TECHNICAL NOTE

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When Is 100% Inspection Not Enough? An Analysis of Three Pickup Truck Front Wheel Assembly Failures

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ABSTRACT: The loss of a cotter pin in the front wheel assembly of cars and trucks has been a problem for several years. This is shown by the fact that the automobile manufacturers have been committed to a 100% inspection of the process for installing them on cars and trucks. In this paper, three accident cases are presented, along with a method by which the forensic engineer can determine if a cotter pin has ever been installed on the front wheel assembly. Testing was done to show what the spindle would look like if the cotter pin had been installed properly and forcibly removed. Photographs show both the accident and test spindle for comparison.

KEYWORDS: forensic science, forensic engineer, accidents, cotter pins, cars, trucks, 100% inspection, spindle, front wheel assembly

Automotive manufacturers today have at their disposal many tools to insure that their product is being properly assembled. Two of the most basic are human visual inspection and video cameras recording the process as long as the production line is running. These two methods working together should insure that all the product components are being installed as required. This is referred to as a 100% inspection of the process. But why is 100% inspection required? It is because the manufacturer has not be able to insure, by any other means, that a particular component is being properly installed on each and every assembly as it passes that particular station. Therefore, in order to eliminate possible injuries to the consumer, which may result in litigation, a 100% inspection policy of the process is instituted. It would seem that such a policy would eliminate any errors in the installation process. This, however, is not true.

The entire wheel and tire assembly on our present day cars and trucks is secured in place by a 25-cent cotter pin. This same process has been used on vehicles for close to 40 years. Every other component used on a vehicle today has undergone some type of change, whether it is material, coatings or sizing. The cotter pin has remained unchanged.

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What makes the loss of the cotter pin such a hazardous situation? The wheel and tire assembly is placed on the axle spindle and an adjustment nut is threaded onto the spindle. The nut is driven home and then backed off approximately ¼ of a turn. A castellated capture nut is placed over the adjusting nut and a cotter pin, which is made of a zinc coated soft metal, is placed between the slots in the castle portion of the nut, and then through a hole in the spindle. The open ends of the cotter pin are then bent or wrapped around each side of the spindle. The grease cup is then placed over the entire assembly and the hub cap or wheel cover is placed on the rim. Figure 1 shows an exploded view of a front wheel assembly.

Automobile and truck manufacturers claim that a 100% visual inspection of this process is performed as it occurs on the production line when the vehicle is being built (Quality Control personnel deposition testimony and assembly plant process sheets). This seems like a simple enough operation and should not present a problem. Unfortunately within the last few years at least three cases have come to light in which the wheel and tire assembly worked its way off the front left spindle of light duty trucks, ending in a tragic accident for the occupants.

Why only the left front wheel assembly? Both front spindles are made with a right-handed thread. This means that the adjusting nut is turned in a clockwise direction when tightening it onto the spindle. This is true for both the right and left-hand sides of the vehicle. The problem is better defined when we look at the rotation of the tires from each side of the vehicle. The right side tire rotates in a clockwise direction when the vehicle moves in the forward direction, which is the same direction used when tightening the nut onto the spindle.

Looking at Fig. 2, the left side of the vehicle, we see the tire now rotates in the counter-clockwise direction when the vehicle is moving in the forward direction. The adjustment nut being threaded onto the spindle still rotates in the clockwise direction. This is where the problem begins. If the cotter pin has not been installed, the adjusting nut may eventually work itself loose and the tire and wheel assembly will start to move outward on the spindle. As it does so the wheel assembly pushes against the adjusting nut. Because of the difference in the direction of rotation of the tire and wheel assembly and the threads on the spindle, the adjusting nut will began to unthread itself from the spindle as the wheel assembly pushes against it. If unchecked, the nut will eventually drop off of the end of the spindle into the grease cup, and the wheel and tire assembly will be moved outward, away from the car and off of the

