# 2014 GT3 Engine Failures

## Understanding what's causing the catastrophic rod bolt failures

**STORY** BY **TONY CALLAS** AND **TOM PRINE** AND **PHOTOS** COURTESY OF **PORSCHE**

Many questions have been asked of us recently regarding why there have been engine fires in the 2014 991 GT3 model. As many of you know, Porsche issued an order to dealers worldwide to stop selling the current GT3 and further requested all owners of these cars to stop driving them until the problem could be resolved. Rather than respond to each question we received, we thought it best to bring everyone up to date with the latest information we have and explain some of the complexities involved.

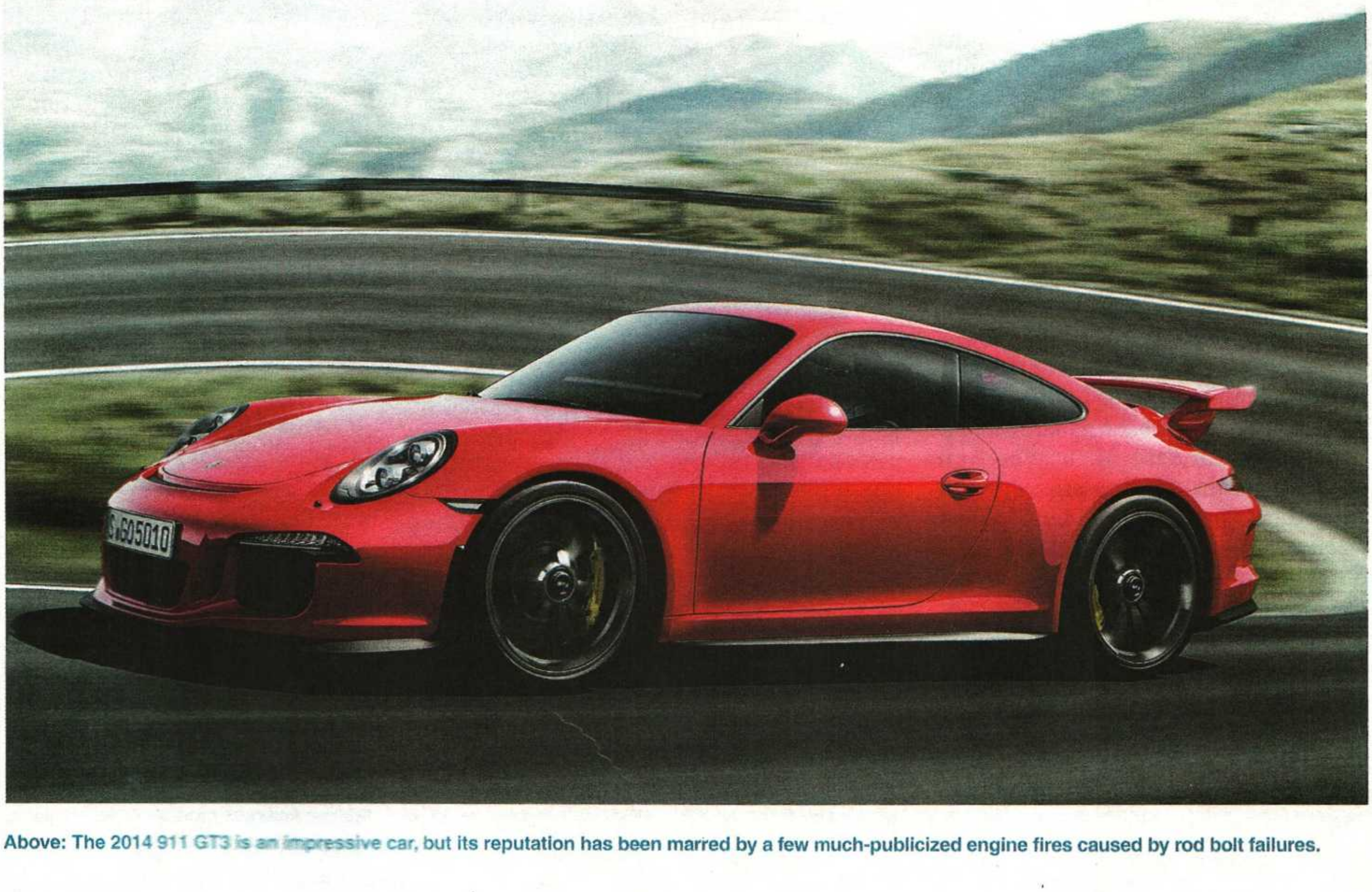
On March 18, 2014, Porsche Cars North America's Public Relations Department published the following news release:

