle, compromising the ability of the knuckle to remain intact;
3. the manufacturing process of using a measure of "torque only" was a reliable indicator of sufficient "draw-in" of the tapered stud-to-hole interface required for joint strength;
4. overload could be achieved from foreseeable events, including reasonably-to-be-expected vehicle abuse for a vehicle marketed for uses such as the H2 is marketed, including road perturbations or very low speed collisions (velocity changes of less than five miles per hour);
5. the original design of the knuckle provided insufficient material to withstand reasonable loading events including ordinary use; in this respect the original design may be compared to the redesigned knuckle, where additional material added considerable strength.

EVALUATION OF FAILURE MODES

1. Surface contact specifications indicate that no less than 75% of the two surfaces (being the stud and the tapered hole) must be in contact to prevent stress concentrations that could cause an inadvertent overload (See Figure 3). All samples retrieved from the field indicated surface contact percentages were within specification.

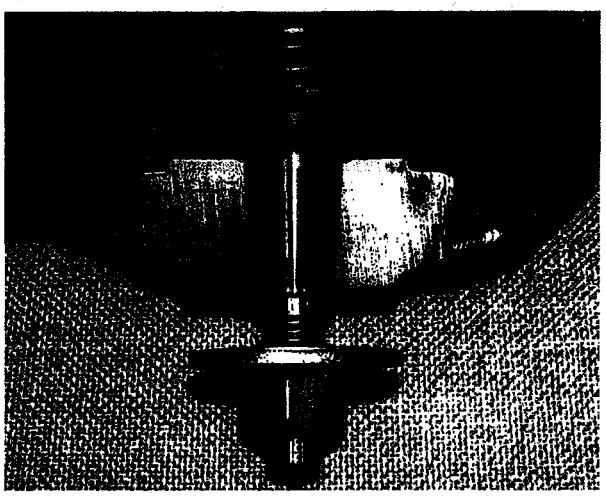

Figure 3

2. Pearlite is a microstructure that forms in ductile iron, which can possess harder but more brittle properties than the normally predominant [in the D4512 ductile iron] microstructure, Ferrite. Significant metallurgical testing was performed at VRTC that established wide variation in levels of Pearlite in the subject knuckles. Tests conducted at VRTC indicated that higher amounts of Pearlite did not reduce fracture toughness sufficiently to compromise the steering knuckle.
3. A field survey of 61 consumer and dealer owned H2's was conducted that indicated that most lower ball joints were not torqued to the GM specified level of 100 Newton Meters (See Table 4). Dynamic tests were conducted at VRTC using a variety of torque levels based on the results of the field survey. It was found that reduced torque in the observed range did not reduce the joint integrity sufficiently to compromise the steering knuckle. Additionally, bench tests indicated that a knuckle at only 33 Newton Meters retained 86% the ultimate strength of a joint tightened to 100 Newton Meters. Table 4 also provides summary data highlighting the effectiveness of the torque specification changes made by GM as production of the H2 moved into the 2004 and 2005 model years.

Torque to Turn (Tighten) Survey

(Units in Nm)	Torque Spec.		
	100Nm *To 6/03*	110Nm *To 6/05*	50Nm+90D *To Present*
Average	73.8	77.1	91.3
St.dev.	14.2	16.6	12.4
Range	67	68	51
Max	102	111	120
Min	**35**	**43**	**70**
Count	45	34	42

Table 4

4. A battery of driving tests with an electronically instrumented Hummer H2 at VRTC revealed that the steering knuckle could withstand all non-collision tests conducted by the agency. To produce a compromise of the knuckle required a direct collision with a large heavy object in excess of five miles per hour.
5. The original subject steering knuckle and the redesigned larger knuckle were tested for strength differences through destructive tensile testing. It was concluded that the new style knuckle was significantly more resistant to failure than the original knuckle. However, since the original knuckle had not failed in any dynamic, non-collision test, there was no basis for concluding that the earlier design was inadequate.

GM's POSITION: GM states that for eight of the fifteen alleged failures, the available evidence indicates a collision caused the failure of the steering knuckle by inducing an impact overload event. After reviewing and analyzing field performance data, incident reports, parts, crash sites, police reports, vehicle inspections, event data recorder downloads and other relevant information, GM determined that the steering knuckles were failing due to single overload events as a result of collisions with other objects. There are 7 other incidents where neither ODI nor GM has any indication that the involved Hummer struck any other vehicle.

REASON FOR CLOSING: When the front wheel of the vehicle is maneuvered into a large heavy object, specific impact markings are created at the knuckle/steering link interface. To date, all available knuckles recovered from the field exhibit this marking pattern. This indicates that they experienced collisions. In these vehicles, it is quite possible that the driver would not observe a curb strike or other similar impact due to the high, long and wide hood, and the absence of low fender material that otherwise might be damaged. In addition, testing indicated that if a joint is not tight, it still retains sufficient strength to maintain structural integrity for its intended use. Other potential causes for knuckle failure were examined but did not support a finding that the knuckles would fail from ordinary use.

It appears that the fractures of H2 steering knuckles can be attributed to wheel/tire collision forces being transferred directly to the steering knuckle. The original knuckle design appears to be sufficient for the H2 application. Evidence from inspected vehicles, photographs, police reports and EDR data indicates collision impact events placed stress on the steering knuckle, causing it to fracture.

ODI also notes that there have been no reports of knuckle failure in the subject vehicles since November 2006. The lack of physical evidence indicating that the knuckles fail without a preceding vehicle crash led ODI to conclude that the likelihood of additional fractures occurring is minimal. In light of the nature and circumstances of the reported problems, further use of agency resources does not appear to be warranted. The closing of this investigation does not constitute a finding by NHTSA that no safety-related defect exists with regard to the subject component; however, the agency reserves the right to take further action on this issue if warranted.

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Safety Defects Engineer

4/30/07
Date

I Concur:

Chief, Medium & Heavy Duty Vehicle Division

4/30/07
Date

Director, Office Of Defects Investigation

4/30/07
Date

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