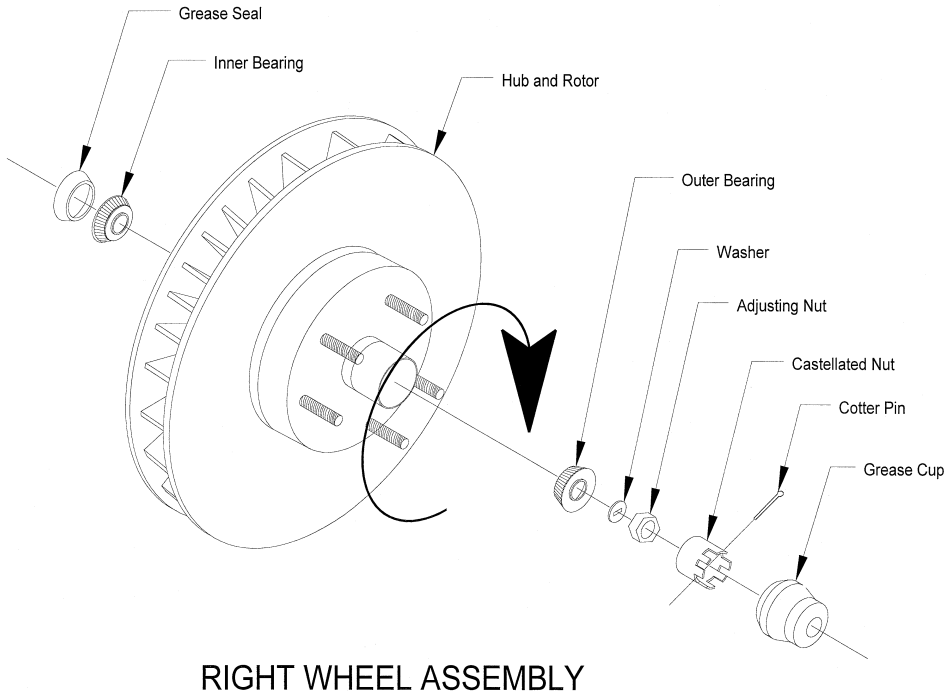

FIG. 1—*Exploded view of a right front wheel assembly.*

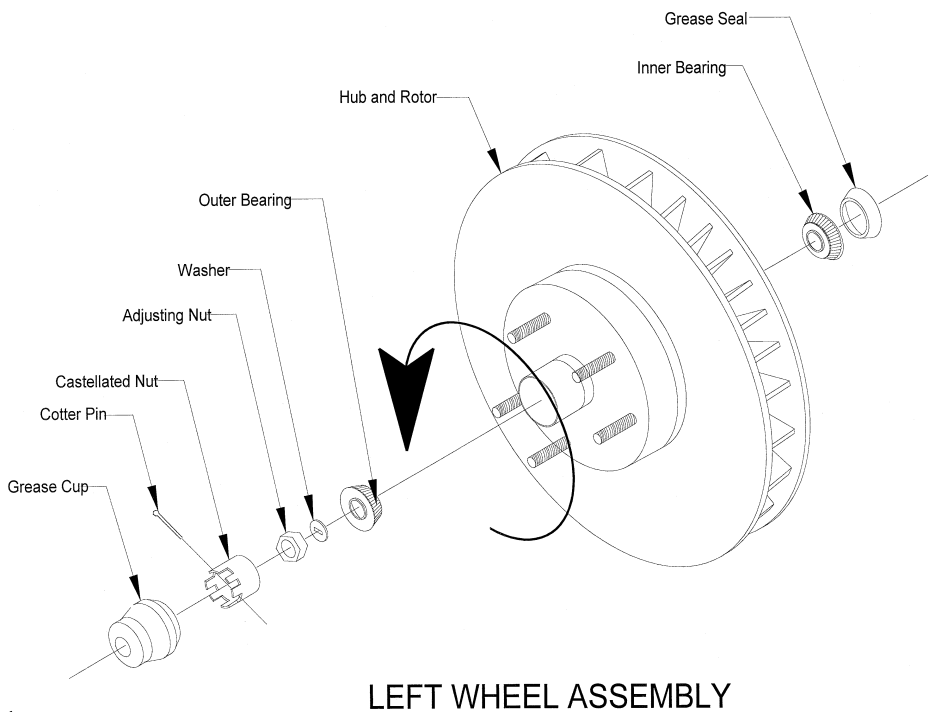

FIG. 2—*Exploded view of a left front wheel assembly.*

spindle. The vehicle's left front suspension and brake assembly will drop down onto the roadway and cause the vehicle to rotate to the left due to the road-brake assembly interface and in some cases the vehicle will overturn, rolling over and causing serious if not fatal injuries. The failure to install the cotter pin started the entire accident sequence.

During the last few years, at least three such cases were brought to light. In each case, the manufacturer of the truck stated unequivocally that there was a 100% inspection of the process in which a cotter pin was inserted in the hole in the spindle to hold the left front wheel assembly on to a pickup truck. In each case, the left front wheel assembly worked its way off of the axle

spindle resulting in an accident and causing severe injuries to the occupants.

In each case, there was an impact with a barrier or another vehicle. The manufacturer's defense was that the impact caused the cotter pin to be sheared off allowing the wheel assembly to come free.

In two of the three cases, a direct impact to, and a scraping of, the roadway surface damaged the left front dust shield for the brake assembly. In addition, the spindle end was severely flattened by impacting the road surface and was ground down as it skidded along the road.

