Wheel Stud Bolt Failures

Three culprits—improper seating, deformed threads, and use of noncalibrated torque wrenches are addressed below.

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Numerous wheel bolt failures in passenger cars and large trucks have been reported. Counterfeit bolts and over-torquing are the primary reasons for failure most frequently cited before serious study.

A wheel failure on a passenger car with a missing lug nut and a dual wheel failure on a large truck will be used to demonstrate two common problems. These examples encompass installation of after-market wheel stud bolts and thread damage.

Background

A brief description of torque and clamp-up force and how they affect wheel bolt failures may be helpful before going into specifics of the two cases. Running a nut down tight by torquing it with a wrench pulls the bolt head towards the nut by the mechanism of inclined threads. If the bolt head is seated against a solid, non-compressing surface, the body of the bolt becomes stretched. The body becomes a big spring pulling the wheel rim against the axle flange. Using a C-clamp in place of the bolt would achieve the same effect—a clamping force. And the more torque applied, the more the clamping force.

Fatigue failures develop in threaded fasteners when a varying or cyclic stress is imposed. Clamp-up forces protect against such cyclic stresses. A simplified, but reasonable representation of the situation is if the clamping force from one nut holding the rim to the axle is greater than the road forces prying the rim from the axle, the wheel stud bolt only experiences a positive clamping force. The bolt will not experience destructive forces until the prying forces exceed the clamp-up forces.

Over-torquing should not lead to a fatigue failure by itself. Over-torquing into the plastic range, if it does not break the fastener in the process, should leave the fastener in the highest possible clamp-up condition. The nut, however, may be difficult to remove because of thread distortion. Torquing fasteners just beyond yield is done in high-strength structural bolts.[1]

Passenger Car Wheel Failure

A twelve-year-old passenger car traveling down an interstate highway suddenly lost the right rear wheel while crossing a bridge. Loss of the wheel caused the car to go out of control and crash. The tire and rim were never found after the accident. All five of the wheel stud bolts remaining in the axle flange were observed to have been broken off. The owner of the car admitted that one of the bolts had been broken prior to the accident. Over-torquing of the lug nuts was thought to be the cause of the bolt failures by those initially investigating the accident. Another theory put forward later was that one broken bolt would inevitably lead to failure of the others.

Evaluation of the broken stud bolts revealed fatigue in all fractures. **Figure 1** shows one of the better preserved fractures. The stud bolts were also observed to be aftermarket bolts and four out of five were not properly seated.

Figure 2 shows a profile view of one unseated bolt. Fatigue fracture covered 90-100% of the fracture surface in three of the bolts. The one seated bolt had 75% of its fracture surface composed of fatigue bands and the last bolt had 40% fatigue coverage.

The effect of the prior broken stud bolt was evaluated by stress calculations. The clamp-up force expected in these wheel stud bolts (7/16-20, comparable to SAE Grade 5) was approximately 11,400 lbs. at 80 ft.-lbs. Dirty threads would be expected to reduce this value by 10-50%.

Calculations reveal that cornering forces produce the highest individual forces, on each individual bolt, when at the bottom location relative to the road. However, these forces at maximum cornering conditions just reached the expected clamp-up forces on each bolt. Since such maximum cornering loads are not encountered very often, properly torqued wheel stud bolts appear to provide an adequate safety margin for fatigue.

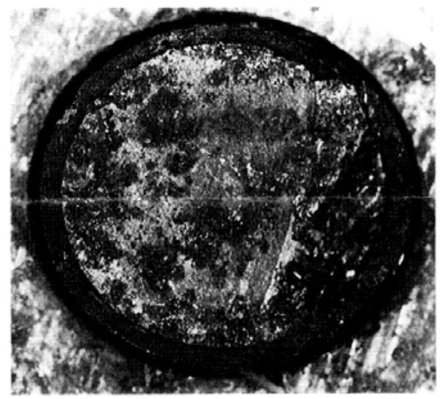

Fig. 1 — This wheel stud bolt from a passenger car has a fatigue crack across 75% of the fracture surface.

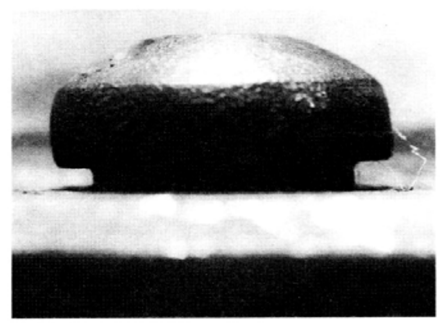

Fig. 2 — Four out of five wheel stud bolts were clearly not properly seated.

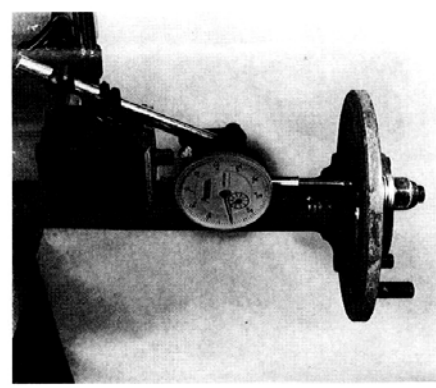

Fig. 3 — A dial gage was used to monitor movement of the bolt head while the nut was run down with a torque wrench.

Removal of one stud bolt out of five produces a case in which the maximum forces at the missing bolt are spread between two bolts for a net reduction in force in the two bolts. If the remaining bolts are properly torqued, a missing bolt would not be expected to affect the life of the others.

