by Guy Avellon

Why Automobile Wheels Fail Part 2

The key to any wheel failure is to cause a loss of clamp load between the wheel and the wheel hub. It was previously stated that clamp load may be lost from a variety of reasons; through repeated reuse of the nut, from using an unregulated impact gun to tighten the wheels, from not retightening the wheel nuts within 100 miles (161 km) after installation, road hazards, heavy loads, thick rust on surfaces that inhibit a solid joint, ABS and Traction Control, embedment into the wheel boss, from not using proper mounting techniques, wheel alignment problems, from over-tightening, the presence of lubricants or using non-strength matching aftermarket parts.

It was also previously mentioned that almost all wheel failures occur to a vehicle with over 100,000 miles (161,000 km). This statistically represents the number of times that a wheel would have been removed and remounted. This would include tire rotations (5,000 – 8,000 mi, 8,000 – 12,800 km), brake inspections and brake replacements (20,000-35,000 mi, 32,000-56,000 km), tire replacement (50,000 mi, 80,000 km), brake rotor turning, winter to summer tire exchange, rebalancing, replacing shock absorbers or struts, etc.

There have been many articles regarding the loss of clamp load when a nut is retightened, caused from the thread deformation and increased friction of the internal threads. Everyone agrees with laboratory tests finding that approximately 50% of tightening energy is consumed from the friction between the mating surfaces as the nut is tightened against the work surface. And, approximately an additional 40% friction is generated between the threads as the threads engage during tightening. Therefore, 90% of the tightening energy is consumed by friction and only 10% is used to tighten the joint.

When these tests were conducted, a standard nut with a flat washer face surface was used. A wheel nut, or wheel stud bolt, has a conical mating surface. The conical surface mates with the conical depression found in most wheels called a wheel boss. The depression helps pilot the wheel and the wheel nut or wheel stud into position. However, these conical surfaces produce an increased surface area that would increase the friction between the rotating surfaces from 50% to an additional 2-6%. This spread will depend upon surface finishes, surface condition and corrosion. Therefore, instead of the normal 10% of tightening energy used to create clamp load, the initial usable energy drops to 8-4%.

Conservatively, this means the surface friction of a new wheel nut increases to 52%, decreasing the tightening energy from 10% to 8%. When the wheel nut is removed and reinstalled, friction between the threads from reuse increases from 40 to 42%, therefore, only 6% of the torque input is used to create the clamping load during a remount. Fortunately, from design and the fact that there are four to five wheel nuts holding the wheel onto the wheel hub, clamp load loss is gradual but can be compounded from the effects of many variables.

Impact Guns

Photo 1 . Classic metal fatigue conchoidal markings and 'chatter' stresses

One of the greatest causes of wheel failures is the use of impact guns. Metal fatigue can be initiated from stress raisers created by the impacting of a common ½" drive air impact wrench (gun). Unregulated air guns create an initial impact between 325 – 425 lb-ft of torque at speeds up to 8,000 RPM. Heavy truck wheels average 500 lb-ft. When the nut hits the wheel boss, there is an initial moment of joint compression, then relaxation, then compression again with each impact as the impact gun continues to impact the wheel nut onto the wheel.

The average passenger vehicle and light truck requires between 80 – 110 lb-ft of torque for proper assembly.

The impacting creates an elastic rebound with the threads of the wheel stud, which creates thread stresses. Automotive manufacturers use assembly machines, such as by Atlas-Copco, with multiple sockets that apply an even torque to all of the wheel nuts at the same time, thereby eliminating the elastic interaction between wheel studs. Unfortunately, this cannot be duplicated in a shop.

All service garages use air tools operated from an air compressor. If a mechanic is asked what the torque output is of his impact gun, the usual reply is "90 pounds". However, this is air pressure in psi (pounds-per-square-inch), not torque which is pound-feet.

Most fully charged air compressors begin at 120 psi. As an air tool is activated and the air chamber pressure decreases, the compressor's motor begins to regenerate pressure when the compressor's pressure drops to 90 psi.

The single shop air compressor is used for car lifts, multiple air guns, tire inflation, tire mounting equipment and other air powered tools. The output air pressure fluctuates between 120 – 90 psi when other tools are used at the same time. For the most part, the fluctuation has an insignificant effect on equipment, except for the output torque when mounting a wheel. No wheel nut will have the same amount of torque applied in this situation.


Photo 2


Photo 3

To be sure the wheel is tight, many mechanics will continue to impact the wheel nuts into the wheel boss. Sometimes, as illustrated by the wheel nuts in *Photos 2* and 3. The conical seat of the wheel boss area will also be damaged. These wheel studs may fail long before the wheel becomes detached, yet the empty wheel hole and missing lug nut will likely go unnoticed by the driver until it is too late.

← Severe impacting destroys the conical seating surface and the first few threads

As an example, Marker #1 in *Photo 4* displays a perfectly round mounting hole that is undamaged. This indicates a wheel stud that failed before the wheel lost clamp load. Its loss of clamp load contributed to the overall loss of the wheel. The mounting hole at the 4 o'clock position has taken a fatigued wheel stud to final fracture when the wheel began to lose clamp load and shift. Markers #2 and #3 illustrate wheel movement in both acceleration and hard braking.


Photo 4

Marker #1 : Perfectly round mounting hole.
Marker #2 & 3 : Wheel movement in acceleration and hard braking.


Photo 5

Rounding of the hexagonal corners


Photo 6

Wheel stud bolts suffering installation abuse

Because of the many variables involved with any joint connection, a common unregulated impact wrench should never be used for assembling any type of joint, especially wheels. For decades, ever since the addition of disc brakes, auto manufacturers have advised against using an impact wrench to assemble wheels. For one, the sudden and increased clamp pressure will warp many rotors. A warped rotor may be felt as a pulsation through the brake pedal when applying the brakes after service. It is recommended to use torque sticks or a torque wrench.

Secondly, it makes it difficult to near impossible to remove the wheel nuts on the roadside with the supplied wrench handle. Yet, the wrench handle is sufficiently long enough for the average person to exert enough downwards force with their body to safely tighten the wheel nuts.

Adjustable output impact guns are very expensive. Better tire shops will use a low torque, around 50 lb-ft, to set the wheel in place. Then they will apply the proper torque to each wheel nut in a criss-cross pattern to each wheel. The best practice is to retighten each wheel nut again. Every joint relaxes. The interval between tightening and retightening is sufficient time to allow the joint to relax, then regain any lost clamp load when retightened.

All new car manuals will state that after a tire is removed and remounted, drive the vehicle for 25 to 100 miles. Then retighten the wheel nuts again. This procedure makes certain any compressible debris or alignment has settled to a normal state, producing a solid joint connection.

Remember; no matter how careful you are, when a nut is removed and retightened, the threads distort again creating more friction between the threads when under pressure (tightening). This cumulative increase in thread friction interferes with the tightening process because torque is a function of friction. Increased friction will reduce the work energy available to tighten the threads of the wheel stud causing a decrease in clamp load every time the nut is reused. This is why, under normal conditions, every time any internally threaded nut is removed and retightened, it will never produce the same clamp load as the moment before it was loosened, even if the same torque was applied.

< More in Part 3 >