The first case involved a pickup truck that had only 2000 miles on it. The owner was traveling on an expressway when he felt the vehicle moving to the left. The more he corrected it, the more it moved to the left. He then began to feel vibrations in the steering wheel. The truck ran up the face of the median concrete barrier where the left front tire caught on the top of the barrier. Since there was nothing to hold the wheel to the spindle, the truck dropped out from underneath the wheel and landed on its right side and slid to a stop. The driver of the vehicle sustained a serious closed head injury.

The second case involved a medium duty pickup truck that was taken to a dealer for front wheel bearing repacking. Two days later, the left front wheel assembly came off. The front left brake assembly hit the ground and the truck slid sideways into another vehicle, seriously injuring the occupants of both vehicles.

The third case occurred in the Southwestern United States on a long stretch of open road, late at night. The vehicle was only a year old with a few thousand miles on it. The vehicle had five men in it coming back from a long day working in the fields.

The left front wheel assembly separated from the left spindle and suspension assembly allowing the left front backing plate to slide along the road. The truck slid down the roadway into oncoming traffic and struck an approaching vehicle. It then careened off of the struck vehicle and slid another 50 ft down the road where it hit an uneven section of paved surface, overturned and slid several feet into the desert. In this case, the castellated nut was jammed into the grease cup and was protruding partially through it. The adjusting nut was never found in any of the cases.

The problem facing the forensic engineer is to determine if a cotter pin was ever placed into the spindle hole. A simple method was

