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4446-4	Oct 26, 2011	Check for cracks in studs removed from Calgary vehicle

Quality Associates – Metallurgical Services

1795 Foundation Drive – Niles, MI 49120 Phone 269-695-2623 FAX 269-695-4423

TO: Tom Peck
DRV
100 West 750 N
Howe, IN 46767

15 June 2011

SUBJECT: Paint Thickness

OBJECT: Measure the paint film thickness on three brake rotor hub faces. Check to see if there is a measureable film thickness on the face of an aluminum wheel.

RECEIVED: Three brake rotors and one wheel were submitted for analysis.

CONCLUSION: Test results are provided herein.

TEST DATA:

Visual Examination

Paint was worn off the entire mounting face of rotor 1 (Figure 1). Some paint remained on the hub face between the boss contact faces on rotor 2 (Figure 2). The as-painted rotor had paint on all contact surfaces (Figure 3).

The mounting face on the wheel exhibited an outline of contact with the rotor face (Figure 4).

Film Thickness per ASTM D1186 and D1400

Paint film thickness was measured using an Elcometer Model 456. Film thickness on the rotors varied with location on the face. Therefore, it was measured in four different locations off each stud (Figure 5), with studs numbered in a clockwise sequence. Test locations included:

A – as cast scallop surface between wheel studs
B – machined face half way between the wheel studs
C – mounting face outboard of the wheel stud
D – mounting face inboard from the wheel stud

Test results (Table I) showed that the average film thickness ranged from 0.0015 to 0.0040 inches, with individual readings ranging from 0.0013 to 0.0059 inches.

No detectable film was found on the face of the wheel.

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Lab File 4398

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ATTACHMENTS: Figures 1 to 5
Table I

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Lab File 4398

Table I. Paint Film Thickness by Location in Each Rotor, Inches							
Wheel Bolt No.	Rotor 1	Rotor 2		Rotor 3			
	A	A	B	A	B	C	D
1	0.0028	0.0044	0.0057	0.0024	0.0035	0.0036	0.0018
2	0.0030	0.0046	0.0059	0.0017	0.0034	0.0032	0.0014
3	0.0027	0.0027	0.0028	0.0021		0.0030	0.0013
4	0.0029	0.0015	0.0028	0.0027		0.0028	0.0013
5	0.0029	0.0010	0.0027	0.0029		0.0033	
6	0.0040	0.0026	0.0040	0.0022		0.0030	
7	0.0036	0.0031	0.0040	0.0017	0.0027	0.0031	0.0021
8	0.0023	0.0035	0.0044	0.0022	0.0033	0.0032	0.0013
Average by Location	0.0030	0.0029	0.0040	0.0022	0.0032	0.0032	0.0015

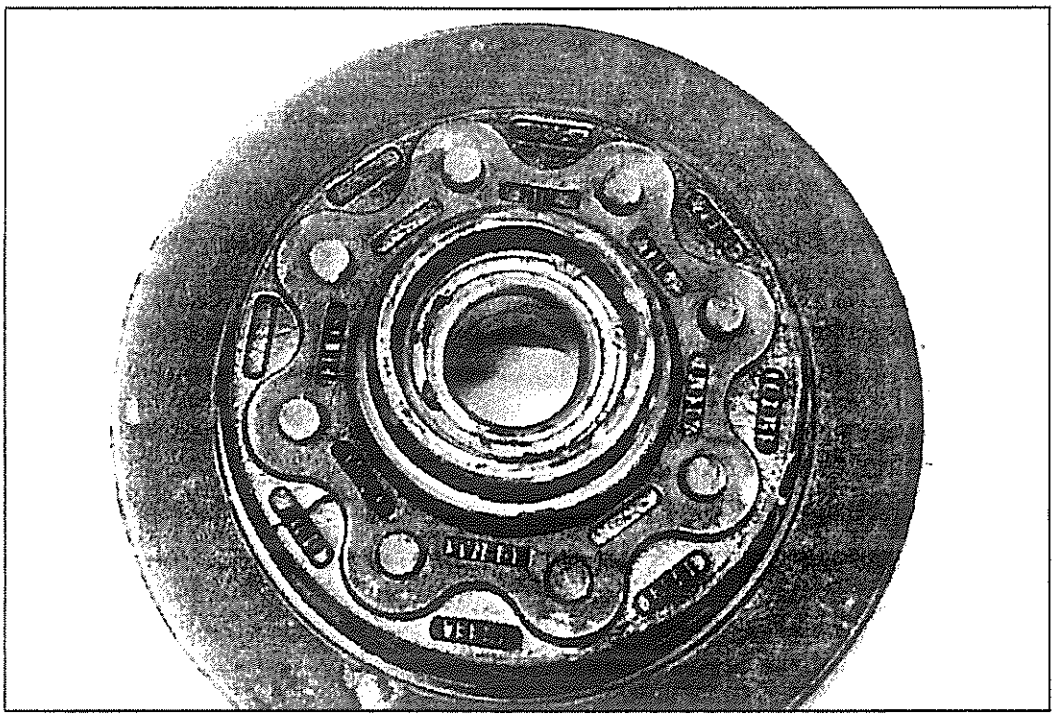

Figure 1. Rotor sample 1 – showing that the paint had been worn off the entire mounting face, leaving paint only on the cast surface

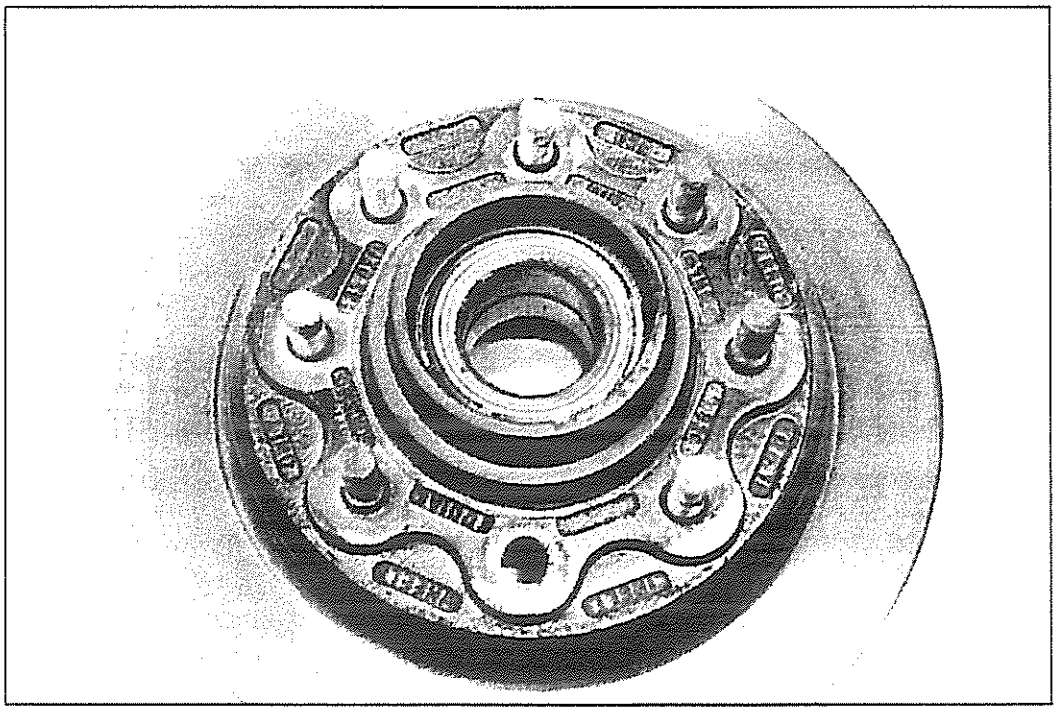

Figure 2. Rotor 2 – paint was worn off the contact surface, but remained on the face between the bosses and on the cast surface

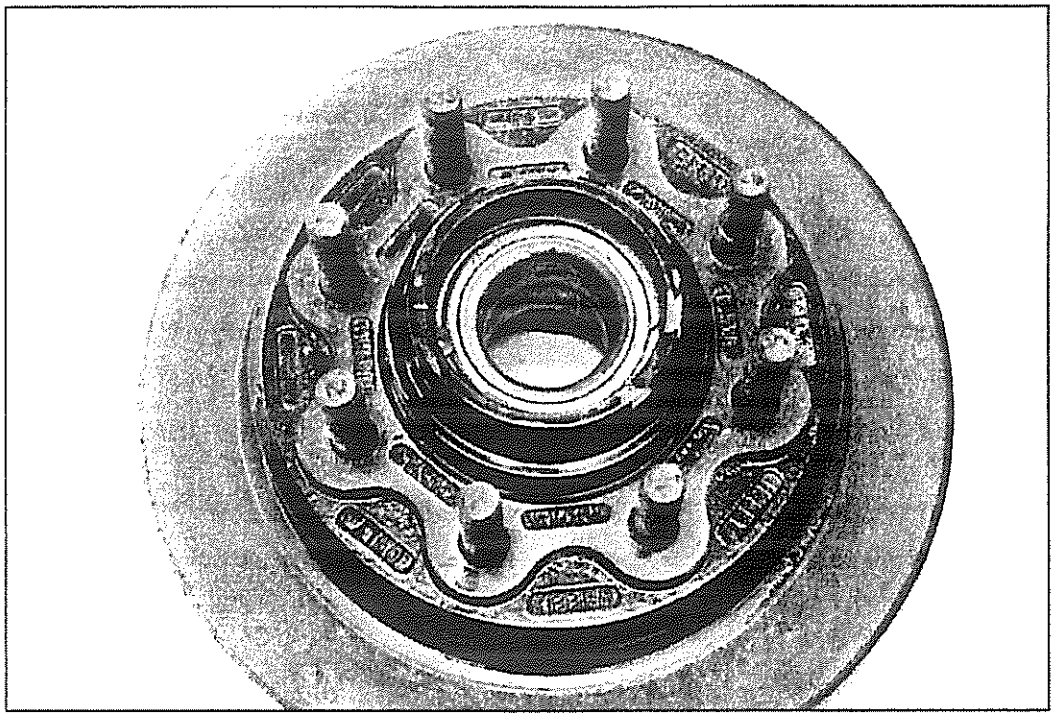

Figure 3. Rotor 3 – showing paint on the entire mounting face and on the cast face

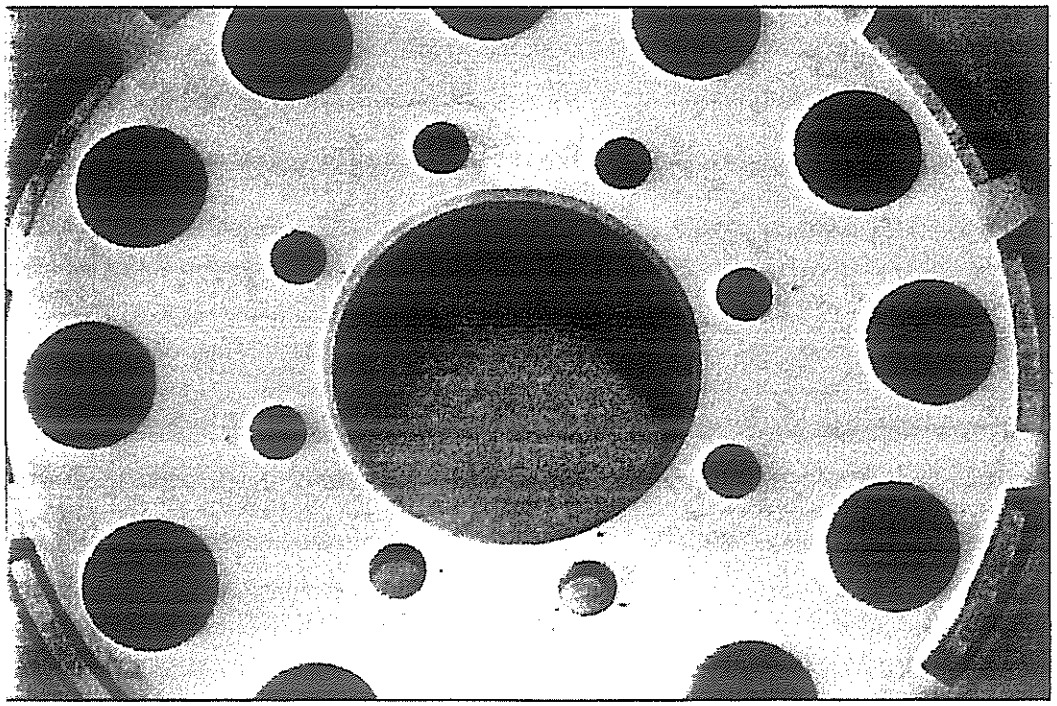

Figure 4. Wheel faces – showing the apparent outline of the contact face with the rotor

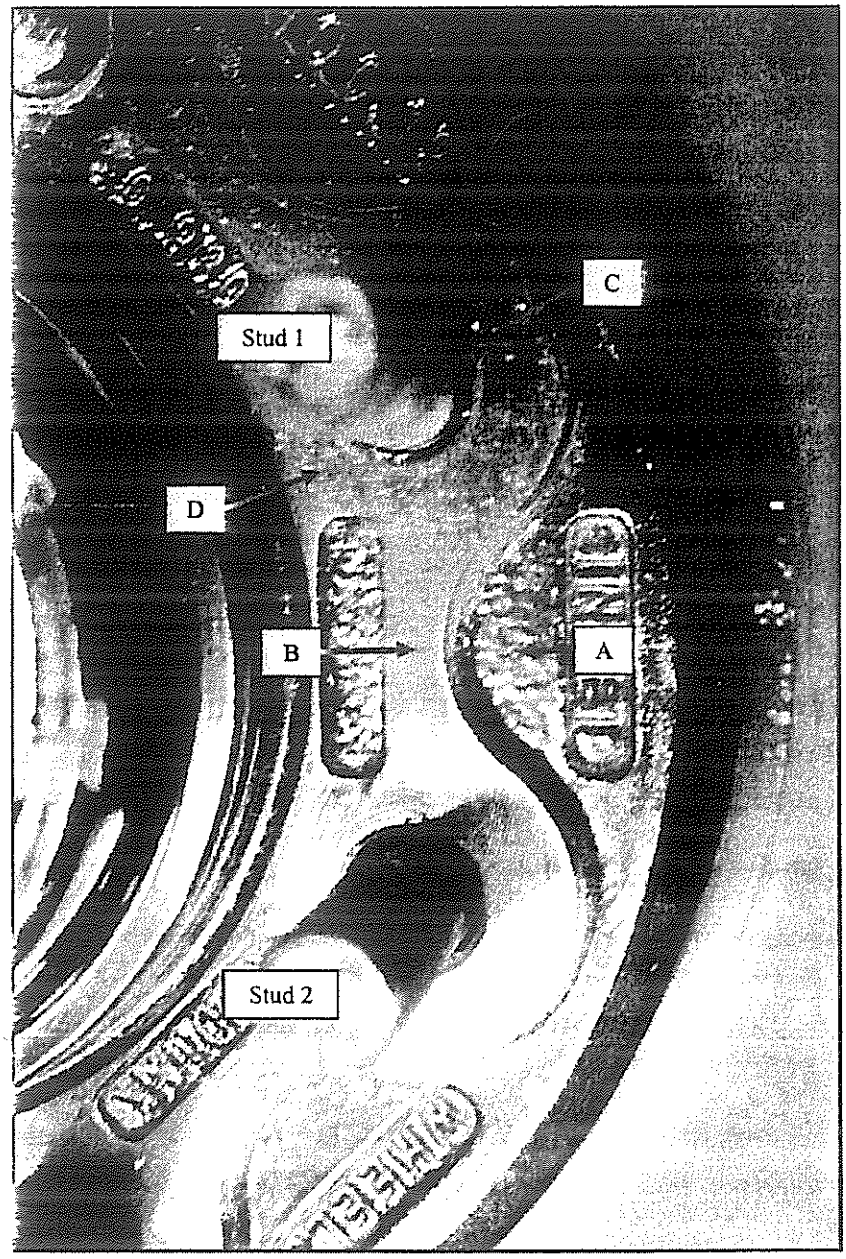

Figure 5. Showing the four locations of paint film thickness measurement relative – measurements were made in a clockwise direction from stud 1 to stud 8

Table I. Paint Film Thickness by Location in Each Rotor, Inches												
Wheel Bolt No.	Rotor 1				Rotor 2				Rotor 3			
	A	B	C	D	A	B	C	D	A	B	C	D
1	0.0028	0.0003	0.0006	0.0002	0.0044	0.0057	0.0004	0.0004	0.0024	0.0035	0.0036	0.0018
2	0.0030	0.0005	0.0004	0.0003	0.0046	0.0059	0.0002	0.0000	0.0017	0.0034	0.0032	0.0014
3	0.0027	0.0003	0.0006	0.0001	0.0027	0.0028	0.0003	0.0001	0.0021	0.0031	0.0030	0.0013
4	0.0029	0.0004	0.0006	0.0002	0.0015	0.0028	0.0000	0.0000	0.0027	0.0030	0.0028	0.0013
5	0.0029	0.0005	0.0007	0.0004	0.0010	0.0027	0.0002	0.0001	0.0029	0.0032	0.0033	0.0016
6	0.0040	0.0006	0.0003	0.0002	0.0026	0.0040	0.0001	0.0003	0.0022	0.0031	0.0030	0.0017
7	0.0036	0.0002	0.0007	0.0003	0.0031	0.0040	0.0004	0.0001	0.0017	0.0027	0.0031	0.0021
8	0.0023	0.0004	0.0003	0.0002	0.0035	0.0044	0.0002	0.0001	0.0022	0.0033	0.0032	0.0013
Average by Location	0.0030	0.0004	0.0005	0.0002	0.0029	0.0040	0.0002	0.0001	0.0022	0.0032	0.0032	0.0016
Comment		Worn Face	Worn Face	Worn Face			Worn Face	Worn Face				

2011-0932
Calgary Field inspection report

VEHICLE DETAILS

Model:	36 TKSB3		Model Year: 2011
Manufacturer:	DRV		Make: MOBILE SUITES
Vehicle Class:	TRAILER		Body Type: TRAILER TRAVEL
VIN:	5KEFA3624B	Verified: Yes	Odometer: 7,000 km
Date Mfrd:	06/07/2010	Purchased: 20/08/2010	Purchase Type: New
Incident Date:	18/06/2011	Vehicle Speed: 90 km/h	

PROBLEM

The case vehicle's left rear wheel studs fractured and the wheel separated while traveling on a rural highway.