A missing wheel stud bolt should not be ignored, however, based on these arguments. A broken stud bolt is a warning that something is wrong. The same problem may have been in the other bolts, but they have not failed yet. The remaining wheel stud bolts should be replaced.

The effect of improperly seated stud bolts was investigated with another axle removed from a similar sedan. It also had similar aftermarket stud bolts improperly seated. As a matter of fact, additional investigation revealed a considerable number of aftermarket stud bolts on axles that could be inspected. A dial gage was set up on the head of the bolt and a nut with hardened washers was used with a torque wrench to try to seat the bolts. Threads were cleaned and lubricated. That setup is shown in **Figure 3**.

All unseated stud bolts moved at 75 ft.-lbs. Two bolts seated at 140 ft.-lbs., and the threads stripped in the third at 130 ft.-lbs., without seating. Had a tire been mounted on this axle, and nuts installed with a torque wrench, full clamp-up could have been achieved if the nuts were torqued to 70 ft.-lbs., but could have moved the stud bolt and destroyed the clamp-up. Failure to seat the stud bolt heads hard against the axle flange results in unpredictable clamp-up and the possibility of fatigue failure of the stud bolts.

Failure to properly seat the stud bolts was the probable cause for fatigue failure of the bolts. This is an important conclusion because stud bolts appear to be replaced more often than was generally recognized. Most shops recognize that presses should be used to install such bolts, but one car manual recommends using lug nuts to seat the bolts. Limited testing reported here makes that approach highly questionable.

Dual Wheel Failure

A dual wheel failure on a ten wheel tractor pulling a load of scrap metal illustrates the effect of thread damage which can prevent proper clamp-up on

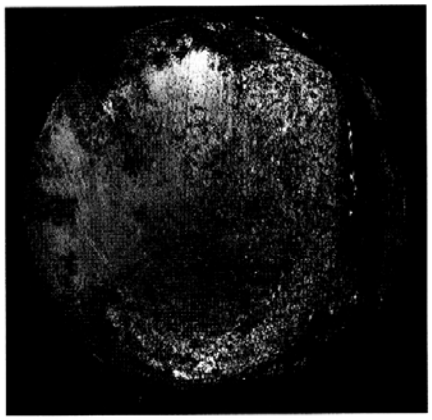

Fig. 4 — This was the best preserved of the five broken stud bolts on a large truck with high-cycle fatigue damage. The banding is indicative of individual trips.

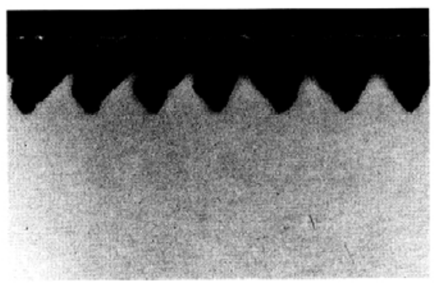

Fig. 5 — Both undamaged and damaged threads can be seen in this section through one of the broken wheel stud bolts from the truck. Thread damage in both directions was observed. This thread damage destroys the normal thread clearances and renders any torque measurements useless.

wheel bolts. This is a case where over-torquing was a problem, but the failure follows the next installation. All ten wheel stud bolts broke off a dual wheel on a highway allowing one tire to strike a car. Laboratory inspection of the broken stud bolts revealed five of the bolts on one side of the wheel had high cycle fatigue damage in one direction **(Figure 4)**. Three of the stud bolts failed in high stress reversed bending fatigue. Fracture surfaces on the remaining two stud bolts were too damaged to determine their nature.

Thread profiles on all bolts were observed to be deformed. The bolts which had high-cycle fatigue and were the first to break had the most thread damage. **Figure 5** shows the thread profile from one of the broken stud bolts.

Maintenance history on the truck revealed that the wheels had been removed twice in the three weeks preceding the accident. In all probability, the nuts were over-torqued the first time and threads were deformed. The air wrench used the second time had the power to remove the nuts. However, there was no way to reinstall the nuts properly because the damaged threads provided too much turning frictional resistance. Thus about half of the wheel stud bolts probably had little or no clamp-up and failed quickly. The remaining bolts failed under the greatly increased forces.

In Conclusion...

To summarize, the three culprits responsible for the majority of wheel stud bolt failures are:

- **Culprit 1** — Improperly seated wheel stud bolts in passenger cars and trucks may present a more serious safety hazard than earlier recognized. Wheel stud bolts are not always properly seated when replaced by mechanics. Improperly seated stud bolts can lead to fatigue failures. Stud bolts must be seated by a hydraulic press.
- **Culprit 2** — Deformed threads from over-torquing wheel stud nuts constitute a serious problem for all vehicles. This problem is that a prior tire installation, with over-torque damaging the threads, makes a later installation impossible to perform correctly. Thread gages are now readily available for the three-piece wheel bolts that are used on large trucks. Similar type gages available for passenger cars would be very helpful.
- **Culprit 3** — There is much misunderstanding about air wrenches used to install lug nuts. The vast majority of air wrenches in service cannot be calibrated to torque. Only the speed can be varied. Torque is controlled by how long the wrench is run, air pressure, and air flow rate. Calibrated, air-driven torque wrenches are available, but they cost approximately eight to ten times as much as wrenches found in most shops. Nut torque on wheel bolts is important because bolt failures can lead to fatal accidents. Use of a calibrated torque wrench on clean, gaged, and lubricated threads is the most reliable approach to ensuring proper nut torque.

For more details contact the author or **Circle 241**. FTI

[1] *Fisher, J.W. and Struik, J.H.,* ***Guide to Design Criteria for Bolted and Riveted Joints****, Chap. 4, John Wiley and Sons, 1974.*