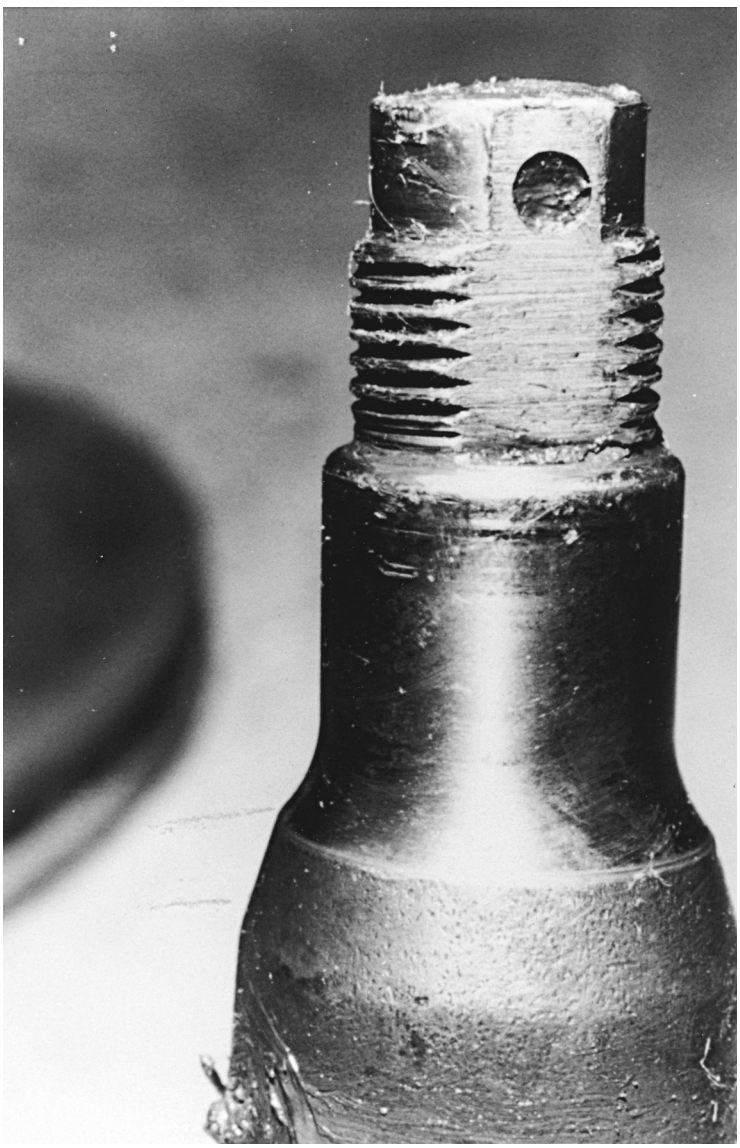

FIG. 3—*Typical accident spindle from a vehicle that lost a front wheel.*

developed to check the roundness of the hole that the cotter pin goes through on the spindle. In each case where the hole was not damaged from hitting the ground, we could see and measure the roundness of the hole. If the hole is not round, then a cotter pin had to be in place, since it would be very unlikely that damage to the interior portion of the hole could be caused by another mechanism. Based on the reconstruction of the accident sequence and the measurements of the roundness of the cotter pin hole, it was determined that no cotter pin was ever in place, or if in place it was never properly secured when installed.

How does a front wheel assembly come free of the front spindle of a truck? Since the adjusting nut jams the assembly against the shoulder of the spindle it either has to be unthreaded or pulled off of the spindle, damaging the threads. Figures 3 and 4 show a spindle from an accident vehicle. Note the hole is round, with no deformity, and full of grease. There is little or no damage to the threads except where they slid along the ground. The adjusting nut damaged the threads near the shoulder as it worked its way off of the spindle. The end of the spindle is relatively soft, as it is not heat-treated. If the cotter pin is in place and is then forced against the outside edge by the adjusting nut pushing against those portions of the cotter pins extending above and below the hole, a shearing force is created. This force, pushing against the inside surface of the hole, deforms the hole, especially at the edges, until the cotter pin separates and the center portion drops out allowing the adjusting nut to become unthreaded. This shearing process would deform the spindle hole to such an extent that many times it can be seen by the naked eye or a low powered magnifying glass.

You must also inspect the wheel bearing cones to locate the witness marks that are left from the tapered wheel bearings as the tire and wheel assembly drops off of the spindle. They are easily spotted. Figures 5 and 6 are good examples. An impact to the wheel assembly could not have caused this damage as the witness marks are in the up and downward direction which are not consistent with a lateral or forward force acting on the wheel assembly during an accident.