VEHICLE INSPECTION

The travel trailer was jointly inspected by the field investigator and a consultant hired by the trailer manufacturer. The left rear wheel had separated from the trailer and caused damage to the left rear of the trailer. The wheels were hub piloted and fastened to the hub by eight 9/16" SAE Grade 8 studs and tapered 18-thread wheel mounting nuts. The studs were splined and press fit into the back side of the wheel hub. The hub face was coated in black paint.

Three of the studs were missing from the failed wheel assembly. The field investigator pressed on the remaining studs and noted they were secure. The complainant was in possession of one of the separated studs and provided it to investigators. All of the fractured studs broke at the thread closest to the bolt head. The fracture surfaces of the studs were photographed and attached to this report. At least one of the stud's (stud #2) fracture surfaces exhibited clear beach marking and a separate and distinct brittle fracture surface. This is indicative of a fatigue failure. Some of the other studs may have also displayed less obvious evidence of fatigue loading. A review by a metallurgist is recommended.

None of the stud holes exhibited obvious evidence of being out-of-round. The interior surfaces of the holes were observed. They had been coated in black paint. The interior surface did not display any obvious evidence of localized yielding from the stud splines. Many of the splines on the recovered stud that separated from the hub were observed to contain a dark, hard material.

All four hub faces were coated in black paint. Much of the paint was observed to be lifted from the hub face at the stud locations. The three remaining wheels had paint deposit on the back side of the rim at the wheel mounting locations. The manufacturer retained the hubs to conduct paint thickness tests.

The torque on the remaining three wheels was measured jointly by the field investigator and consultant. A chart of the measured torques is attached to this report. Torque values ranged from 45 to150 ft-lbs (61 to 203 N-m). The manufacturer's recommended torque values, identified on a red and white sticker on the pin box, were 120 to 125 ft-lbs (163 to 169 N-m). No cracking or failures were noted on any of the studs at the remaining three wheel locations. One of the studs on the right front wheel was difficult to remove. Metal shavings were observed on the stud treads after removal. All available hubs, studs, lug nuts, and wheels were retained by the trailer manufacturer for testing.

The available rims were size 16X6.5J and stamped A855. The field investigator is unaware of the meaning of the stamp. ASTM designation A855 refers to a zinc-5% aluminum-mischmetal alloy-coated steel wire strand. Thus, this stamp does not appear to be an ASTM designation. The rims are assumed to have been manufactured from aluminum. The rims were stamped with a rated load of 3750 lbs (1700 kg), which is consistent with the GAWR. The tires were LT235/85R16 Goodyear G614 RST. The maximum rated load for the tire and rim was 3750 lbs (1700 kg) each, which is also consistent with the GAWR.

Weight distribution of the trailer was provided by the trailer owner. The weight of the finished unit was measured at the factory prior to shipment. In the empty condition with the trailer resting on its front landing gear, the weight on the left rear wheel was 2390 lbs (1084 kg). The weight on the left rear wheel in the towing condition is statically indeterminate, but it would be less than that with the trailer resting on its front landing gear. It does not appear that the weight of the left rear wheel would have exceeded its rated capacity (3750 lbs/1700 kg) at the time of failure.

INTERVIEW WITH TRAILER OWNERS

The owners were interviewed by the field investigator and a consultant working on behalf of the manufacturer. The driver was an experienced heavy truck operator and owned his own logging truck company. At the time of the failure, the trailer was being towed by a GMC Sierra 3500 Duramax Diesel pickup truck with dual rear wheels and an aftermarket engine retarder. The driver had just finished negotiating a right curve on a mountain highway and was travelling approximately 90 km/h when he noticed the trailer's left rear wheel was not attached. He was unaware when it separated and was unable to locate it. The driver noted that two of the fractured wheel stud faces had a dark and dull finish, unlike the others, which where shiny. He was able to push one of the dull finished studs out of its hole by simply pressing on it with his finger. The owner provided the field investigator with the loose stud.

The driver had not been braking hard prior to the failure and there were no significant road elevation changes, potholes, or objects on the highway near the failure location. The driver indicated that he tightened the lug nuts within 1000 km of the failure. He did not

utilize a torque wrench. The driver's wife indicated that she had looked at the left rear wheel prior to their departure and noted that all the lug nuts were on the wheel.

The owners indicated that the trailer was loaded rather light. They estimated that there was approximately 30 gallons (114 litres) of water in the trailer at the time of the incident.

The owner was not aware of any unusual loading circumstances or road impacts (ex. pothole strikes) during the life of the trailer. The trailer had been subject to some tight turns, which is not unusual when entering and exiting campsites. The rear right side trailer damage was caused by an unrelated event. The trailer struck a post while turning in a campground.

DISCUSION

Wheel stud fractures often occur as a result of a loose connection (low clamp load). Low clamp loads can be generated by numerous reasons. They can be caused by failing to torque the joint sufficiently. A low clamp load can also be created by over-torqueing (over stretching) the bolt such that it plastically deforms/stretches. Another common cause of low clamp load is excessive paint thickness at the clamped joint. Excessive paint and/or improperly cured paint can create a soft joint which can lead to low clamp loads and wheel stud failures.

Two of the 24 studs were observed to be over-torqued 10 to 20% above the manufacturer's recommendation. The majority of the wheels were observed to be under-torqued. Paint lift-off on the hub face and plastic deformation of the paint (wheel imprint observed in paint) was observed at the stud locations. The hubs were retained by the manufacturer for paint thickness testing in a laboratory. The vehicle owner did not utilize a torque wrench when tightening the wheels. The original torque on the studs is not known and, therefore, the effect of paint thickness on the clamped joint's integrity could not be assessed.

It is understood that the manufacturer no longer paints the hub faces, and have implemented 17.5" rims with 5/8" studs.

CONCLUSION

The subject vehicle's left rear wheel studs fractured while traveling on a rural highway. One or more of the studs were subject to a fatigue failure. The failure was likely initiated by a low clamp load on the studs/nuts. The cause of the low clamp load could not be determined with certainty. Paint on the wheel hub may have been a factor. Improper torqueing may also be a factor.

DRV has retained the failed parts and the other three wheel assemblies for paint thickness testing and material verification. Follow-up with the manufacturer on their laboratory test findings is recommended.

File: 2011-0932

Date: 6/29/2011

Wheel Location	Stud Location	Torque (ft-lbs)	Notes:
Left Front 110 psi	1	70	
	2	80	
	3	80	
	4	110	
	5	100	
	6	100	
	7	75	
	8	105	
Left Rear	1	N/A	
	2	N/A	
	3	N/A	
	4	N/A	
	5	N/A	
	6	N/A	
	7	N/A	
	8	N/A	

Right Rear 110 psi	1	120	
	2	100	
	3	125	
	4	150	
	5	120	
	6	125	
	7	105	
	8	140	
Right Front 110 psi	1	70	
	2	80	
	3	45	
	4	50	
	5	70	
	6	80	
	7	90	
	8	80	- Nut very difficult to get off. Seems to be binding.

Quality Associates – Metallurgical Services

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QA Lab Report No. 4446-1

TO: Tom Peck
DRV, LLC
160 West 750 N
Howe, IN 46767

5 September 2011

SUBJECT: Brake Rotor Hub to Wheel Joint

OBJECT: Determine the paint film thickness on the four brake rotor hub faces.

RECEIVED: Four brake rotors were submitted for analysis. They were identified as being from Calgary and had been removed from a 2011 Model 36 TKSB3 vehicle, VIN 5KEFA3624B which was manufactured 06/07/2010.

CONCLUSION: Test results are provided herein.

TEST DATA:

Visual Examination

Paint was present on the cast surface and mounting face of all four samples (Figures 1 to 4). This paint had been worn off or partially worn off in the areas adjacent to the wheel bolts.

Film Thickness per ASTM D1186

Paint film thickness was measured using an Elcometer Model 456. Film thickness of the rotors varied with location around the wheel bolt. Four different locations were selected to demonstrate the variation in paint thickness. Test locations included:

A- As cast scallop surface between wheel bolts
B- Machined face half way between the wheel bolts
C- Mounting face outboard of the wheel bolt
D- Mounting face inboard from the wheel bolt

Test results (Tables I and II) showed that the average film thickness varied from hub to hub and with location within the hub. Average paint film thickness on the right rear rotor hub was significantly less than that on the other three rotor hubs. Average paint film thickness on the worn surface was less than that on the unworn surface.

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P. Murphy
Lab File 4446-1

Report by:

Matt Guisbert

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ATTACHMENTS: Figures 1 to 4
Tables I and II

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P. Murphy
Lab File 4446-1

Table I. Paint Film Thickness by Location, Inches								
Wheel Bolt No.	Left Rear Rotor SOLVENT				Right Rear Rotor E-COAT			
	A	B	C	D	A	B	C	D
1	0.0032	0.0042	0.0000	0.0001	0.0012	0.0005	0.0004	0.0003
2	0.0024	0.0038	0.0000	0.0001	0.0007	0.0006	0.0004	0.0002
3	0.0029	0.0034	0.0008	0.0001	0.0004	0.0005	0.0001	0.0001
4	0.0032	0.0038	0.0000	0.0003	0.0010	0.0005	0.0001	0.0004
5	0.0036	0.0046	0.0000	0.0001	0.0010	0.0005	0.0003	0.0003
6	0.0030	0.0037	0.0000	0.0000	0.0011	0.0006	0.0004	0.0003
7	0.0018	0.0035	0.0000	0.0003	0.0011	0.0005	0.0003	0.0003
8	0.0031	0.0034	0.0000	0.0001	0.0011	0.0006	0.0004	0.0004
Average	0.0029	0.0038	0.0001	0.0001	0.0010	0.0005	0.0003	0.0003
Comment		4	Worn Face	Worn Face			Some Wear	Worn Face

(1) THOUGHT PAINT WOULD PEEL IN RECESS, NMH SHOWS OTHERWISE

Table II. Paint Film Thickness by Location, Inches								
Wheel Bolt No.	Left Front Rotor SOLVENT				Right Front Rotor SOLVENT			
	A	B	C	D	A	B	C	D
1	0.0027	0.0049	0.0032	0.0006	0.0031	0.0047	0.0026	0.0008
2	0.0025	0.0046	0.0039	0.0006	0.0036	0.0036	0.0029	0.0027
3	0.0032	0.0037	0.0029	0.0002	0.0031	0.0039	0.0026	0.0022
4	0.0023	0.0034	0.0017	0.0001	0.0031	0.0042	0.0010	0.0005
5	0.0022	0.0032	0.0021	0.0002	0.0029	0.0038	0.0025	0.0001
6	0.0032	0.0049	0.0032	0.0015	0.0023	0.0042	0.0030	0.0022
7	0.0038	0.0049	0.0028	0.0003	0.0034	0.0037	0.0025	0.0011
8	0.0037	0.0051	0.0032	0.0002	0.0033	0.0046	0.0020	0.0012
Average	0.0030	0.0043	0.0029	0.0005	0.0031	0.0041	0.0024	0.0014
Comment			Some Wear	Worn Face			Some Wear	Worn Face

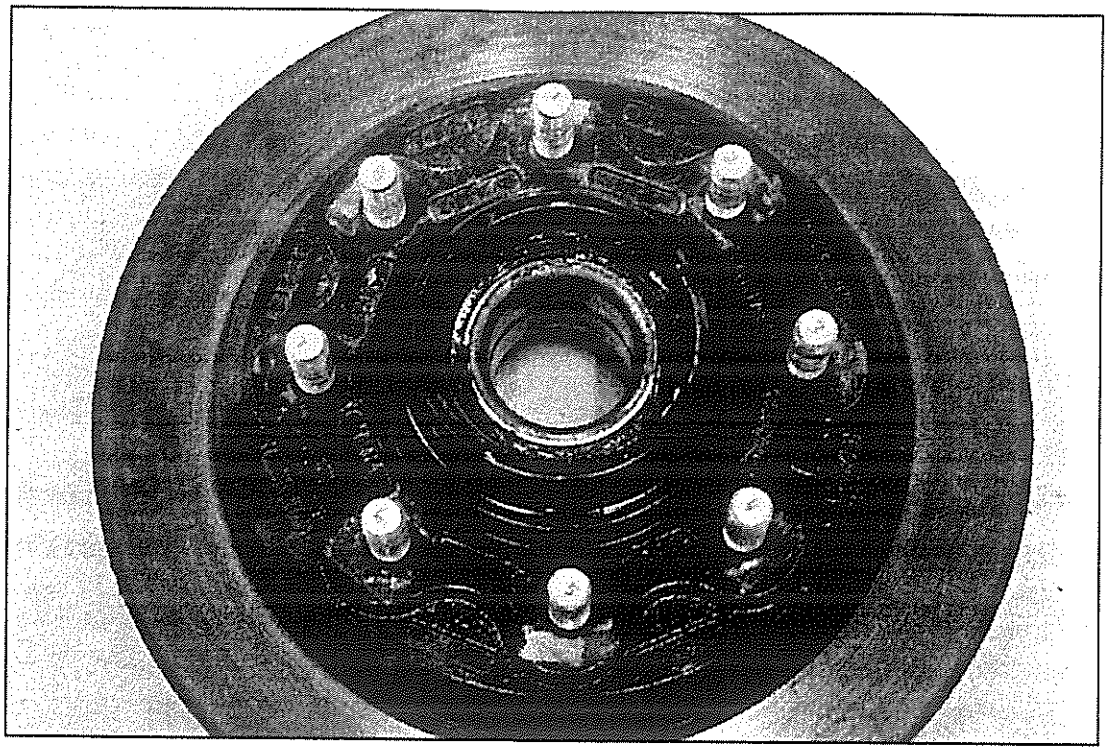

Figure 3. Left front rotor showing wear on the hub mounting face in the inboard and outboard areas adjacent to the wheel bolt

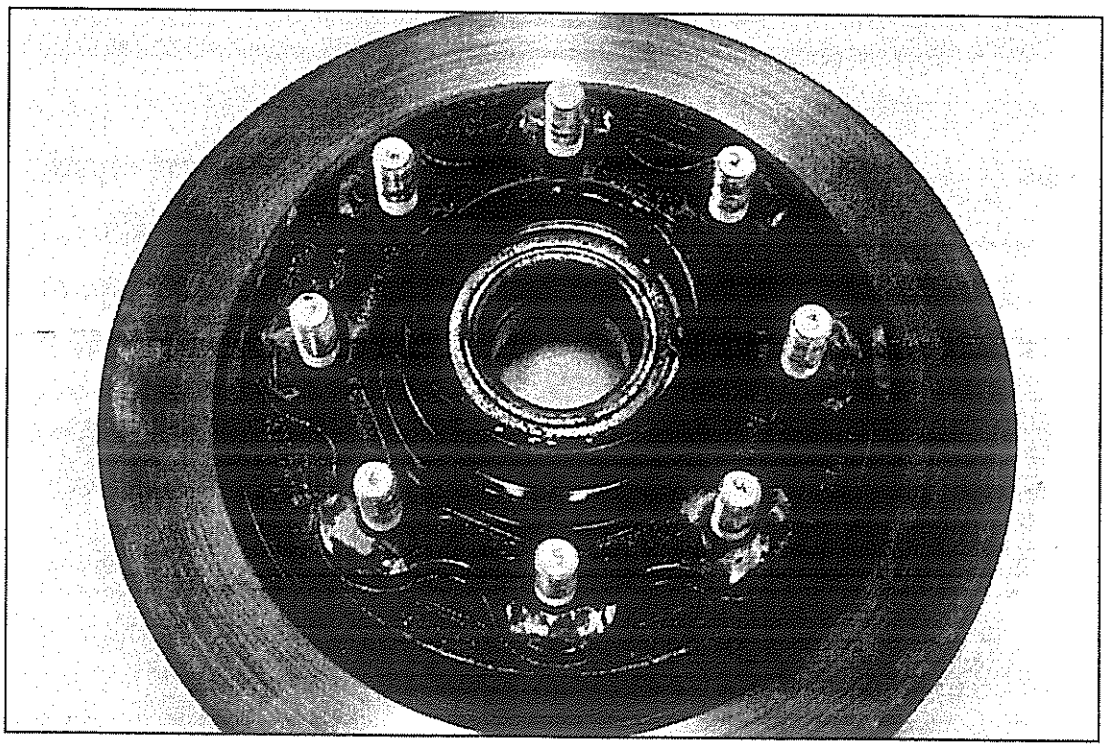

Figure 4. Right front rotor showing wear on the hub mounting face in the inboard and outboard areas adjacent to the wheel bolt