*ANALYSES COMPLETED: PORSCHE TO REPLACE ENGINES OF CURRENT 911 GT3 MODELS*

*Atlanta, Georgia—Sports car manufacturer Porsche will be replacing the engines of all 2014 model year 911 GT3 vehicles. This is the corrective action derived from intensive internal analyses that were initiated in response to two engine fires. Meanwhile, it has been confirmed that engine damage resulted from a loosened fastener on the connecting rod. The loose connecting rod damaged the crankcase, which in both cases led to leakage of oil which then ignited.*

*After becoming aware of the two accident cases, Porsche promptly took action to avoid any risk to customers by advising them to cease using the affected 785 vehicles until further notice and have them picked up by a Porsche dealer. Now, engines with optimized fasteners will be used in all 2014 Porsche 911 GT3s—including in those that have not been delivered yet. Porsche is in direct communication with customers worldwide to discuss the further course of action.*

*Porsche points out that no other 911 models or other model series are affected by this action.*




**Above: The 2014 911 GT3 is an impressive car, but its reputation has been marred by a few much-publicized engine fires caused by rod bolt failures.**

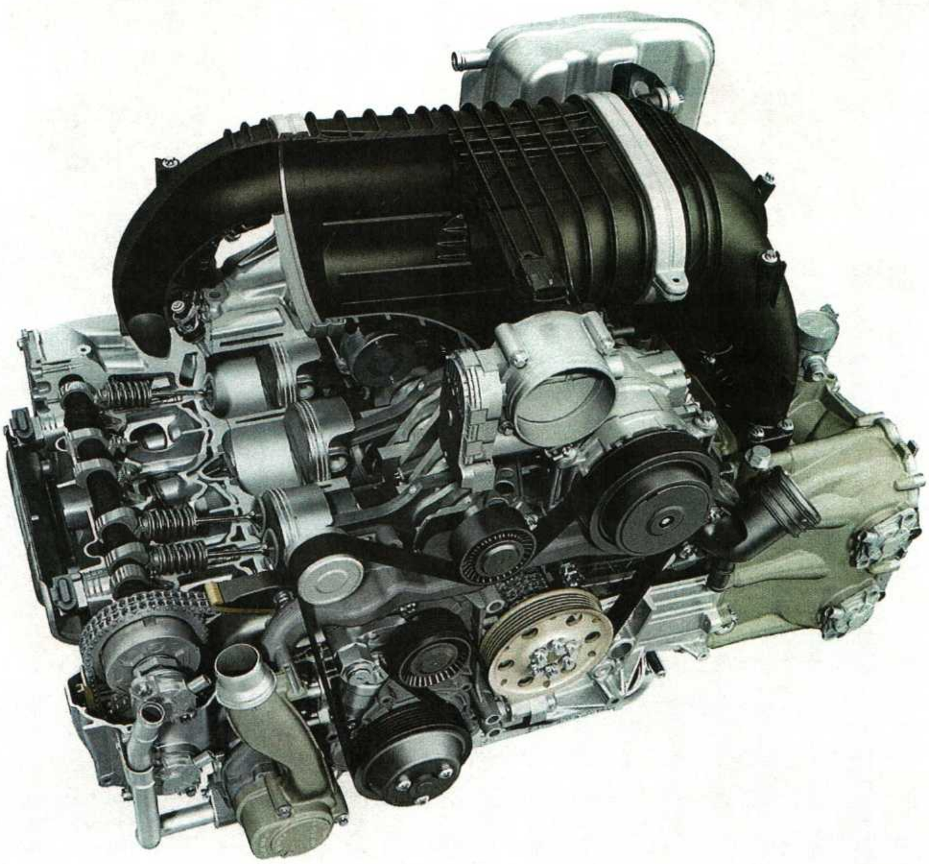
Clearly, Porsche responded decisively to the problem and moved quickly to stop any further damage or property loss. We suspect that Porsche found the problem in engines that had not yet failed which allowed engineering to positively identify the cause. The above news release has two important statements. First, "it has been confirmed that engine damage resulted from a loosened fastener on the connecting rod," and second, "Now, engines with optimized fasteners will be used in all 2014 Porsche 911 GT3s."