Two tests were conducted using a new wheel assembly, complete with cotter pins, adjusting nut and wheel bearing cones in

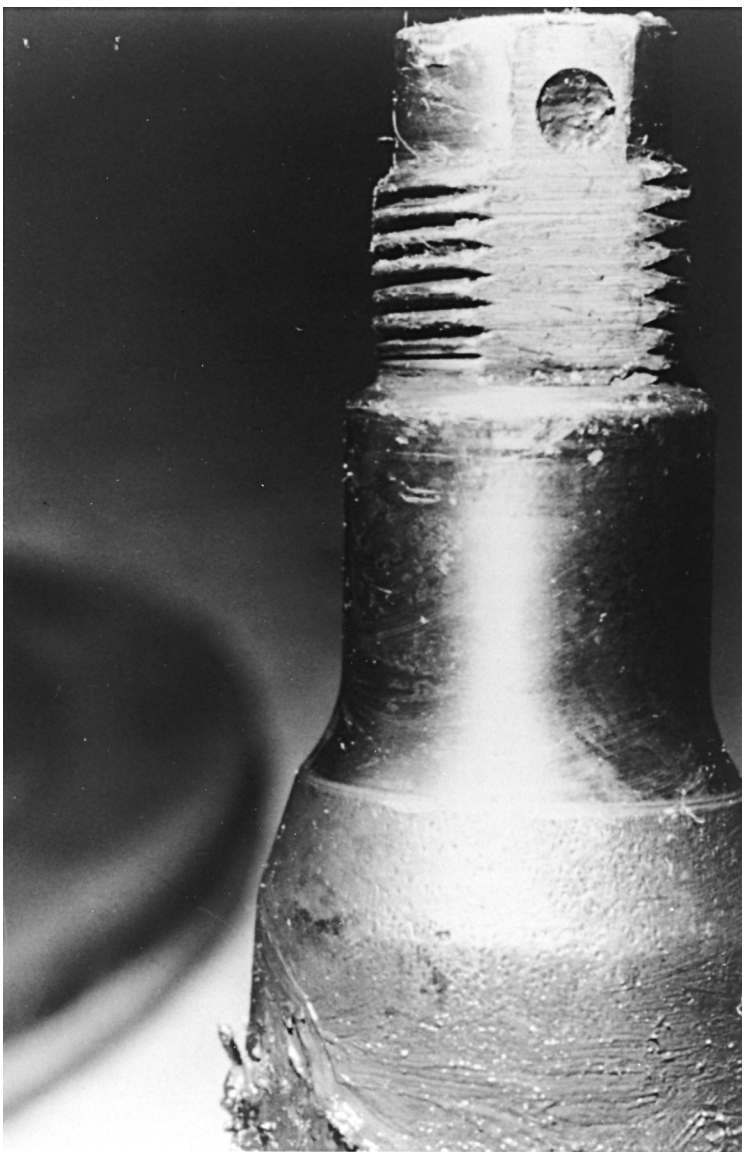

FIG. 4—*Close up view of a accident spindle from a vehicle that lost a front wheel.*