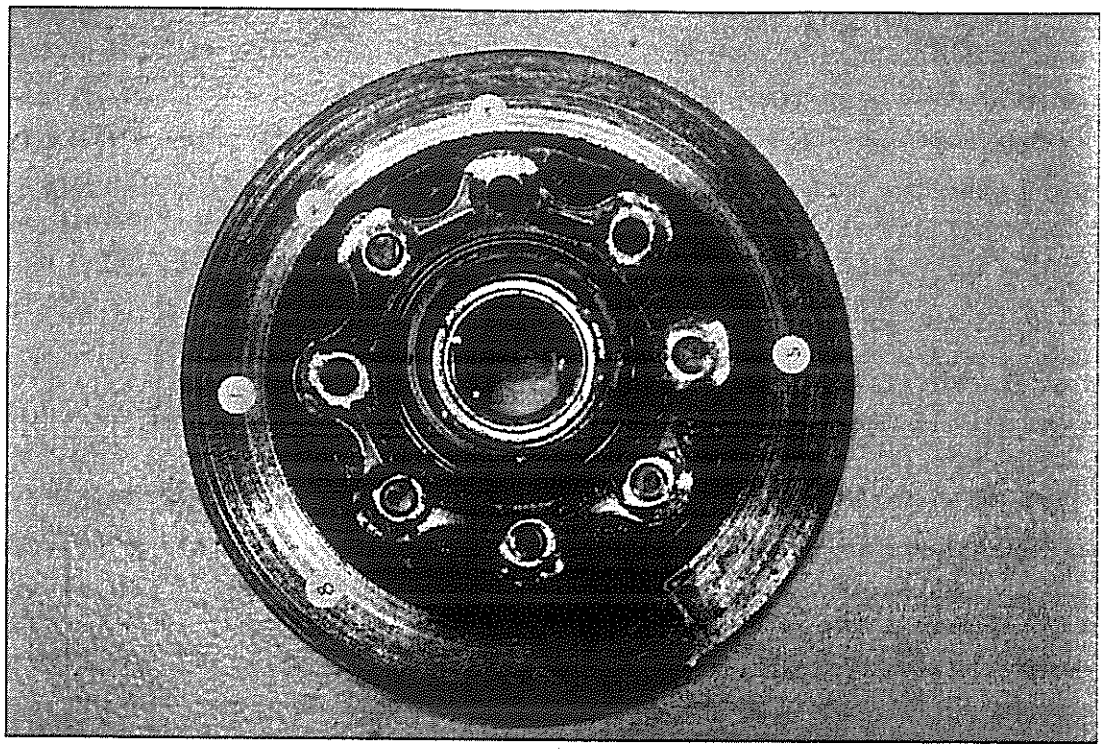

Figure 1. Left rear rotor showing wear on the hub mounting face in the inboard and outboard areas adjacent to the wheel bolt

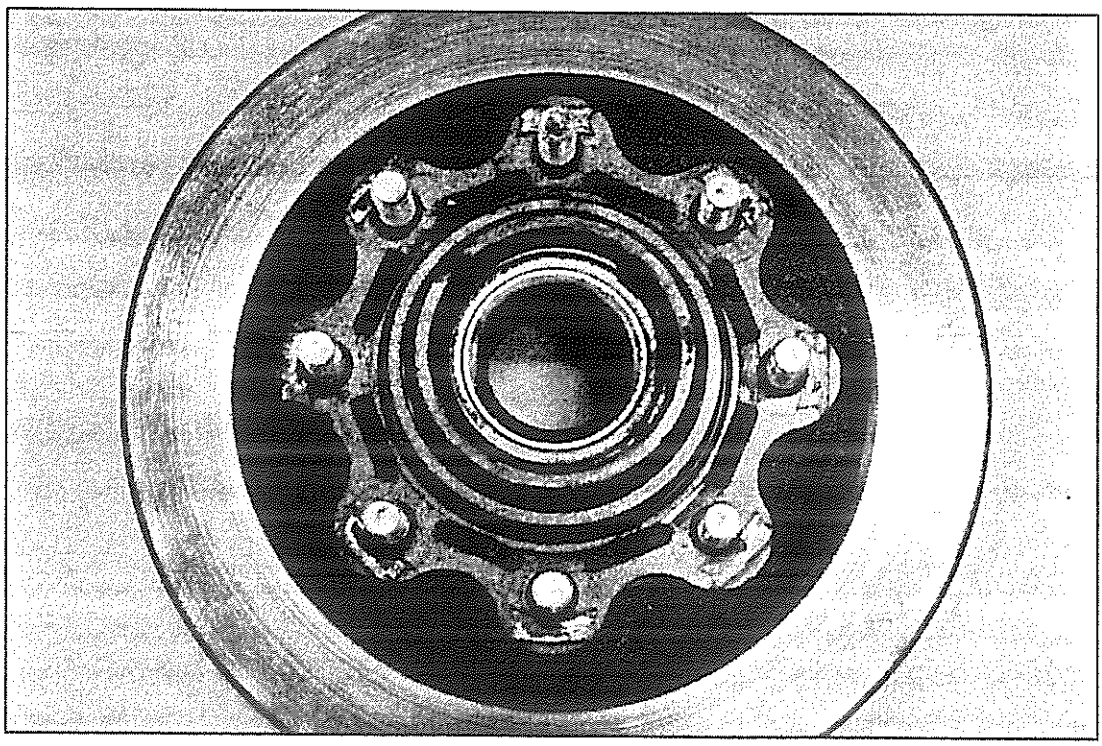

Figure 2. Right rear rotor showing that the wear was located primarily on the hub face outboard of the wheel bolt

Quality Associates – Metallurgical Services

1795 Foundation Drive – Niles, MI 49120 Phone 269-695-2623 FAX 269-695-4423

 QA Lab Report No. 4446-2

TO: Tom Peck
DRV, LLC
160 West 750 N
Howe, IN 46767

7 September 2011

SUBJECT: Brake Rotor Hub to Wheel Joint – Wheel Bolt Breakage

OBJECT: Determine the mode and possible cause of breakage.

RECEIVED: The left rear brake rotor and a separate broken bolt were submitted for analysis. This rotor was identified as being from Calgary and had been removed from a 2011 Model 36 TKSB3 vehicle, VIN 5KEFA3624B , manufactured 06/07/2010. The separate bolt was reported to be from the same assembly and had simply come out of one of the three locations with missing bolts.

CONCLUSION: Breakage of the bolts occurred in unidirectional bending fatigue, apparently as the result of insufficient clamp force in the joint between the wheel and hub. A specific cause of the looseness was not identified.

It is noted that three of the eight bolts came loose from the hub and that the one loose bolt may have come from location 3.

Three of the eight bolts were analyzed. All three were made from the same melt batch of 1340H alloy steel. The composition, hardness and microstructure all complied with requirements for Grade 8 product. There was no metallurgical cause for breakage.

TEST DATA: Visual Examination

Bolts 1, 3 and 4 were missing from the rotor (Figure 1). Wear on the mounting face revealed that the wheel had been loose. This wear was not uniform. Head and serration ends of bolts 2 and 5 to 8 remained in the assembly. All five bolts broke at the thread runout (Figures 2 to 5). Some post fracture damage to the fracture faces was apparent along with wear and damage to the taper sections on the bolts. All thread ends and nuts were missing.

The separate loose bolt broke at the thread runout (Figure 6). Wear on the taper to the serration section also showed that the wheel was loose. This bolt fit loosely in location 3 and it turned freely within the rotor. It did not fit in

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Lab File 4446-2

TEST DATA: (Continued)

locations 1 or 4. If this bolt came from this wheel assembly, it most likely came from location 3.

Head markings on all five bolt ends in the rotor assembly as well as the loose bolt were identical (Figure 7). They exhibited the six radial lines indicative of Grade 8. They also exhibited the manufacturer's identification marking, W.

Bolt 2 fracture features revealed that breakage originated off the thread root in an area near the inner diameter of the hub (Figure 8). Multiple fatigue origins were revealed by the ratchet marks or steps on one side. Fatigue, as revealed by the beach marks, extended across 70 percent of the bolt cross section before final fracture on the other side. No defects such as seams or pre-existing cracks were found in association with the origin.

Bolts 5, 6 and 7 (Figures 9 to 11) exhibited fracture origins near the same relative orientation as that of Bolt 2; however, the direction of propagation changed shortly after initial crack formation. Fatigue crack propagation extended across approximately 60 percent of the cross section. Final fracture was at an angle to the hub axis and to that of the fracture in bolt 2.

Bolt 8 (Figure 12) exhibited a similar location of the initial fatigue crack origins, but the direction of fracture changed significantly, with final fracture in a circumferential direction.

Fracture features on the loose bolt (Figure 13) were significantly different from those on the five bolts that remained in the hub. Although there was an arc section that exhibited initial bending fatigue origins, the majority of the fracture progression occurred in what appeared to be rotating bending fatigue. In order for this bolt to be subjected to rotating bending fatigue, it would have to rotate within the hub so that the bending fatigue load would be applied at different orientations. As noted earlier, rotation was possible in location 3 in that the serrations were ineffective in holding the stud in place. Final fracture in the center occurred as the result of a tensile overload, most likely during the final separation of the wheel joint.

Metallographic Examination per ASTM Methods

Bolts 2, 6 and the loose piece were examined. General microstructures of the three samples consisted of fine-grained, tempered, medium-carbon martensite (Figure 14). This microstructure complies with the requirement for 90 percent minimum martensite in the core of a Grade 8 product. No decarburization or carburization was observed in the spline. Overall results comply with the requirements for Grade 8.

Hardness per ASTM E18

Core hardness in bolts 2, 6 and the loose piece was measured. Normally, core hardness is checked at the mid radius, 1 to 1½ diameters from the threaded end.

TEST DATA: (Continued)

As these sections were not available, core hardness was measured in the cross section cut in the serration section closest to the thread. Results (Table I) comply with product specifications.

Chemical Analysis per ASTM E415

Compositions of samples 2, 6 and the loose piece revealed that all three were made from the same melt batch of vanadium grain refined 1340H alloy steel (Table II). These results comply with product specifications for Grade 8.

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Matt Guisbert

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ATTACHMENTS: Figures 1 to 14
Tables I and II

DISTRIBUTION: T. Peck
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Lab File 4446-2

Table I. Core Hardness, HRC				
Location	**Bolt 2**	**Bolt 6**	**Loose Bolt**	**Specified**
¾ Radius	36.0	33.4	35.1	
½ Radius	35.0	33.6	35.3	33-39

Table II. Composition, Weight Percent					
Element	**Bolt 2**	**Bolt 6**	**Loose Bolt**	**Specified[1]**	**1340H[2]**
Carbon	0.37	0.37	0.38	0.28-0.55	0.37-0.44
Manganese	1.70	1.70	1.70		1.45-2.05
Phosphorus	<0.010	<0.010	<0.010	0.030 Max.	0.035 Max.
Sulfur	0.006	0.005	0.006	0.050 Max.	0.040 Max.
Silicon	0.21	0.21	0.22		0.15-0.35
Nickel	0.08	0.08	0.08		0.25 Max.
Chromium	0.05	0.05	0.05		0.20 Max.
Molybdenum	<0.01	<0.01	<0.01		0.06 Max.
Copper	0.04	0.04	0.05		0.35 Max.
Aluminum	<0.002	<0.002	<0.002		
Columbium	<0.002	<0.002	<0.002		
Vanadium	0.028	0.028	0.028		
Titanium	<0.002	<0.002	<0.002		
Boron	<0.0002	<0.0002	<0.0002		

Notes:

1. Must be made from alloy steel with the prescribed limits to carbon, phosphorus and sulfur
2. 1340H is defined as an alloy steel

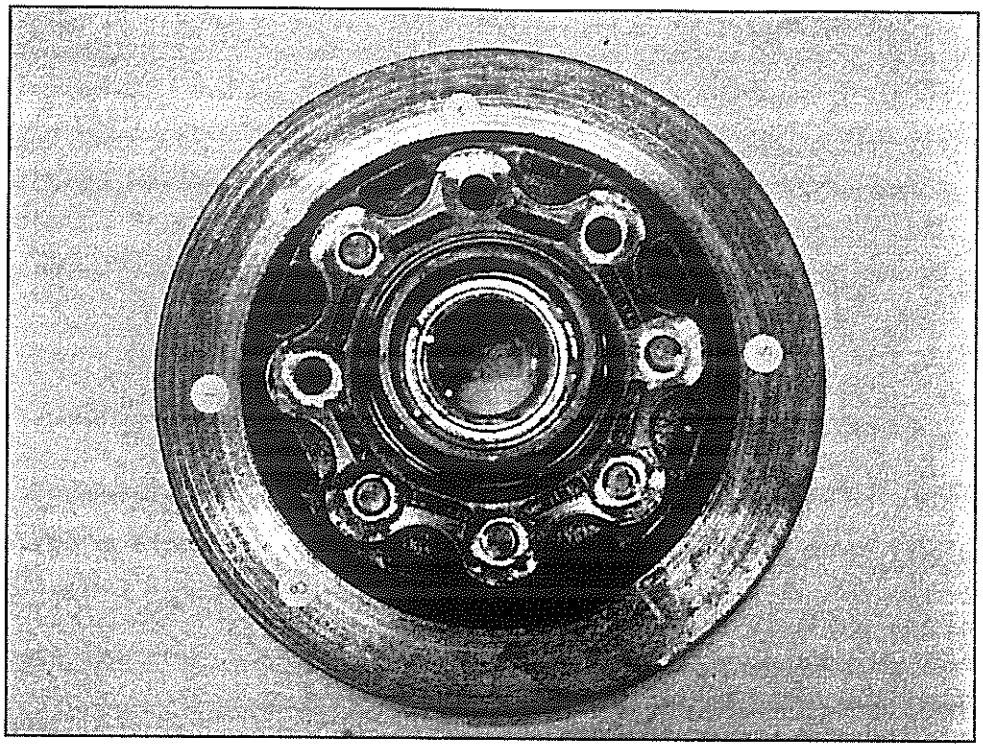

Figure 1. Three of the eight wheel bolts were missing from the rotor assembly – missing bolts were from locations 1, 3 and 4 (*location numbers assigned by DRV personnel*)

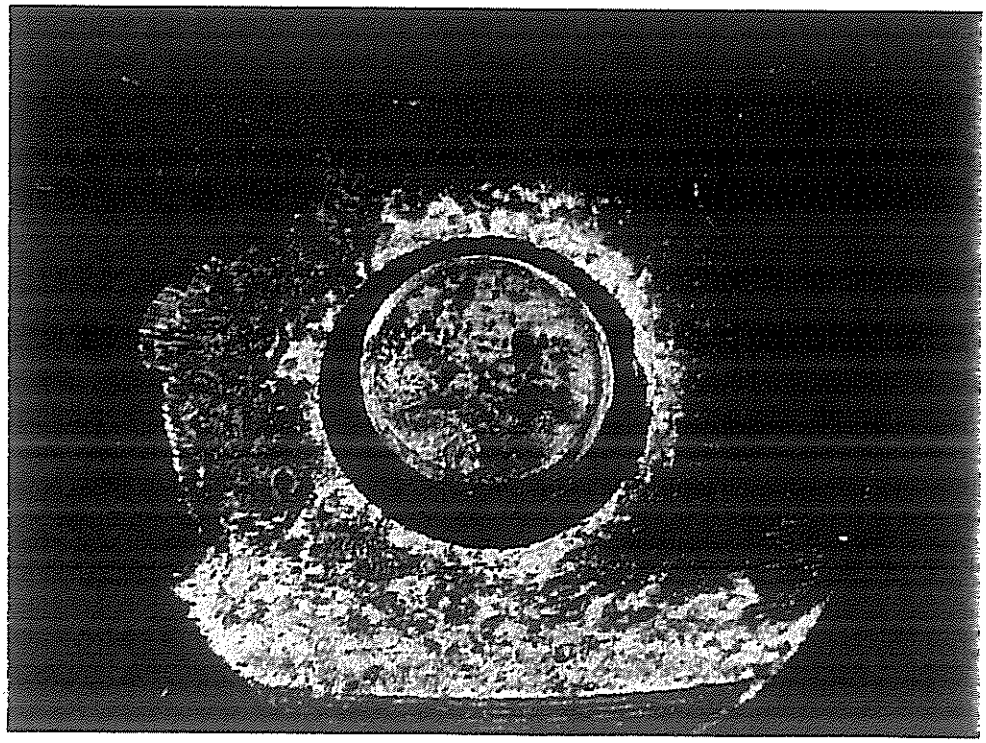

Figure 2. Bolt 2 broke at the thread runout – the mounting face exhibited non-uniform contact based on the wear

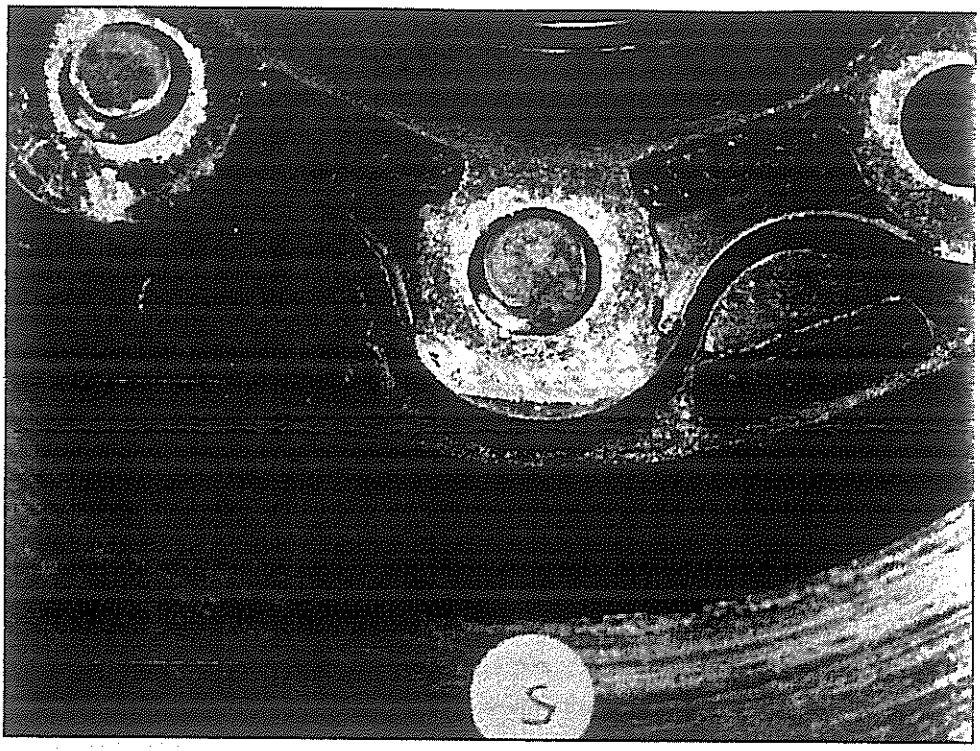

Figure 3. Showing the location of fracture on bolts 5 and 6 was at the thread runout – edges of the bolts to the taper were damaged by looseness of the wheel