We feel that these two statements are somewhat in conflict, since loosened or optimized fasteners could suggest two potentially different problems. Were the fasteners installed incorrectly or was an incorrect fastener being used? We will come back to this, but first we would like to talk about the dynamics associated with connecting rod fasteners.

The connecting rod bolt is arguably the highest-stressed fastener in an internal combustion engine. During every crankshaft revolution, the stroke movement of each piston assembly (which includes the weight of the piston, its rings and wrist pin) come to a complete stop twice in the cylinder bore, once at top dead center (TDC) and again at bottom dead center (BDC). Because of this, the speed of the piston assembly is constantly changing; it is either accelerating from or decelerating to zero. Additionally, the movement of the connecting rod assembly is also constantly changing as the large end of the rod (which includes the rod cap) moves horizontally and vertically while at the same time following the stroke distance of the piston and the rotation of the crankshaft.

The other critical parameter that affects the connecting rod bolts is engine speed. This is because the stroke distance and maximum rate of acceleration imposed on the moving mass (piston and connecting rod assemblies) is what determines the reciprocating mass. This is but one of the design factors that the connecting rod fasteners must meet. The rod bolt must control the bending forces between the rod and the rod cap, plus fatigue resistance caused by repetitive high stresses. Also, careful consideration must be given to the shape and finish of the fastener to ensure no stress risers are present which can lead to fatigue failure.

Connecting rod fasteners are among the most critical fasteners in an engine.

Above: The GT3's 3.8-liter flat-six has a factory redline of 9,000 rpm and puts out 475 hp at 8,250 rpm and 325 ft-lb of torque at 6,250 rpm. This output is good for a 0-60 time of 3.3 seconds and a top speed of 195 mph.

Other critical engine fasteners include cylinder head bolts or head studs (depending on engine design) and the crankshaft main bearing cap bolts or studs. When it comes to critical fasteners, these are typically designed and manufactured to extremely rigorous specifications. Companies that produce critical fasteners of this type typically test every manufacturing run to ensure the quality of each piece. Testing typically means testing to failure and sacrificing randomly selected components to ensure that the others meet the needed specifications.

The connecting rod fasteners are designed, manufactured and installed with the specific application requirements established so as to apply adequate clamping force to hold the rod cap, rod bearings and the connecting rod together on the crankshaft. If the connecting rod fasteners loosen, this will allow a slight deflection movement and separation of the connecting rod cap from the connecting rod. As the dynamic reciprocating forces alternate, it causes an ongoing cycle of stretching and relaxing that ultimately fatigues the rod bolt to the point that it fails.

Typically when a rod bolt fails, it breaks. Even if the second fastener on the rod is not loose, it will sustain damage and break, too. At this point, the rod cap comes off and the connecting rod separates from the crankshaft with enough force to send it through the engine case. Keep in mind that there is very little room inside the engine crankcase beyond the turning radius of the rotating crankshaft assembly. This type of failure is not unusual in a racing engine that has been over-revved; of course, this is not possible in the 2014 GT3, due to the PDK transmission. Porsche has been designing and manufacturing racing and high performance road engines for years; why would the connecting rod fasteners become compromised or fail?