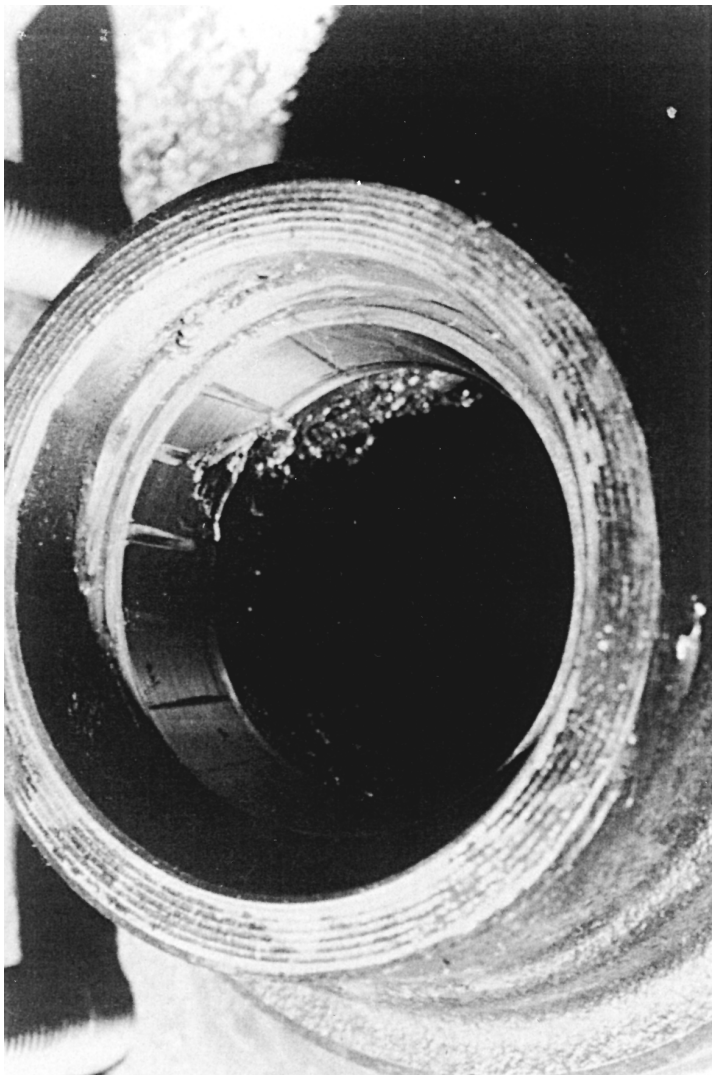

FIG. 5—*Bearing housing showing bearing marks and metal fracture from spindle.*

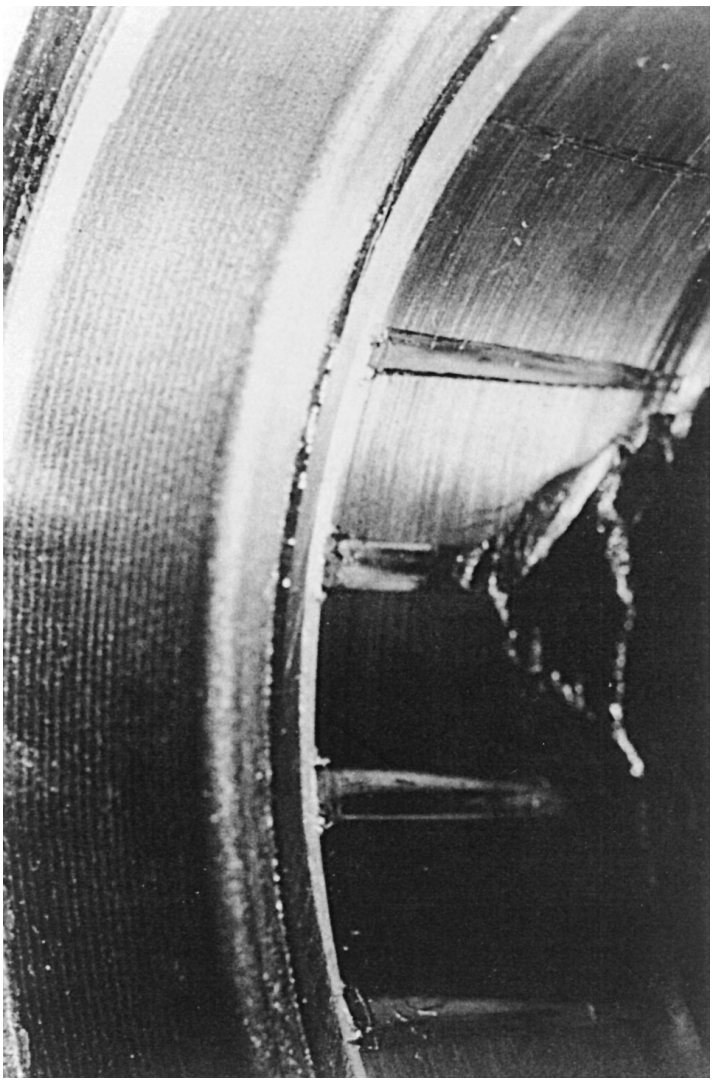

FIG. 6—*Close up of bearing housing with bearing impressions.*

place. The wheel assembly was placed in a tensile-testing machine with the spindle facing upward. Locking devices held down the wheel assembly.

The adjusting nut was pulled off along the axis of the spindle. A constant load was applied until the adjusting nut sheared the cotter pin and came free of the spindle. The test data is no longer available. No other tests were performed such as twisting the nut off using a wrench since this is not consistent with accident facts and the inspection of the accident spindles. Figures 7 and 8 show the results of the testing. Note the elongated hole and the damage to the threads. None of the accident vehicle spindles exhibited elongated holes or damage to the threads. A second confirming method involves a little more cost and work. All cotter pins are zinc coated. The use of the electron microscope will show if any particles of zinc are left inside of the hole. To be sure the zinc is truly from the cotter pin, the greases and other components must be checked to insure there is no zinc residue deposited by them during their use.

How can the problems of the missing cotter pin be prevented? Ironically this problem did not exist in the 1950's. Chrysler Corporation used a left-hand thread on the left wheel spindle and a right-hand thread on the right wheel spindle. If a cotter pin was left out during the assembly process, either at the initial installation or during some repairs to the front wheel, the nut could not be worked free by the bearing assembly working against it due to the direction of rotation of the left front wheel and tire assembly. The reason they stopped using that design is a matter of speculation.

The most commonly heard reason was that professional and even "Shade-tree Mechanics" had trouble cross-threading the left side spindles, i.e., trying to force them into a right-hand thread. Since 1980, there has been a variety of patents issued as a replacement for the common cotter pin (1–3). These devices basically consist of a captured nut made from cone shaped laminated washers. The device can only be used once by its design. This prevents a used nut from being inadvertently used when it will not work as designed. Unfortunately there is no data available to the public regarding their use.