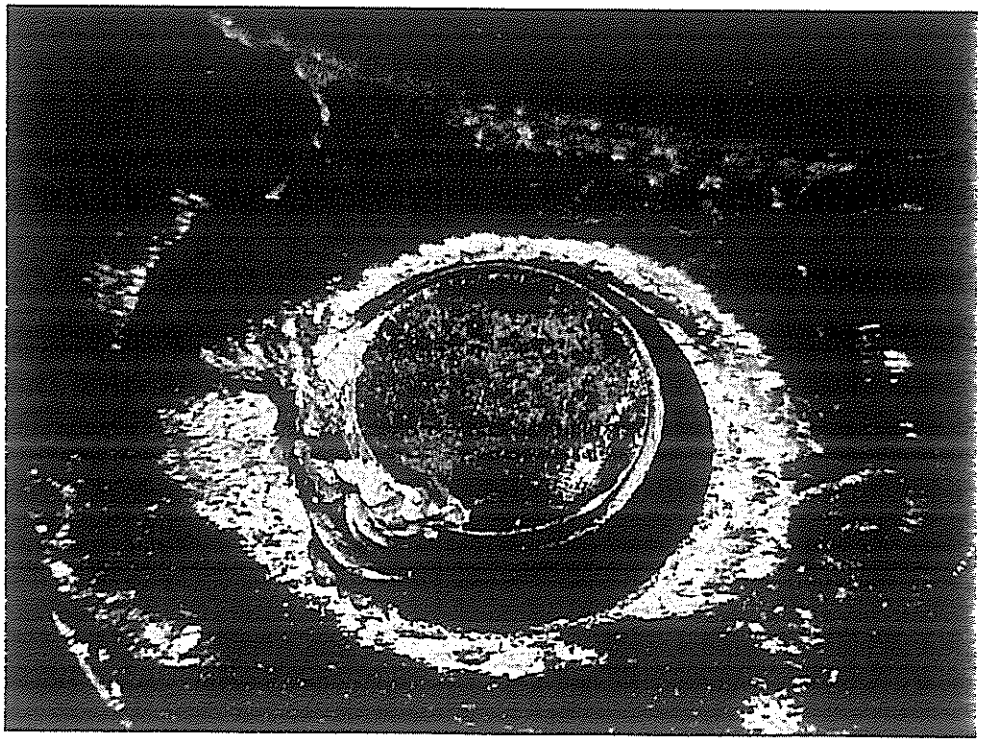

Figure 4. Showing the location of fracture on bolt 7 at the thread runout – edges of the bolt and fracture were damaged by looseness of the wheel

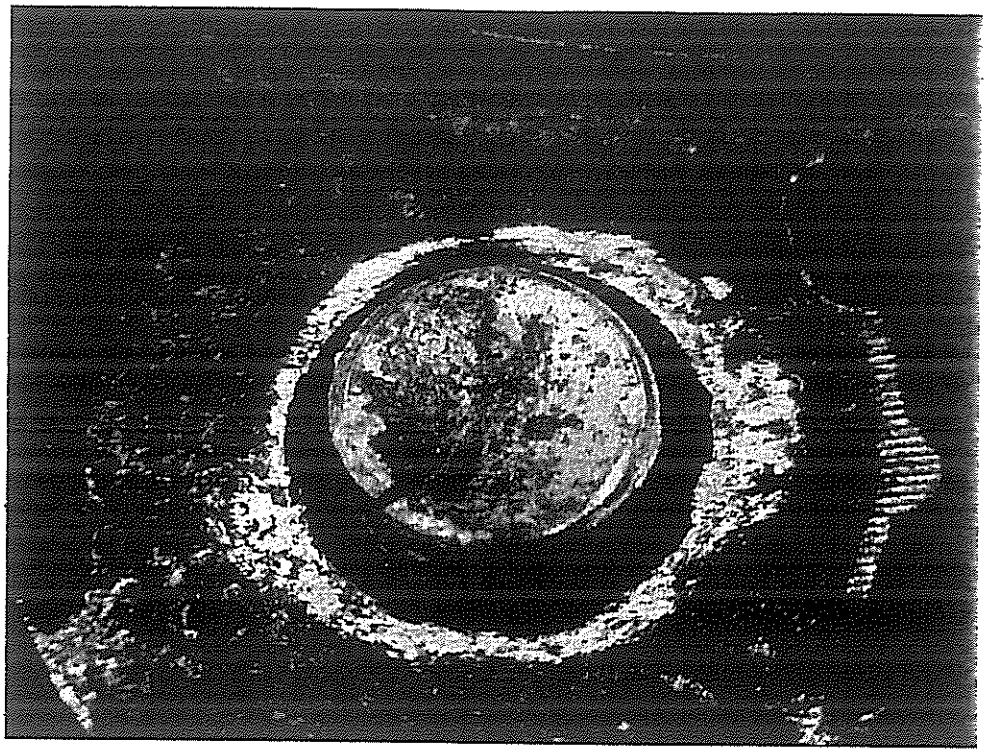

Figure 5. Showing the location of fracture on bolt 8 at the thread runout – edges of the bolt and fracture were damaged by looseness of the wheel

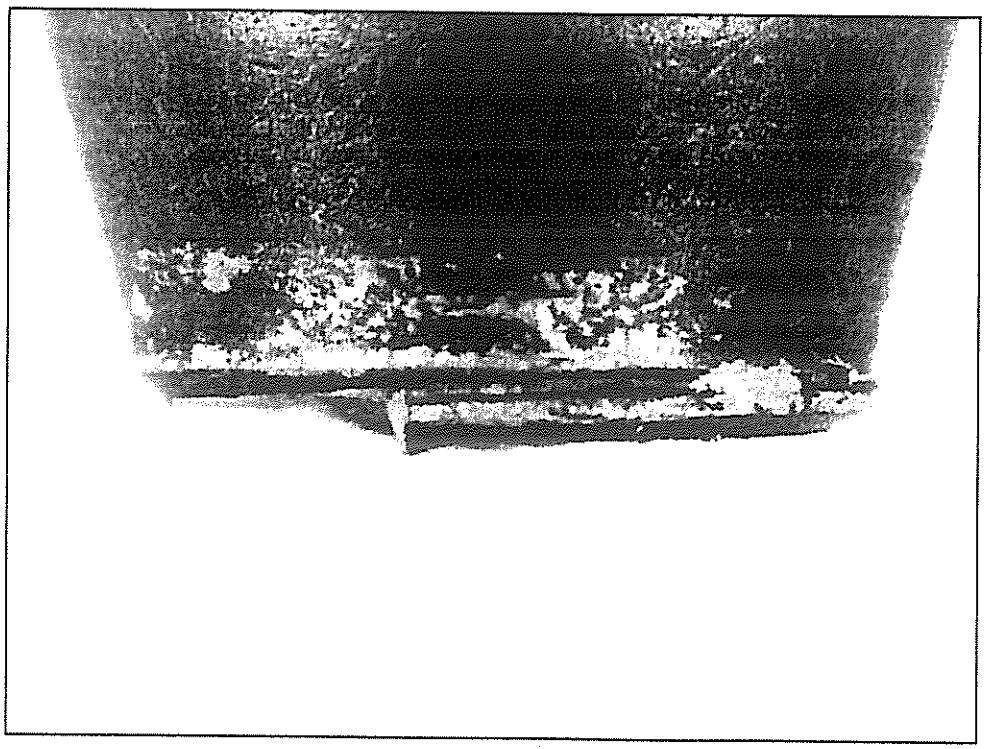

Figure 6. Location of the fracture on the separate loose bolt that was submitted with the rotor assembly

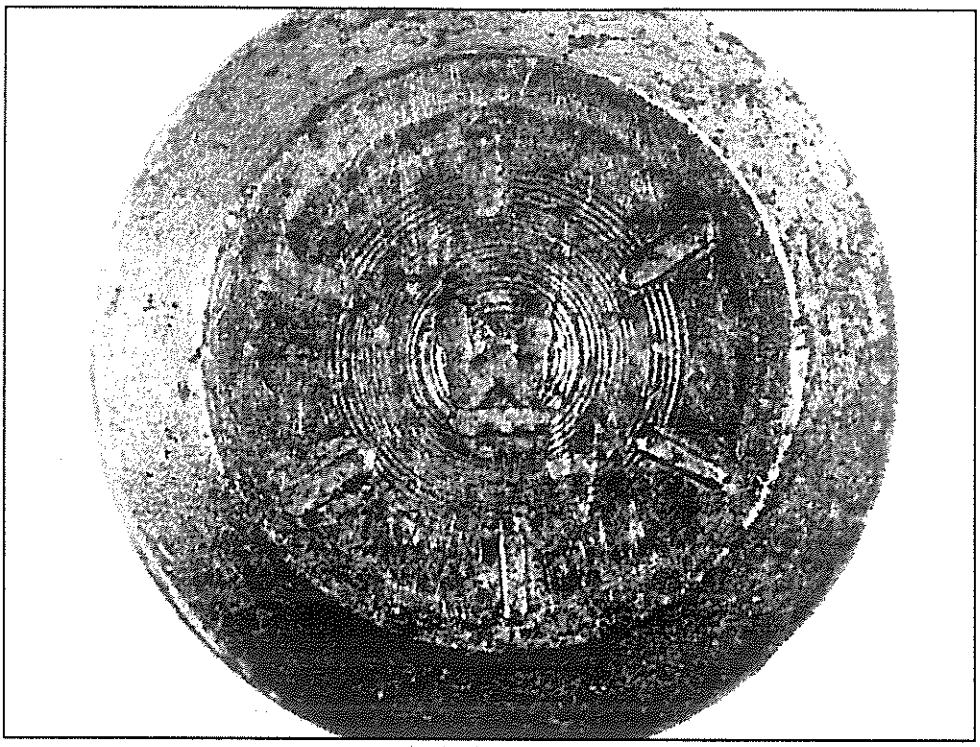

Figure 7. Head markings on the five bolts remaining in the rotor assembly and the loose bolt were identical – 6 radial lines for Grade 8 and the manufacturers identification, W

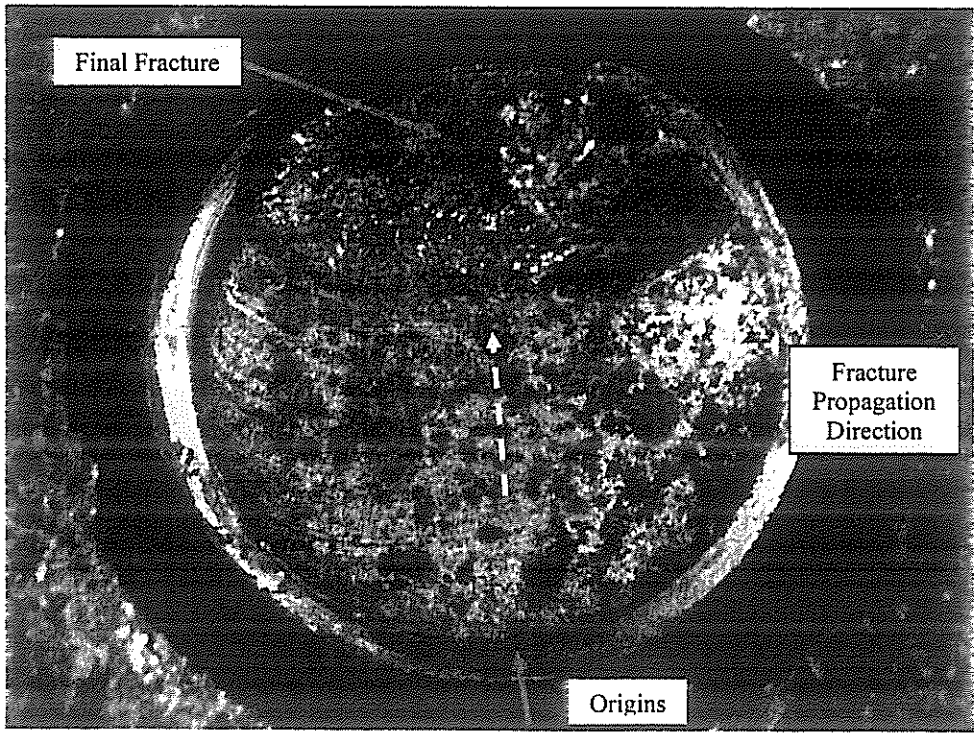

Figure 8. Bolt 2 – fracture features revealed that breakage occurred in unidirectional bending fatigue, with origins at a slight angle to the hub axis – centerline is down

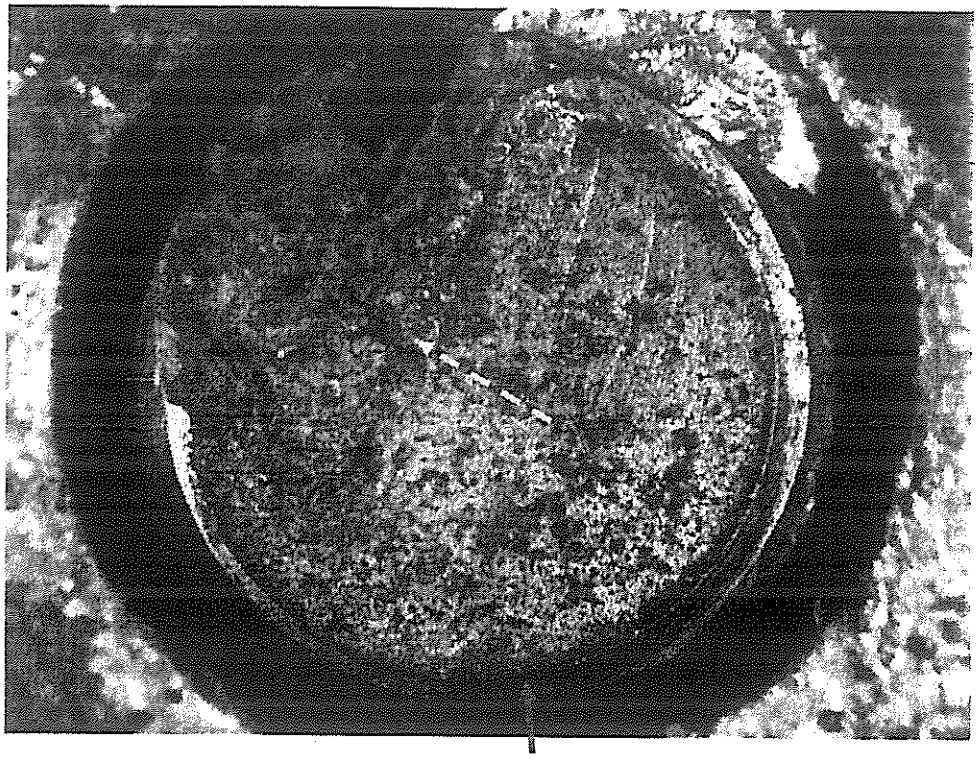

Figure 9. Bolt 5 – fracture features revealed that breakage occurred in unidirectional bending fatigue, but origins were originally nearer the inner diameter – centerline is down

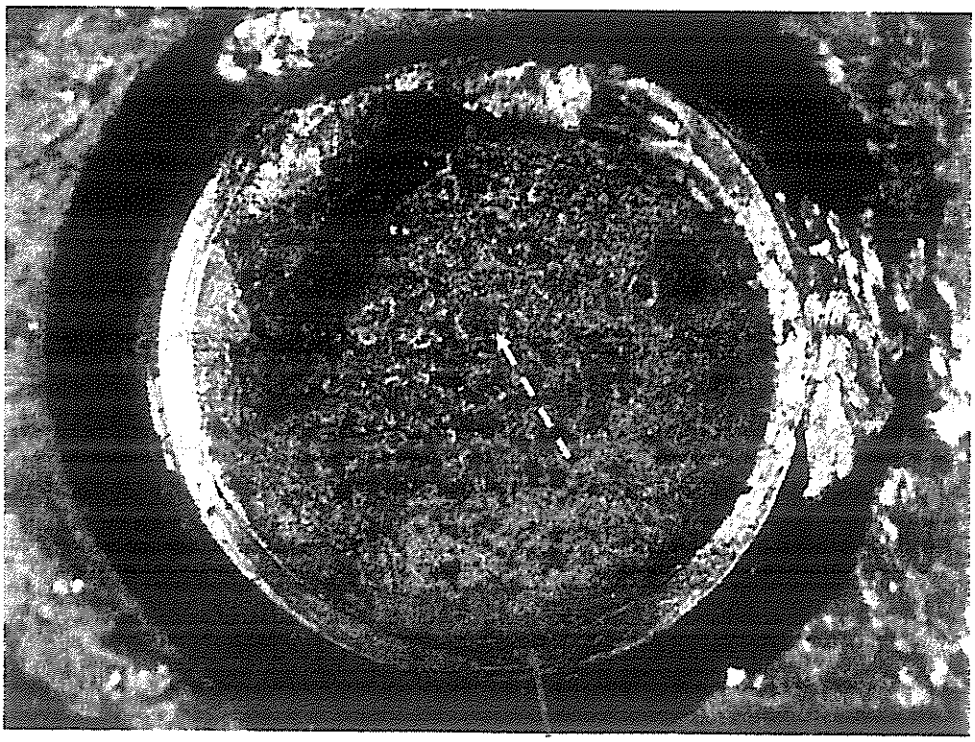

Figure 10. Bolt 6 – fracture features revealed that breakage occurred in unidirectional bending fatigue, with origins at an angle to the hub axis – centerline is down