## Connecting Rod Fastener Failure Scenarios

**1. The connecting rod bolts were too loose:** The factory didn't tighten the rod fasteners properly.

**2. Too-tight connecting rod nuts; Torque to Yield (TTY) fasteners compromised:** Over-tightened connecting rod fasteners can cause premature component failure.

**3. Material failure:** Defect in manufacturing and/or metallurgical defects.

**4. Engineering issue:** Under-designed fastener (tensile strength too weak), application for the particular fastener incorrect, RPM too high for that particular fastener, and/or inadequate radiuses where threads start/end.

**5. Component damaged prior to or during installation:** A nick, scratch, dent, or even corrosion on the surface of the fastener can cause a stress riser (failure point).

**6. Incorrect procedure during installation:** Lubrication issue with threads or head of fastener and/or machine, robot and or tool defect causing incorrect tightness or installation.

**7. Connecting rod bearing failure causing fastener failure:** Connecting rod bearing failure caused by lack of lubrication, connecting rod bearing failure caused by pre-ignition/detonation and/or incorrect tolerances of bearing to crankshaft.

**8. A part that has exceeded its lifespan (stressed too many times):** Obviously not the issue in this particular situation.

**Note: Anything that can make the rod bearing cap loose will lead to fastener failure.**

Why do rod fasteners loosen? Generally, the rod fasteners will loosen due to an insufficient preload between the connecting rod and the rod end cap. The preload is the tension or clamping force being generated by the connecting rod fastener at the connection between the rod and the rod cap. This preload must exceed the dynamic forces acting against the fastened joint so that under no situation where the engine is operated within its design parameters (including its maximum RPM) will the connection become compromised.

As noted above, there is significant dynamic force acting against the connecting rod and the rod end cap. If the engineering department has done its job and designed a fastener capable of producing the clamping force necessary to hold everything together, that fastener must also be installed in such a way that the design preload tension is achieved.

Consider a bolt to be like a spring: When a bolt is installed to connect two components together and the nut is turned down to its maximum safe capacity, the bolt will stretch. It is at this point that the bolt is applying its maximum tension or clamping force to the connection.

A bolt has a specific amount of elasticity or stretch which is designed and built into it. The uninstalled bolt length can be measured; if it is then installed and tightened within its correct preload limits and re-measured, the bolt will be longer than in its relaxed, previously measured state. Uninstall the bolt and measure it again, and you'll see it has returned to its original length. This is known as elastic deformation: The fastener will stretch under tension but return to its original parameters when the tension is removed.

The amount of acceptable bolt stretch is specific to the material and design of the fastener and the manufacturer's testing and specifications, which some fastener manufacture's suggest is at 80 to 90 percent of a bolt's yield point. An example of an acceptable stretch for one rod bolt supplier for a Porsche racing engine is 0.0095 to 0.0100-inch stretch, or roughly one-hundredth of an inch. At this point, the bolt is providing maximum clamping force. If, however, the bolt is over-tightened beyond its safety stretch factor, the bolt will not return to its original length. If after removing the bolt and re-measuring its uninstalled length, you found that the bolt grew 0.0006 from its original length, the fastener is damaged and must be replaced. This is called plastic deformation; the fastener has been tightened beyond its yield point.

With regard to rod bolt fasteners "loosening," if the fastener was properly designed for its intended application—taking into account all of the engine's dynamic operating parameters—then the rod bolt was incorrectly installed or there must be a defect in the component(s). The rod bolt must be installed with the proper bolt stretch taking place. This ensures that the preload tension on the rod end joint is correct and that the bolt will not come loose.

Connecting rod bolts that are not installed with the correct amount of stretch/preload will not handle the forces being generated within the engine. If the installation specification for the fastener was not followed, the fastener may be tight but very likely not tight enough to endure the dynamics to which it will be subjected. Follow the fastener manufacturer's installation instructions.