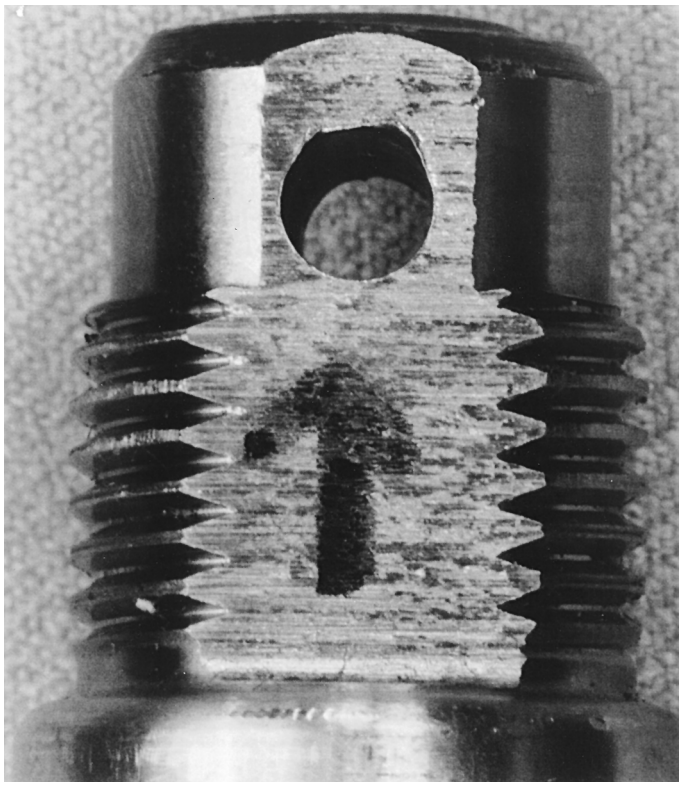

FIG. 7—*Close up view of spindle test specimen with deformed hole.*

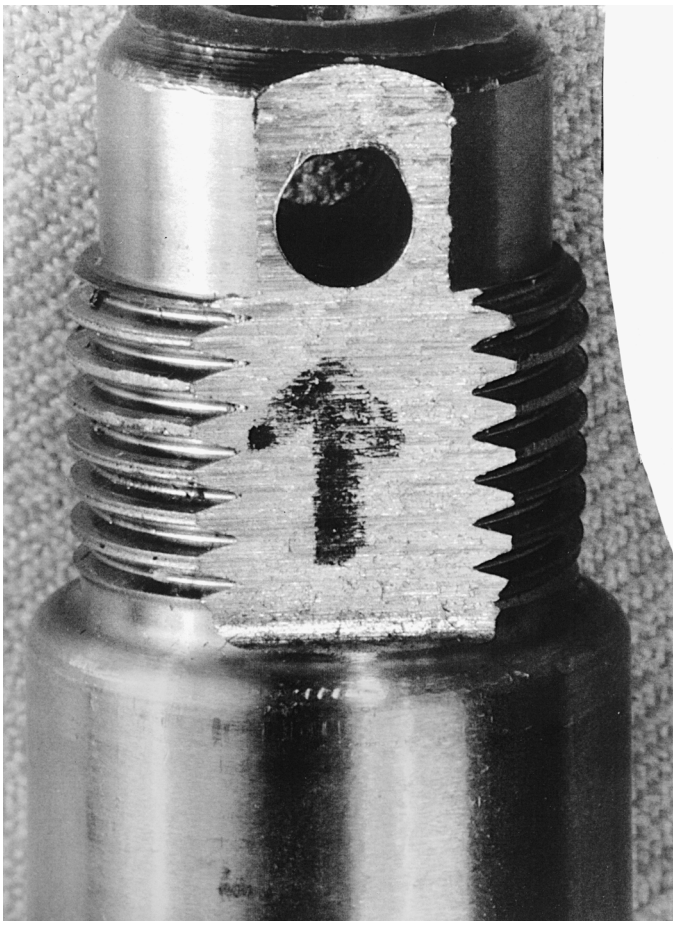

FIG. 8—*Close up view of obverse side of test spindle with deformed hole.*

Conclusions

It is obvious that a 100% visual or video taped inspection is not the answer to the problem. What is needed is a device that eliminates the possibility of a missing part. It must also be replaced whenever the front wheels are taken off of the vehicle. The laminated nut devices have been available since 1980. The technology is here and the product is available.

This is neither a widespread nor even a common problem in the assembly or even repair of a vehicle, as far as can be determined. However, three cases in two years by a single firm should be brought to the attention of others working in the field.

A reconstruction of the accident must be performed to rule out the possibility of an off axis impact which may have caused the wheel assembly to come off of the wheel assembly. Once this type of impact has been ruled out then a detailed examination of that spindle must be conducted.

Close examination of the front left spindle of a vehicle that loses a front wheel assembly in an accident must be examined very carefully for the lack of a deformed spindle hole. This possible cause of the accident can easily be eliminated by this simple inspection technique.

If the engineer is still unsure of the loss of a cotter pin then the use of the electron-scanning microscope will show if any particles of zinc are left inside of the hole. To be sure the zinc is truly from the cotter pin, the greases and other components must be checked to insure there is no zinc residue deposited by them during their use.

We need someone to say, "That even if it costs more than a cotter pin and it will save a severe injury or possibly a life, then it is worth it."

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