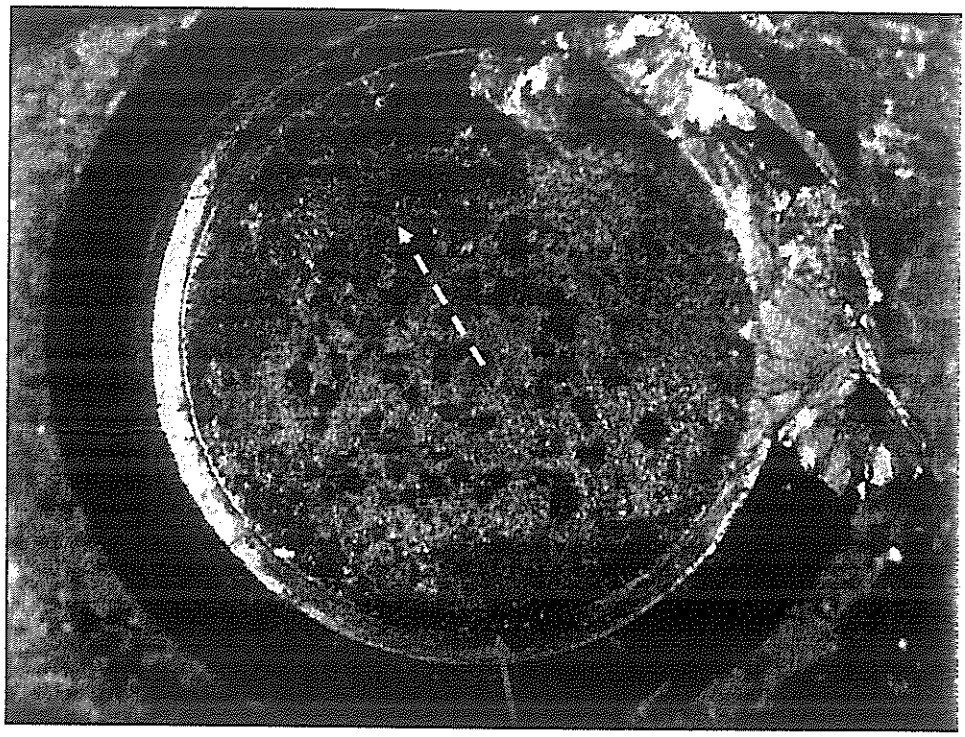

Figure 11. Bolt 7 – fracture features revealed that breakage occurred in unidirectional bending fatigue, with origins at an angle to the hub axis – centerline is down

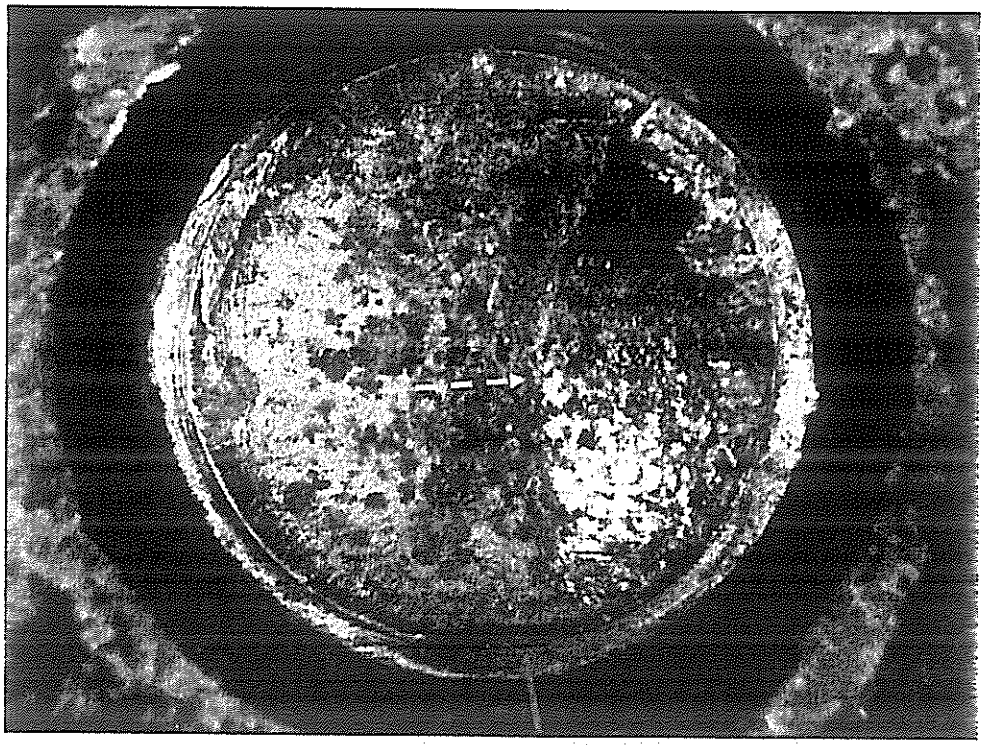

Figure 12. Bolt 8 – fracture features revealed that breakage originated in unidirectional bending fatigue near the inner diameter, but the direction of propagation changed

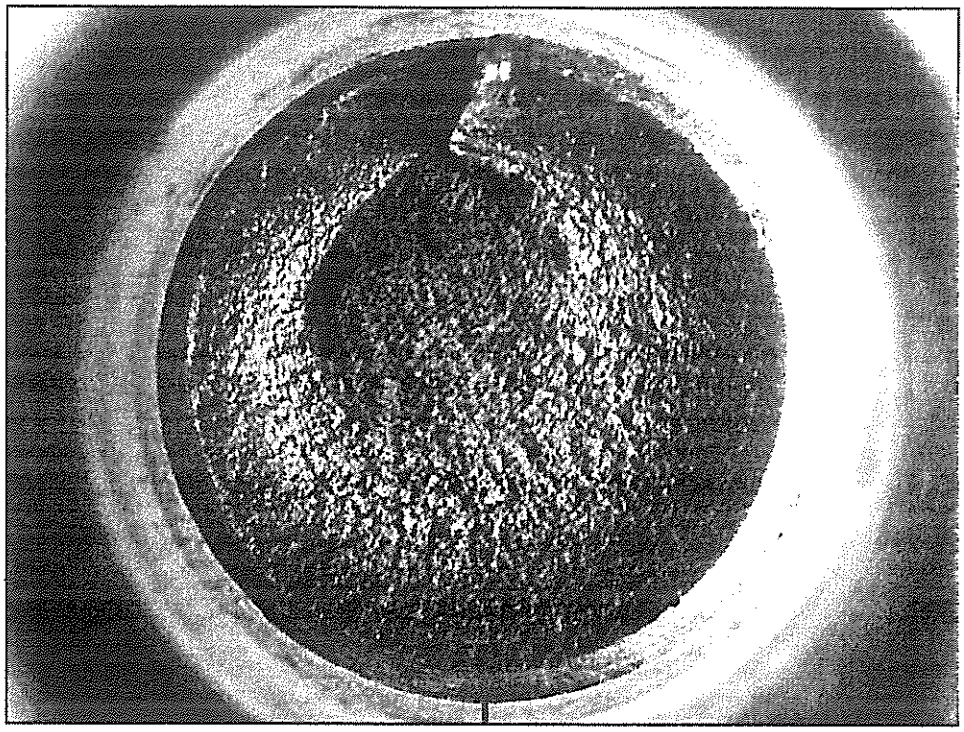

Figure 13. Loose bolt – although there appear to be some primary bending fatigue origins along the bottom edge, a majority of the fracture occurred in rotating bending fatigue

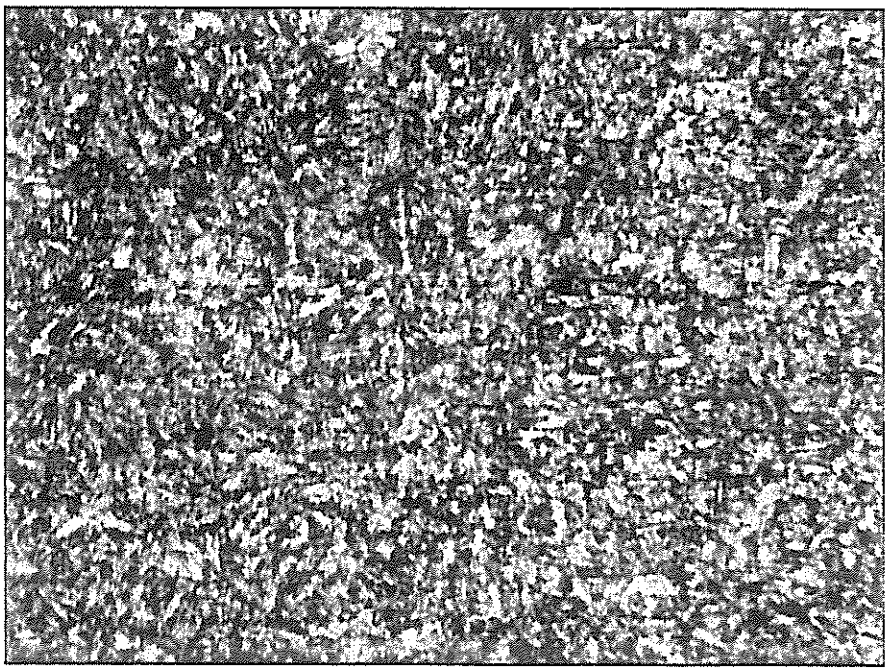

Figure 14. Bolt 2, Core Microstructure – the microstructure consisted of fine-grained, tempered, medium carbon martensite – Nital Etchant, 500X

Quality Associates – Metallurgical Services

1795 Foundation Drive – Niles, MI 49120 Phone 269-695-2623 FAX 269-695-4423

 QA Lab Report No. 4478-1

TO: Tom Peck
DRV, LLC
160 West 750.N
Howe, IN 46767

12 October 2011

SUBJECT: Paint Thickness

OBJECT: Measure the paint film thickness on the four brake rotor hub faces.

RECEIVED: Four brake rotors off a unit from Colorado were submitted for analysis.

CONCLUSION: Test results are provided herein.

TEST DATA:

Visual Examination

Paint was present on cast and machined surfaces of all four samples (Figures 1 to 4). Wear and/or compression of the paint was observed to varying degrees in locations C and D. Some of the variation is attributed to wear caused by relative movement between the brake rotor and wheel rim.

Film Thickness per ASTM D1186

Paint film thickness was measured using an Elcometer Model 456. Film thickness of the rotors varied with location around the wheel bolt. Four different locations were selected to demonstrate the variation in paint thickness. Test locations included:

A- As cast scallop surface between wheel bolts
B- Machined face half way between the wheel bolts
C- Mounting face outboard of the wheel bolt
D- Mounting face inboard from the wheel bolt

Test results (Tables I and II) showed that the average film thickness varied at the different location within the hubs, and from hub to hub. Average paint film thickness on hub "C" was significantly less than that measured on the other three hubs. Average paint film thickness was less on worn surfaces within the hubs.

DISTRIBUTION: T. Peck
Lab File 4478-1

Report by:

Matt Guisbert

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Approved by:

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ATTACHMENTS: Figures 1 to 4
Tables I and II

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Lab File 4478-1

Table I. Paint Film Thickness by Location, Thousandths of an Inch								
Wheel Bolt No.	Hub A				Hub B			
	A	B	C	D	A	B	C	D
1	0.0013	0.0012	0.0007	0.0011	0.0010	0.0009	0.0005	0.0002
2	0.0013	0.0012	0.0007	0.0013	0.0010	0.0009	0.0009	0.0003
3	0.0013	0.0012	0.0007	0.0012	0.0009	0.0009	0.0008	0.0004
4	0.0014	0.0013	0.0006	0.0009	0.0012	0.0010	0.0008	0.0002
5	0.0013	0.0012	0.0007	0.0007	0.0020	0.0010	0.0007	0.0003
6	0.0014	0.0010	0.0009	0.0011	0.0016	0.0010	0.0008	0.0003
7	0.0014	0.0012	0.0005	0.0012	0.0008	0.0009	0.0008	0.0003
8	0.0010	0.0011	0.0004	0.0010	0.0012	0.0009	0.0006	0.0003
Average	0.0013	0.0012	0.0007	0.0011	0.0012	0.0009	0.0007	0.0003

Table II. Paint Film Thickness by Location, Thousandths of an Inch								
Wheel Bolt No.	Hub C				Hub D			
	A	B	C	D	A	B	C	D
1	0.0003	0.0006	0.0005	0.0005	0.0013	0.0013	0.0008	0.0014
2	0.0009	0.0005	0.0002	0.0004	0.0017	0.0012	0.0007	0.0010
3	0.0006	0.0005	0.0003	0.0001	0.0011	0.0011	0.0005	0.0007
4	0.0007	0.0006	0.0001	0.0005	0.0012	0.0010	0.0007	0.0003
5	0.0003	0.0004	0.0001	0.0006	0.0014	0.0010	0.0006	0.0003
6	0.0007	0.0005	0.0001	0.0003	0.0006	0.0010	0.0004	0.0009
7	0.0004	0.0005	0.0003	0.0004	0.0014	0.0010	0.0006	0.0009
8	0.0002	0.0005	0.0002	0.0005	0.0014	0.0010	0.0006	0.0012
Average	0.0005	0.0005	0.0002	0.0004	0.0013	0.0011	0.0006	0.0008

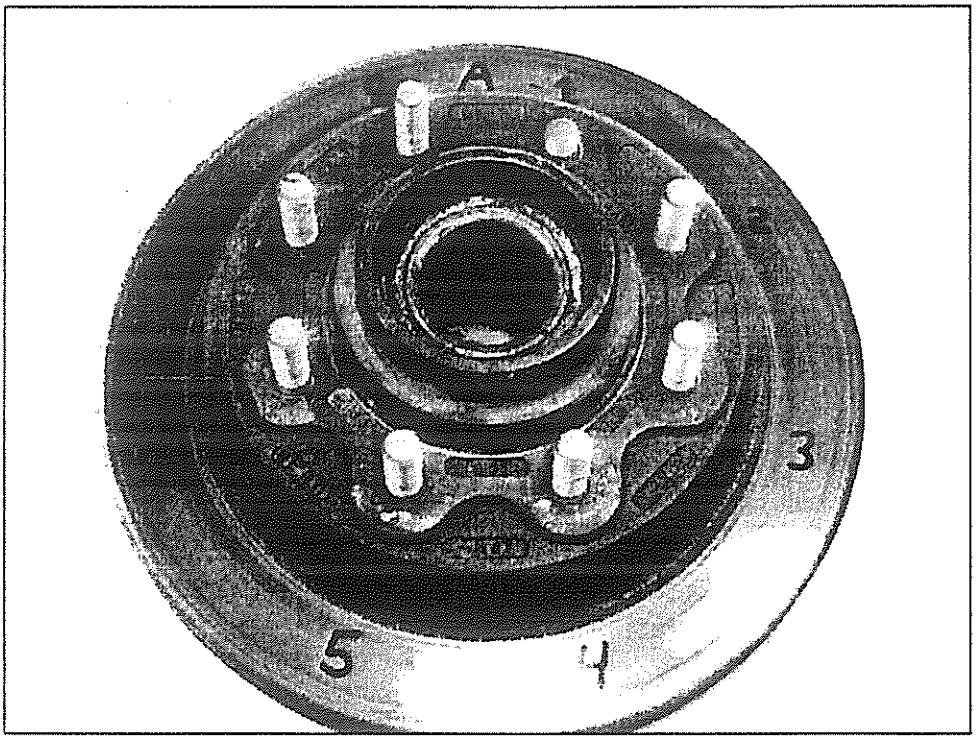

Figure 1. Brake rotor "A" showing scattered wear in the D position

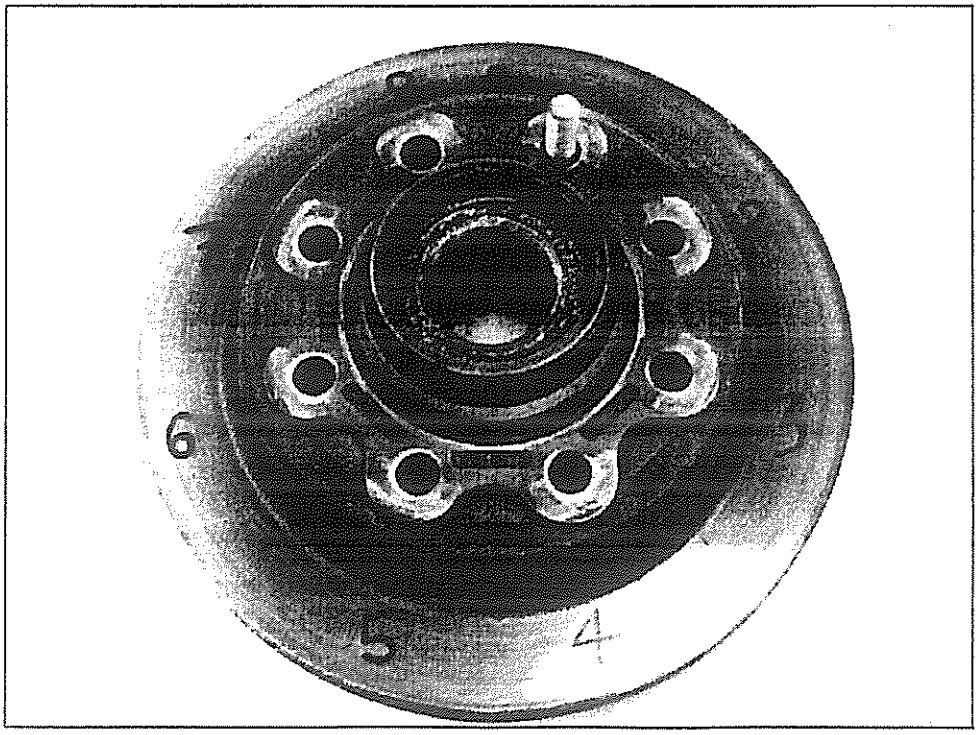

Figure 2. Brake rotor "B" showing scattered wear in the C and consistent wear in the D positions