## Methods for Tightening Critical Fasteners

### Torque Wrench

Tightening a critical fastener with a torque wrench is the most common way to install fasteners; however, it could be the most difficult means to insuring the correct installed preload has been achieved. A torque wrench measures the resistance needed to turn the fastener. There are many factors that affect resistance; the manufacturer's recommendations must always be followed.

Friction will be generated by the bolt head against the connecting rod cap surface and resistance in the threads. Some rod bolt manufacturers recommend oil or specific lubricants to be utilized during rod bolt installation. Tightening the bolt once to the manufacturer's torque specification will begin to somewhat overcome the friction between the various surfaces involved but will not preload the rod bolt sufficiently.

A second tightening will polish the threads on the bolt and the rod cap surface. This also helps to ensure that the bolt is seated in the rod. Installing the rod bolt for a third time will allow for less friction as the surface becomes more evenly polished.

Another big variable in using only a torque wrench to determine the fastener installation torque is that many torque wrenches are not accurate. Torque wrenches used in professional applications should be tested for accuracy, adjusted and then certified annually. Many fasteners on the car can be adequately installed with a torque wrench only, but if you have a choice it would not be our recommendation.

### Torque Angle

The torque angle method also known as TTY (Torque to Yield) uses a low torque setting to position the fastener in place. Then, using an angle gauge attached to the torque wrench, the wrench is then turned a predetermined number of degrees to tighten the fastener to its recommended preload.

Friction is generally no longer an issue because the initial torque setting is low. By making the final tightening in degrees, setting the preload is relatively easy. As an example, all bolts are initially tightened to 20 ft-lb, the final torque would then be 30 degrees of clockwise rotation. This method provides a consistent preload between all fasteners. This method does rely significantly on the installation instructions and specifications provided by the fastener manufacturer, as this is the means for ensuring correct settings.

Many original equipment manufacturers utilize this method because load scatter (inconsistencies in final torque setting between fasteners, especially on cylinder heads) is kept to a minimum. However, we would not recommend this method for connecting rod bolt installation.

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### Rod-Bolt Stretch Gauge

This method uses a gauge to measure the installed length (stretch) of the connecting rod bolts. This method provides the most accurate way to ensure that the fasteners' manufacturer recommended preload has been achieved. Most engine builders rely on this method because of its accuracy, and it provides the best means to avoid future problems. The gauges we have—as well as others we have seen—utilize a dial indicator that provides a clear and accurate means to measure bolt length (stretch). The bolt is measured prior to installation to determine its relaxed length and then tightened down until the specified bolt length (stretch) is achieved. Always follow the instructions and specifications of the rod bolt manufacturer.

### Thoughts

With respect to the 2014 GT3 engine, consider that this engine has a 9,000-rpm redline. At this engine speed, the crankshaft makes a complete rotation 150 times per second, each piston comes to a complete stop 300 times per second, and the reciprocating weight at maximum rpm could exceed 40,000 lbs.

For a road car that can be driven daily and revved to redline at your discretion, this is really quite impressive. In fact, the 2014 GT3 engine is the highest-revving engine Porsche has ever manufactured for a production road car. This new engine's output seriously rivals Porsche's own 2007 factory RSR racecar. The GT3 comes in at 475hp at 8,250 rpm and 325 ft-lb of torque at 6,250 rpm on pump gas. The 2007 RSR produced 485hp at 8,250 rpm and 321 ft-lb of torque at 7,250 rpm on race gas. Some have asked if Porsche has gone too far with the engine output and performance of this car. We don't think so; technology has come a long way in the past few years.

Clearly, something was wrong with the connecting rod bolts in the 2014 GT3 engine. We believe what Porsche suggested in their news release: that the fasteners were not optimized for the dynamics of this engine. If the rod bolts really had been left loose, the engine would have likely failed before it left the factory.

Again, we believe that Porsche has done a great job in responding to this issue timely and decisively. ■