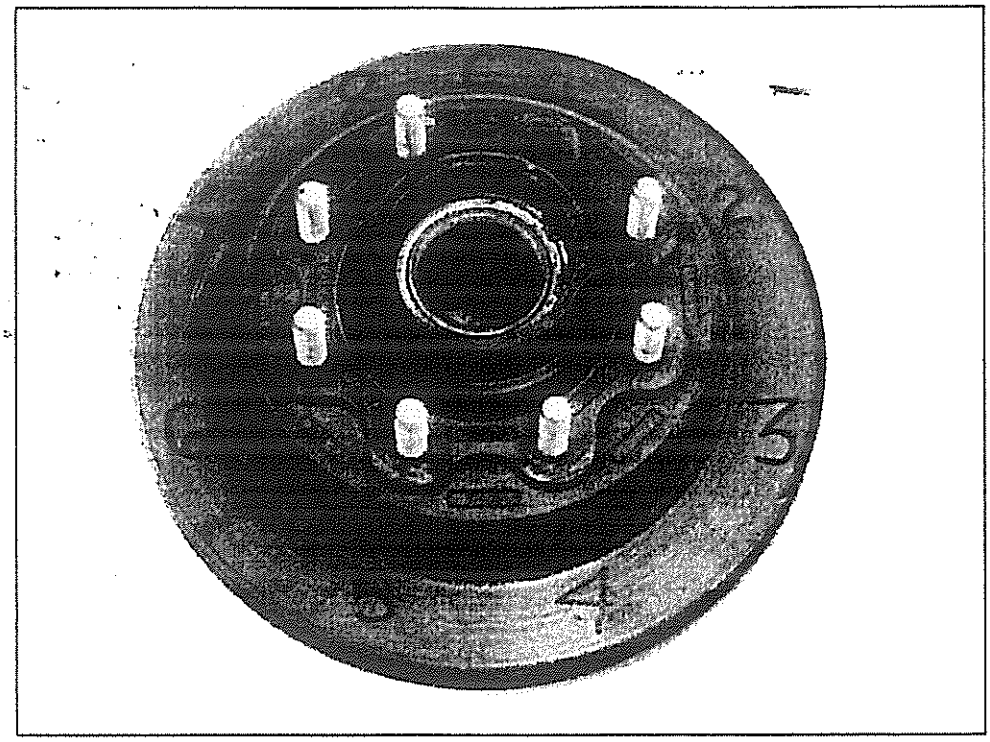

Figure 3. Brake rotor "C" showing consistent wear in the D position

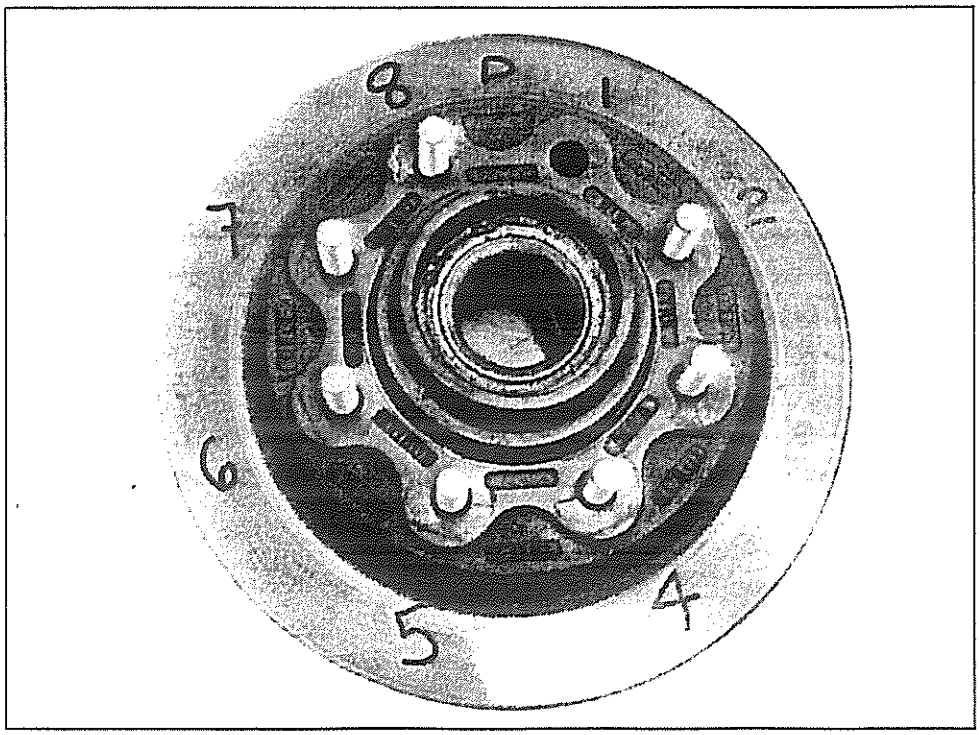

Figure 4. Brake rotor "D" showing consistent wear in the D position

Quality Associates – Metallurgical Services

1795 Foundation Drive – Niles, MI 49120 Phone 269-695-2623 FAX 269-695-4423

 QA Lab Report No. 4446-3

TO: Tom Peck
DRV, LLC
160 West 750 N
Howe, IN 46767

24 October 2011

SUBJECT: Brake Rotor Hub to Wheel Joint – Wheel Bolt Breakage

OBJECT: Examine the bolt hole surfaces in the brake rotor hub.

RECEIVED: The left rear brake rotor and a separate broken bolt were submitted for analysis. This rotor was identified as being from Calgary and had been removed from a 2011 Model 36 TKSB3 vehicle, VIN 5KEFA3624B , manufactured 06/07/2010. The separate bolt was reported to be from the same assembly and had simply come out of one of the three locations with missing bolts. In QA Lab Report No. 4446-2 it was theorized that the loose bolt came from location 3.

CONCLUSION: Three of the eight holes, No. 2, 7 and 8, exhibited the serration groove and paint patterns expected in an assembly where the bolts remained securely in place after assembly.

Hole locations 5, 6 and 3 exhibited wear features indicative of wheel bolt rotation. The cause of bolt rotation is unknown, but it could have occurred during assembly, when the bolt torque was checked, or during joint breakage.

Hole surfaces in locations 1 and 4 exhibited serration marks that extended through the hub. Since the serration length on the bolt is less than the full length of the hole, it is believed that the broken bolt may have been pulled through the hole after the head broke off.

TEST DATA: Visual Examination

The submitted hub assembly is shown for reference purposes, with the bolt locations numbered 1 to 8 (Figure 1). Bolts were missing from locations 1, 3 and 4, but remained in locations 2 and 5 to 8. Those that remained were pressed out for examination of the hole surface. The six bolts available for examination, which includes the separately submitted loose bolt, broke at the thread runout.

Hole surfaces in locations 2, 7 and 8 exhibited typical serration engagement features (Figures 2 to 4). Serration markings extended part way through the hole,

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Lab File 4446-3

TEST DATA: (Continued

but only for the length of the serrations on the bolt shank. Paint was present on the remaining portion of the hole and in between the serration grooves.

Location 5 and 6 surfaces (Figure 5 and 6) appear to show that the wheel bolt rotated within the hole, scraping off the paint between the serration markings. Serration marks remained on the surface, but they were relatively shallow.

Location 3, which corresponds to one of the missing bolts, exhibited a high level of wear (Figure 7). Serration grooves appeared to have been almost completely worn off. This surface suggests that the bolt rotated within the hole and that its movement was not restricted.

Locations 1 and 4, the other two locations where bolts were missing, exhibited wear and serration marks that extended the full length of the hole (Figure 8 and 9). Serration markings for the full length suggest that the bolt was pulled through the hole. In order for the bolts to pull through the hub, the heads would have had to break off.

Report by:

Matt Guisbert

Matt Guisbert

Approved by:

David A. Guisbert, P.E.
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Niles, MI 49120
Phone: (269) 695-2623
FAX: (269) 695-4423

ATTACHMENTS: Figures 1 to 9

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Lab File 4446-3

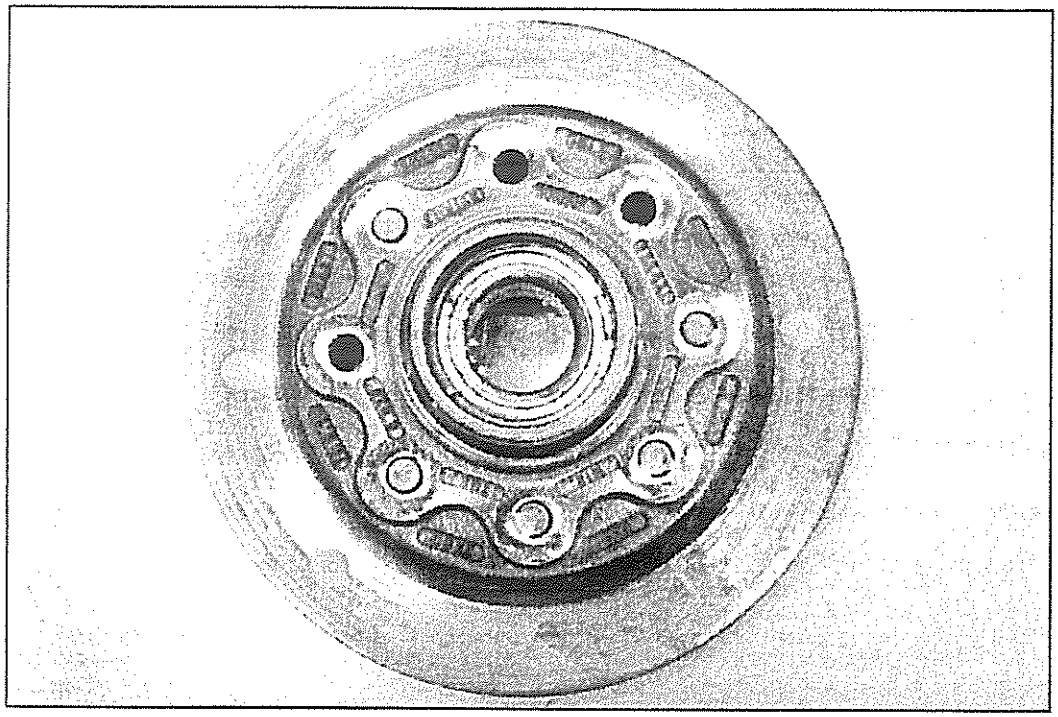

Figure 1. Showing the hub had bolts missing in locations 1, 3 and 4 – the other 5 bolts remained in the hub, but were later pressed out for examination of the hole surface

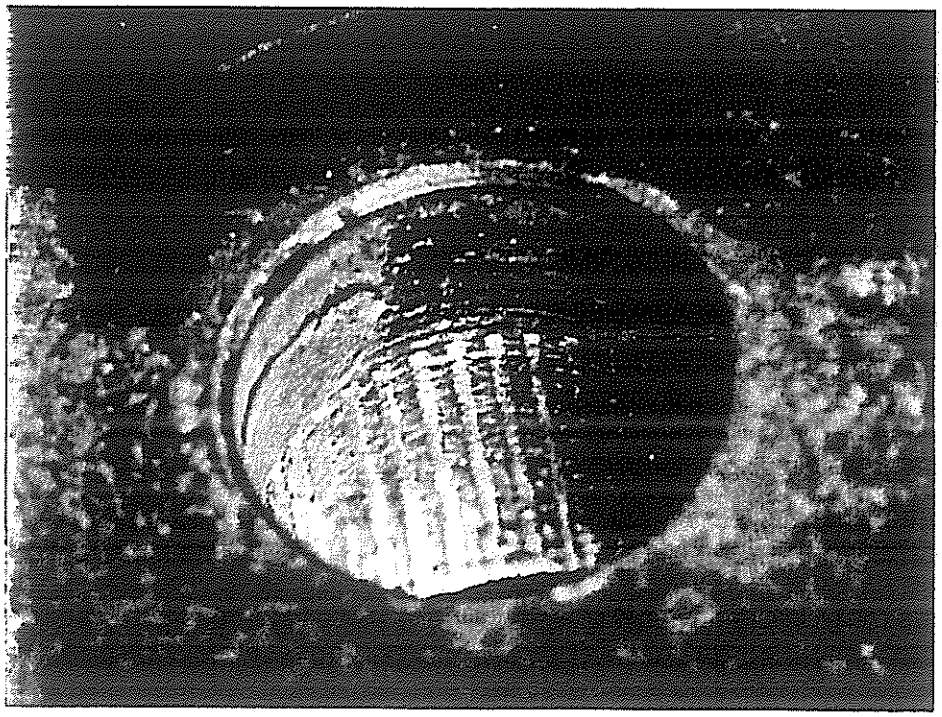

Figure 2. Location 2 – serration marks from the bolt extended from the inside toward the outside for an appropriate length – paint remained between the serration grooves

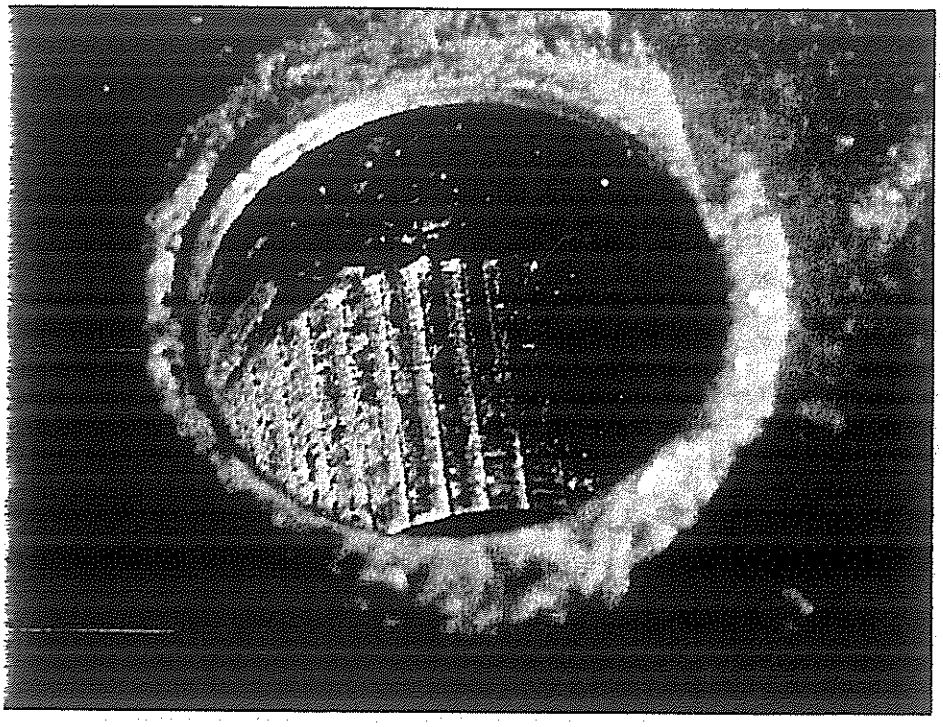

Figure 3. Location 7 – serration marks from the bolt extended from the inside toward the outside for an appropriate length – paint remained between the serration grooves

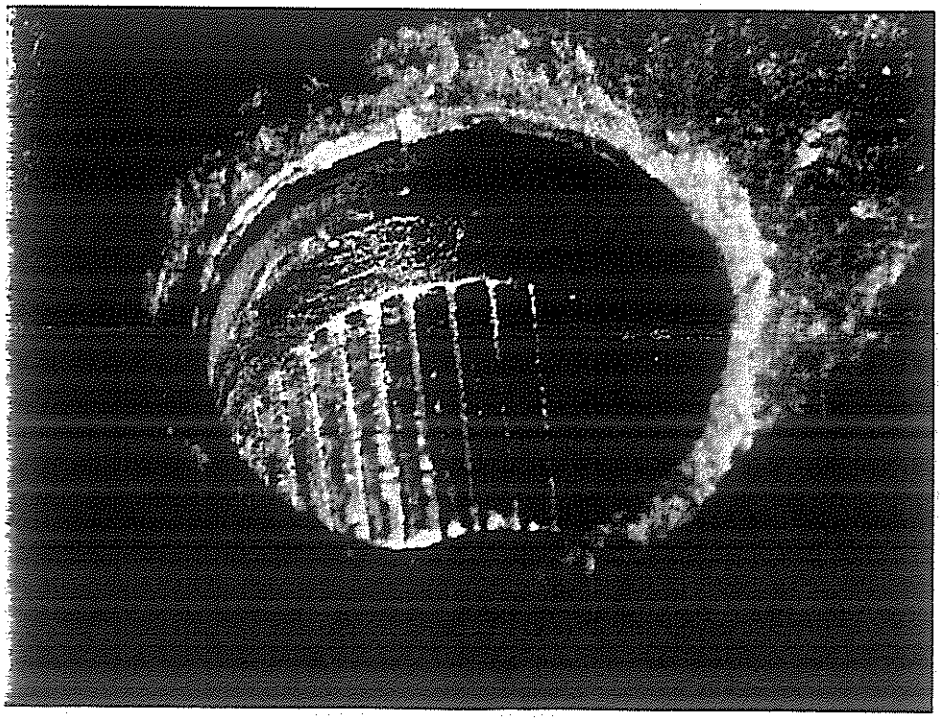

Figure 4. Location 8 – serration marks from the bolt extended from the inside toward the outside for an appropriate length – paint remained between the serration grooves

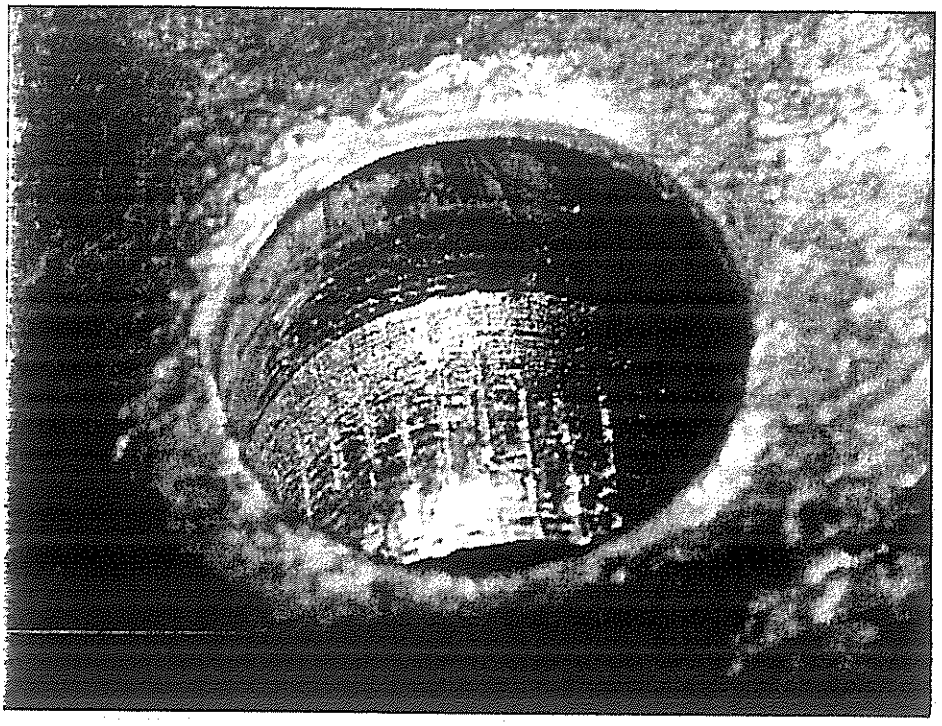

Figure 5. Location 5 – serration marks from the bolt extended from the inside toward the outside for an appropriate length – paint was removed when the bolt spun in the hub

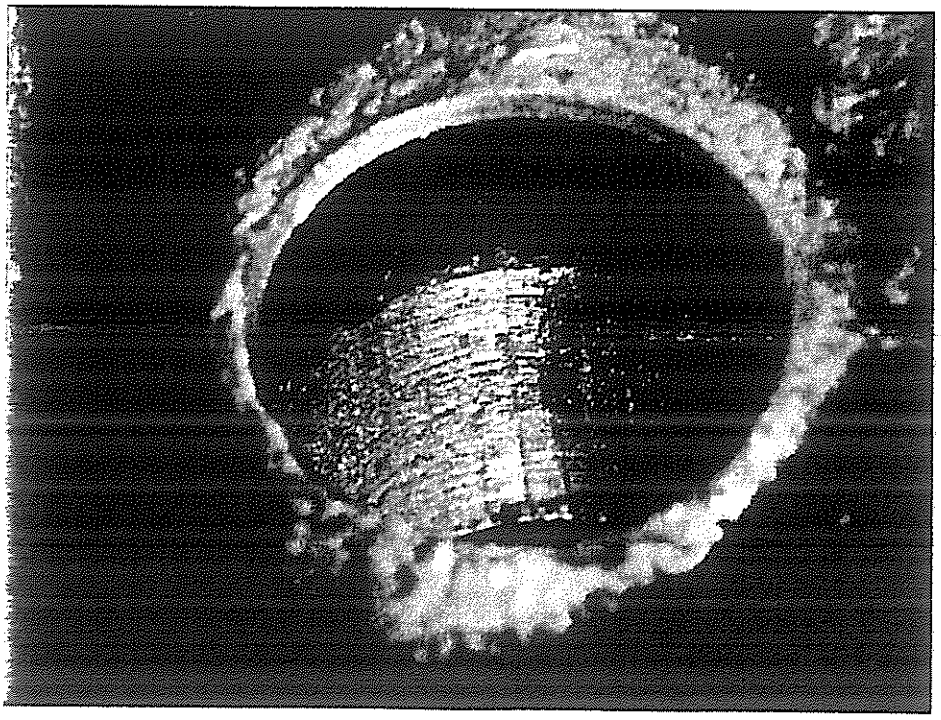

Figure 6. Location 6 – serration marks from the bolt extended from the inside toward the outside for an appropriate length – paint was removed when the bolt spun in the hub

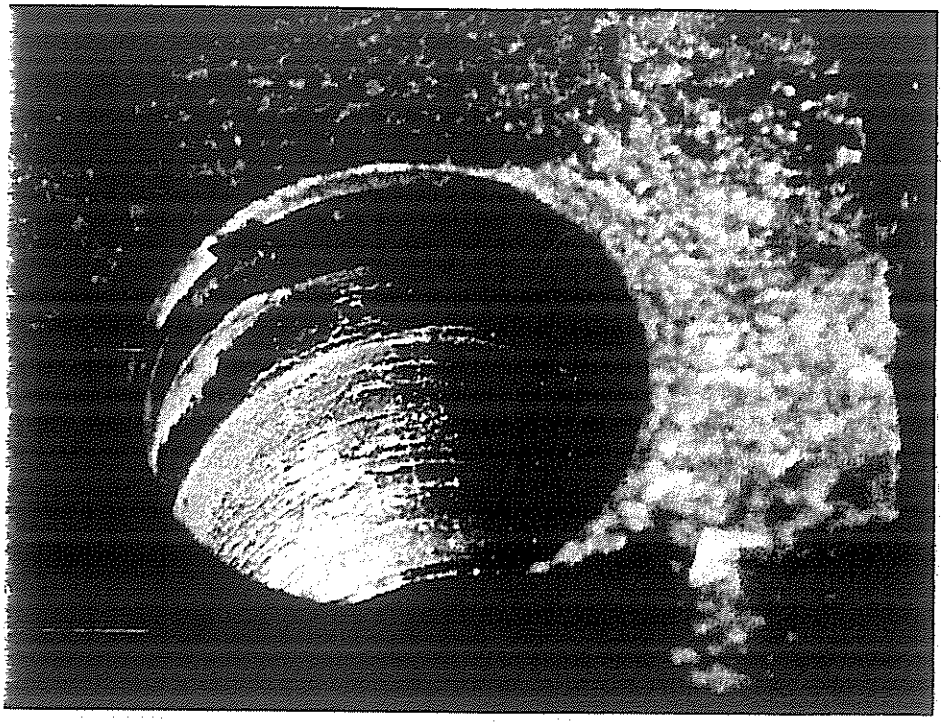

Figure 7. Location 3 – serration markings were almost completely worn off the surface apparently as the result of the bolt rotating in the hole

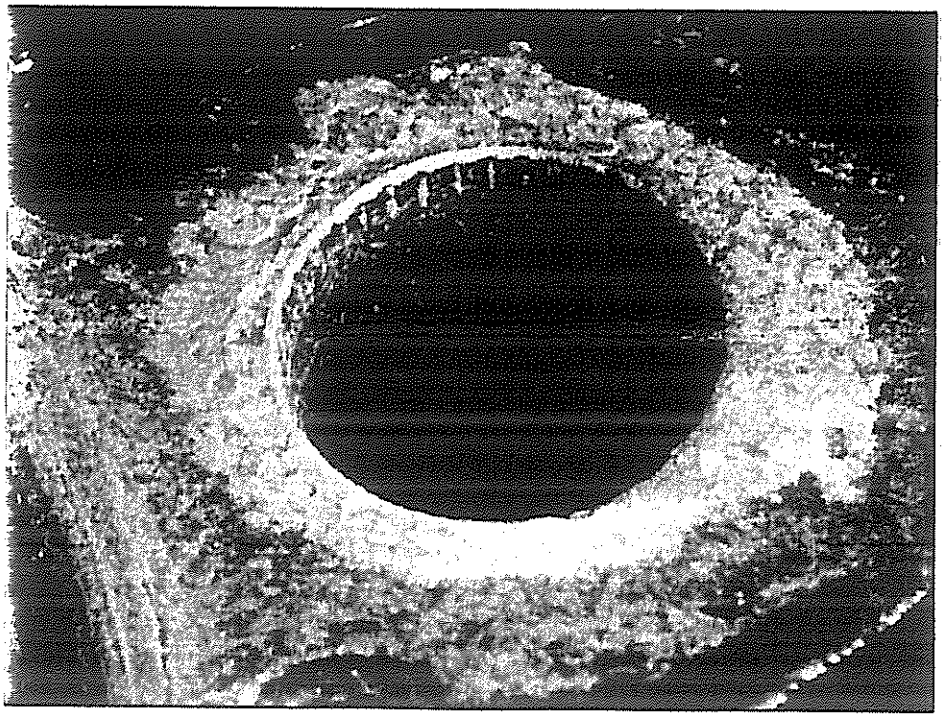

Figure 8. Location 1 – serration marks were found extending for the entire length of the hole and the surface was worn, which removed all paint

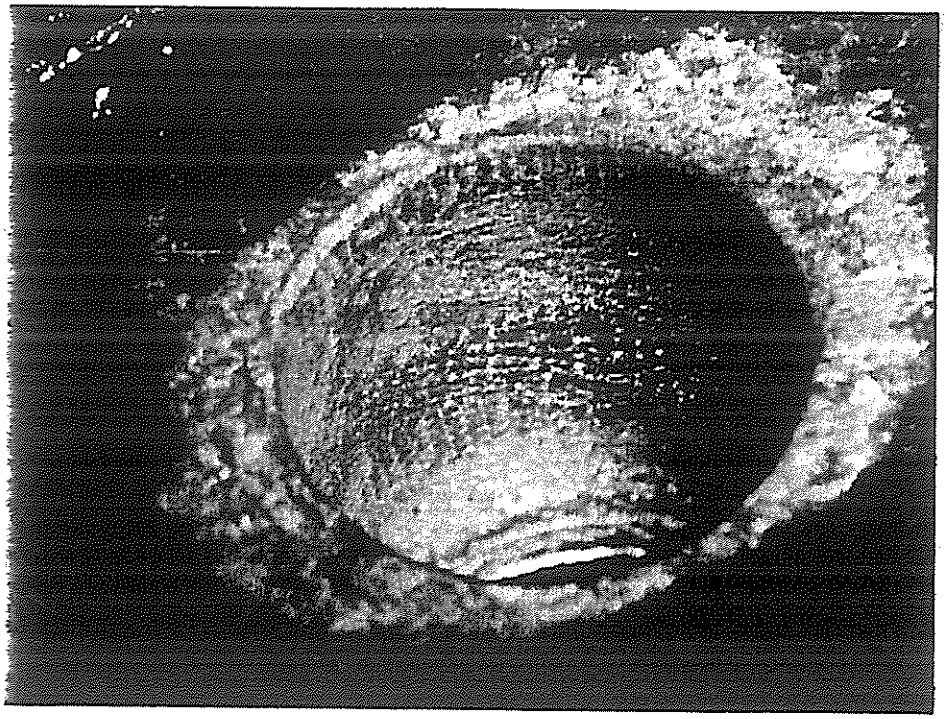

Figure 9. Location 4 – serration marks were found extending for the entire length of the hole and the surface was worn, which removed all paint

Tom Peck

From: DAGuisbert@aol.com
Sent: Wednesday, October 26, 2011 11:01 AM
To: tompeck@drvsuites.com
Cc: murphy114@earthlink.net
Subject: Lab report 4446-3
Attachments: 4446-3.pdf

Tom - Pat,

Attached is a report on the visual observations of the bolt holes in the wheel that broke off.

If you have any questions, do not hesitate to ask.

Dave

Quality Associates – Metallurgical Services

1795 Foundation Drive – Niles, MI 49120 Phone 269-695-2623 FAX 269-695-4423

QA Lab Report No. 4446-4

TO: Tom Peck
DRV, LLC
160 West 750 N
Howe, IN 46767

26 October 2011

SUBJECT: Brake Rotor Hub to Wheel Joint – Wheel Bolts – Hubs without Bolt Breakage
Part Number: Not Provided / Serrated Shank Wheel Bolt 5/T6 Dia.
Specification: Grade 8 per SAE J429

OBJECT: Determine if there are cracks in the wheel bolts of hubs where breakage did not occur.

RECEIVED: The three brake rotor hubs that did not exhibit wheel bolt breakage are the subject of this analysis. They were from Calgary, removed from a 2011 Model 36 TKSB3 vehicle, VIN 5KEFA3624B , which was manufactured on 06/07/2010.

CONCLUSION: Several small indications were detected at the thread runout during magnetic particle inspection. Metallographic analysis revealed that the indications were the result of small laps and sharp corners from thread rolling. No cracks were found in the bolts of these three wheels.

TEST DATA:

Visual Examination

All bolts exhibited a zinc plating finish, with a clear dichromate conversion coating. Head markings included the Grade 8 identification and a manufacturer's identification marking of "W".

Magnetic Particle Inspection per ASTM E709

All bolts were pressed out of the hub for examination. Wet fluorescent particle inspection revealed faint indications of possible cracks in several of the bolts in the right front and right rear hubs. These indications were observed in the thread runout. The indications ranged from 2 to 5 mm in length. No indications were detected in bolts on the left front.

Metallographic Examination per ASTM Methods

Four bolts that exhibited longer indications were selected for examination. Two were taken from each of the two hubs that showed indications.

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Lab File 4446-4

TEST DATA: (Continued)

Right Front:

Bolt 6 exhibited a sharp corner at the bottom of the thread, at the thread runout (Figure 1). A grain boundary is seen to be aligned with the sharp corner, but there was no evidence of a crack. The magnetic particle inspection indication is attributed to the sharpness of the corner. In a cross section cut 90 degrees to this indication, a small lap from thread rolling was observed in the thread root (Figure 2). There was no evidence of crack propagation off the lap.

Bolt 8 a small lap from thread rolling (Figure 3) was observed at the thread root. There was no evidence of crack propagation off the lap.

Left Front:

Bolts 5 and 8 exhibited similar sharp corner features from thread rolling at the thread runout (Figures 4 and 5). In addition to these features a small lap from rolling was observed on the flank of Bolt 5. No evidence of crack propagation was found in association with these indications.

General Microstructure:

Microstructures of the bolts consisted of fine-grained, tempered, medium carbon martensite throughout. This microstructure is consistent with the requirements for Grade 8 product. Thread profile and root surfaces exhibited no evidence of decarburization. Overall quality of the heat treatment was good.

Material cleanliness based on the size and distribution of the nonmetallic inclusions was good.

Report by:

Matt Guisbert

Matt Guisbert

Approved by:

David A. Guisbert, P.E.
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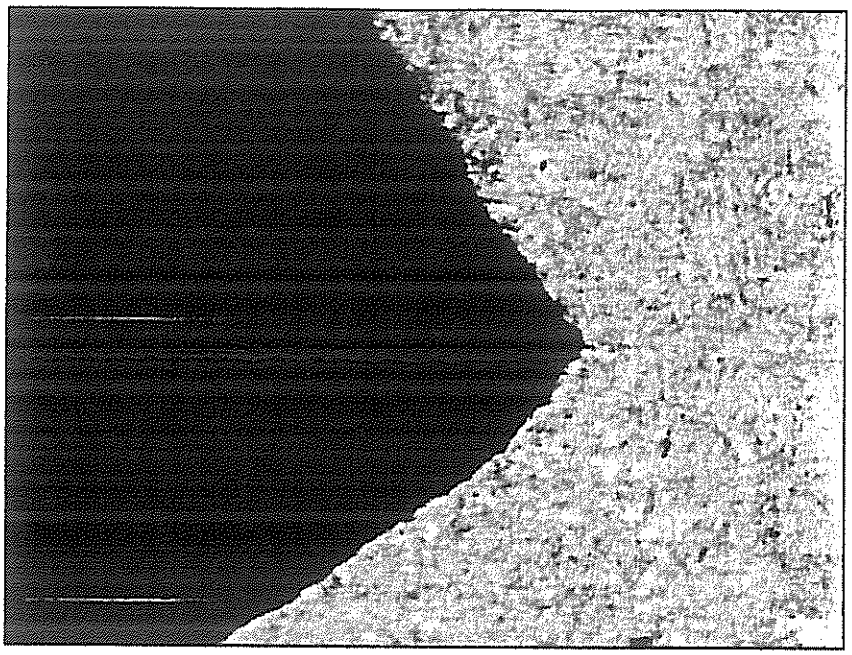
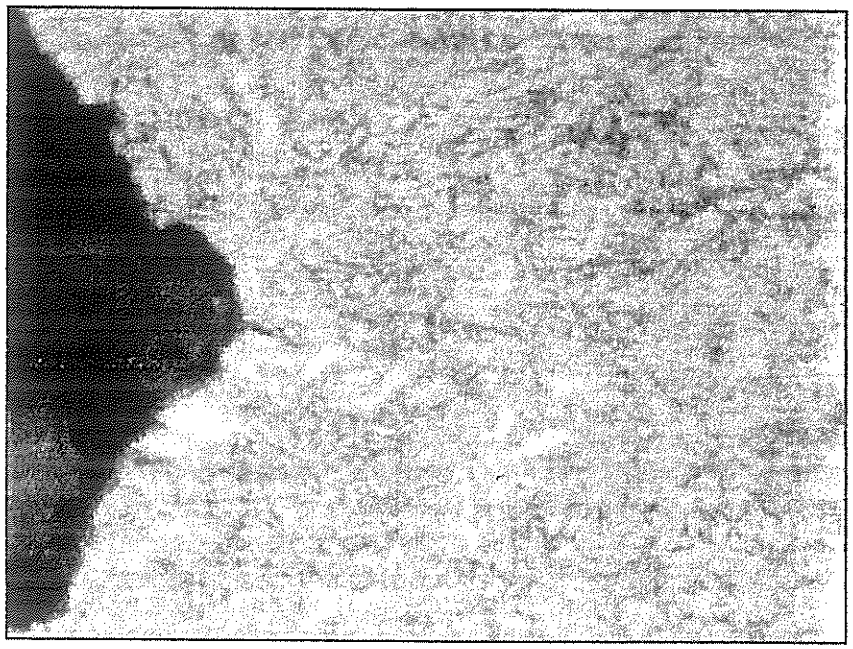
ATTACHMENTS: Figures 1 to 5

DISTRIBUTION: T. Peck
Lab File 4446-4

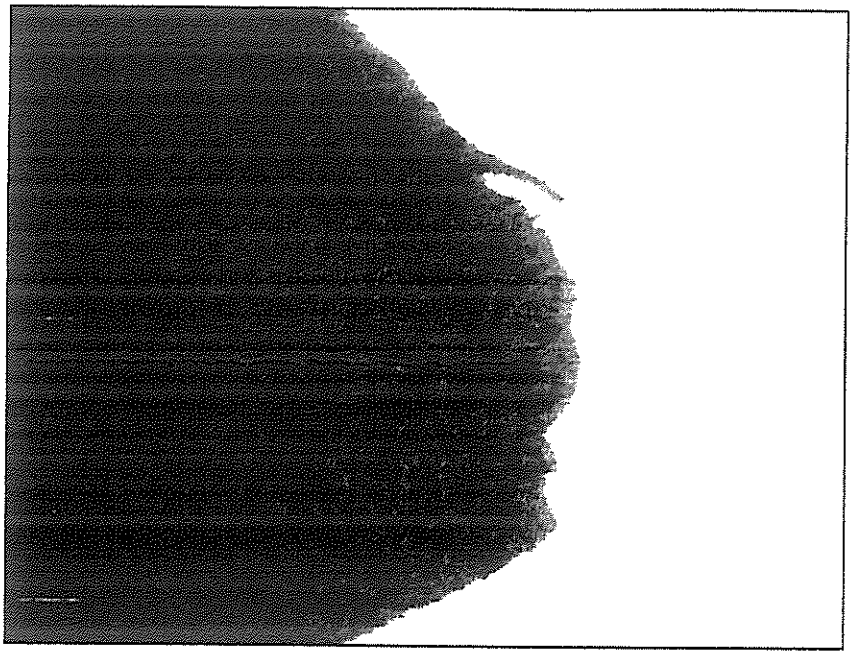


a) Nital Etchant, 500X

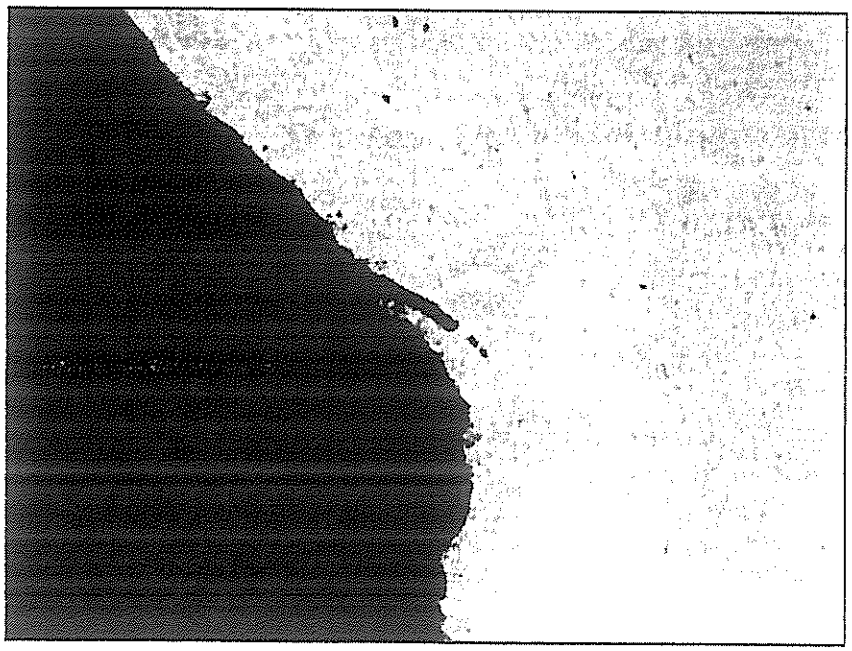


b) Nital Etchant, 2500X

Figure 1. Right Front, Bolt 6 – showing a sharp corner at the bottom of the thread root at the thread runout – a grain boundary is seen at the bottom of the corner, but this did not appear to be a crack

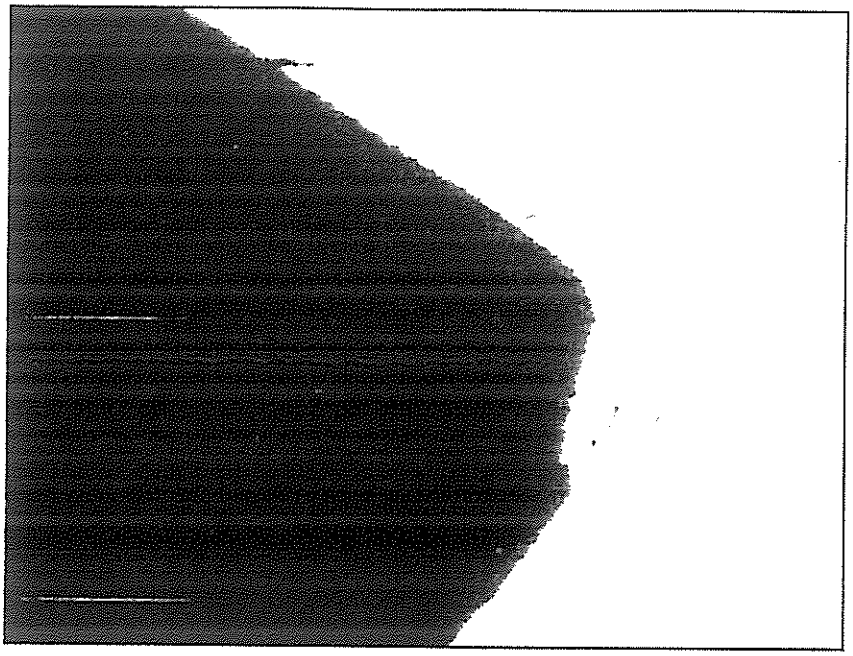


a) As Polished, 250X

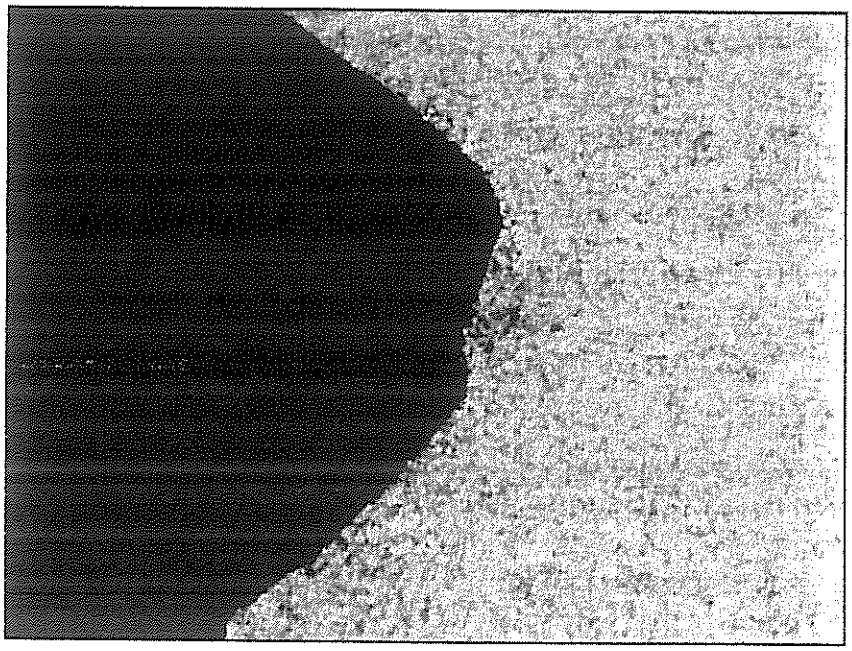


b) Nital Etchant, 250X

Figure 2. Right Front, Bolt 6 – this cross section at 90 degrees to Figure 1 shows a small lap from thread rolling in the bottom of the thread profile near the thread runout – no evidence of cracking was observed in association with the lap

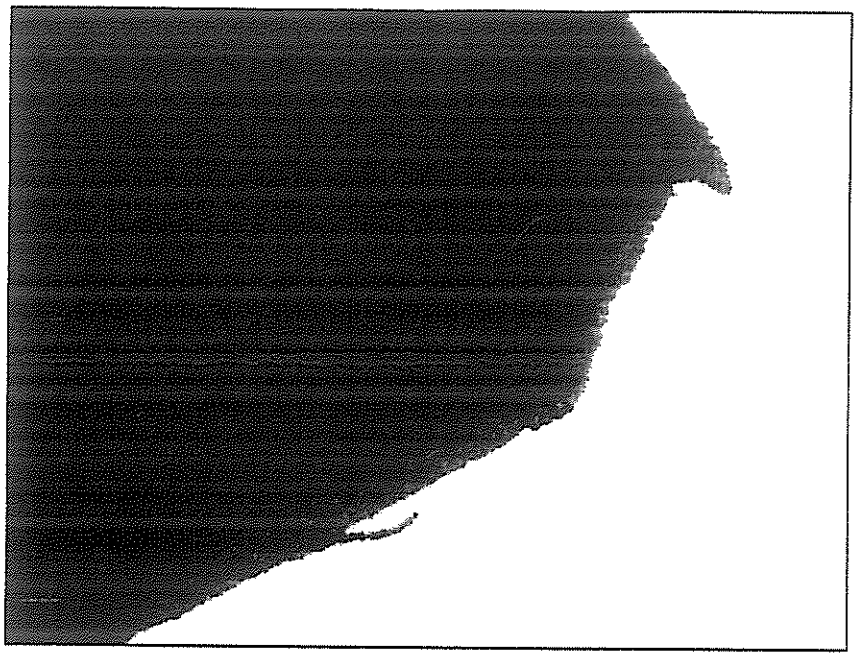


a) As Polished, 250X

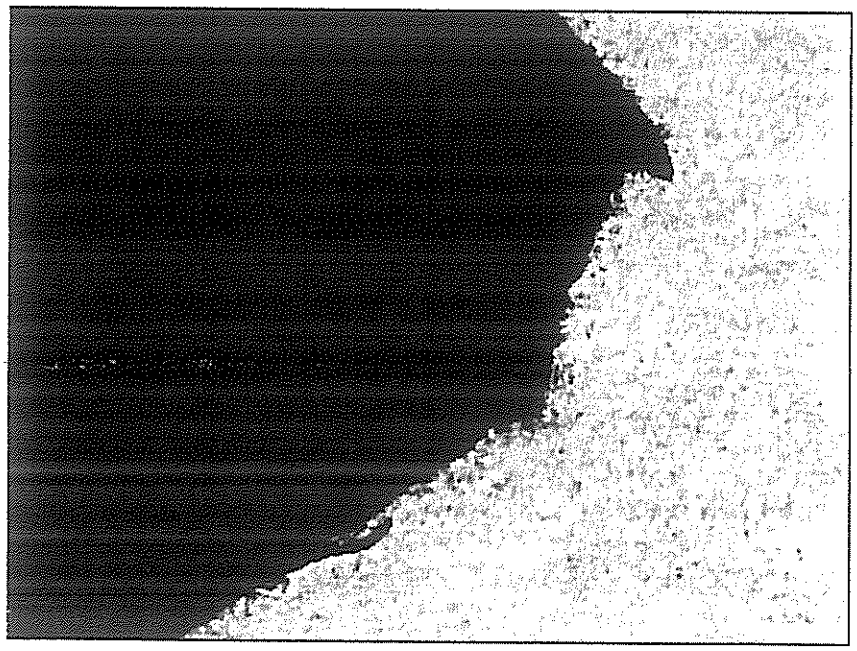


b) Nital Etchant, 250X

Figure 3. Right Front, Bolt 8 – showing a small lap from thread rolling in the bottom of the thread root at the thread runout – there was no evidence of crack propagation off the lap

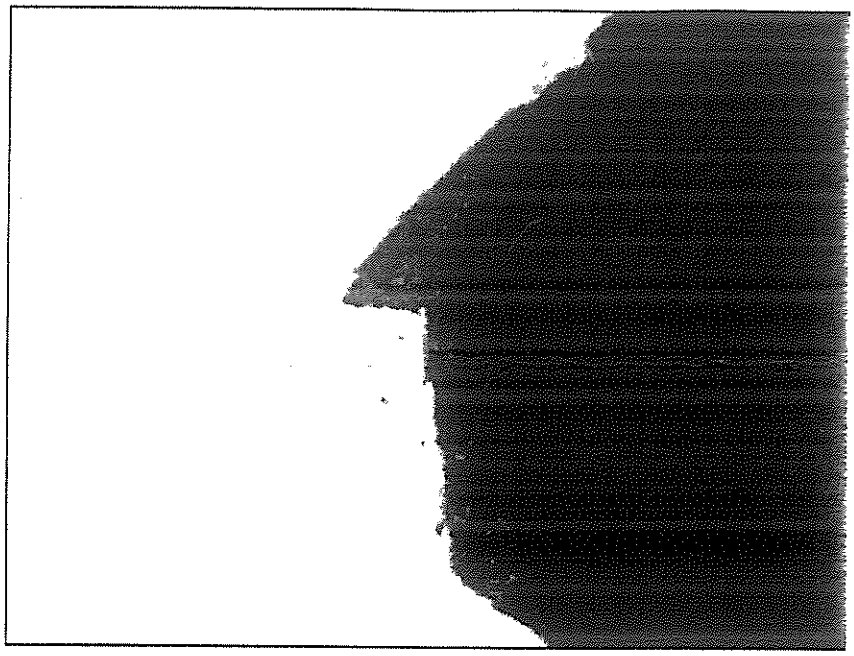


a) As Polished, 250X

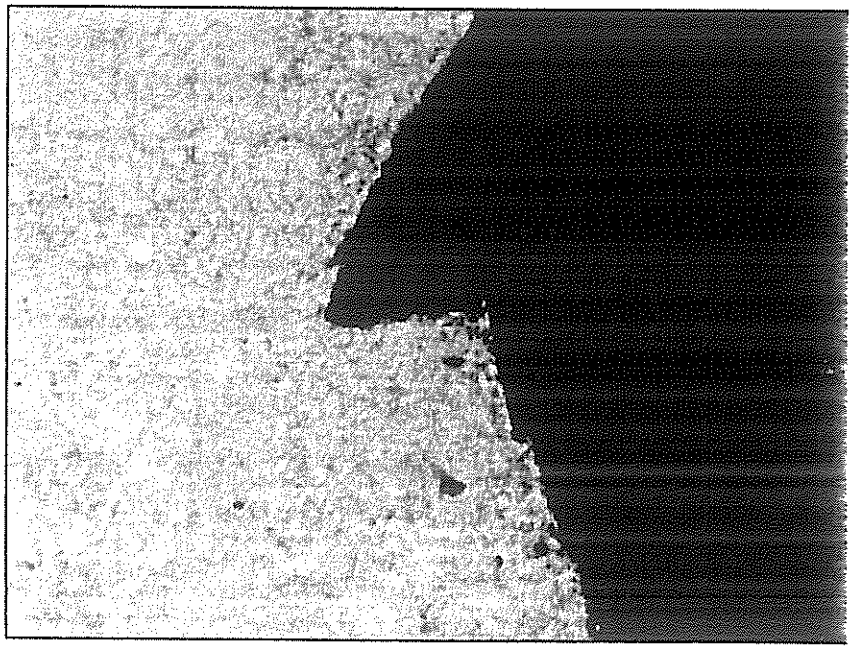


b) Nital Etchant, 250X

Figure 4. Left Front, Bolt 5 – showing a sharp bottom corner in the thread root and a small lap on the thread flank at the thread runout – there was no evidence of crack propagation



a) As Polished, 250X



b) Nital Etchant, 500X

Figure 5. Left Front, Bolt 8 – showing a sharp corner in the bottom of the thread at the thread runout – there was no evidence of crack propagation off the corner