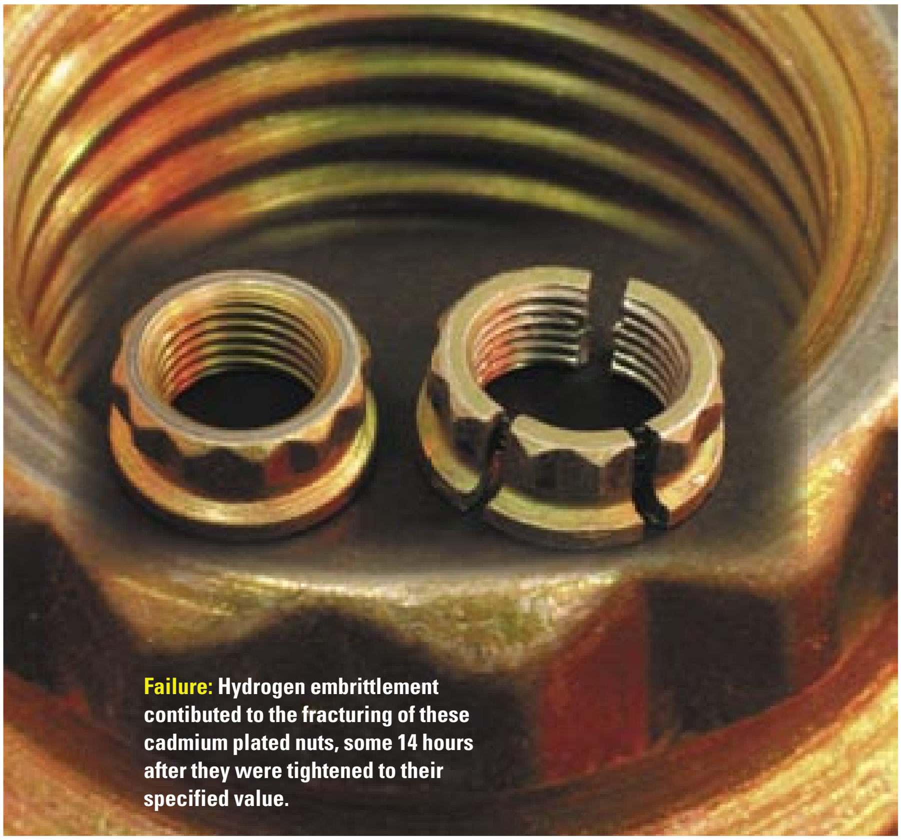
# Brittle nuts

Newly cadmium plated nuts failed during an engine overhaul. If they lasted a little longer, they might have failed in flight with catastrophic results, writes Obaid Soomro.



**Failure:** Hydrogen embrittlement contibuted to the fracturing of these cadmium plated nuts, some 14 hours after they were tightened to their specified value.

GEOFF COMFORT

THE TECHNICIAN overhauling the Teledyne Continental Motors reciprocating engine was doing a great job. Each part was either brand new or repaired to high standards by an approved organisation. All parts were thoroughly inspected before installation.

The technician opened a pack of double-hexagon (12-point) nuts. Recently cadmium plated, they shone like nuggets of gold.

He used a recently calibrated torque wrench to tighten the bolts to their specified value.

On their arrival at the engineering workshop the next morning, the mechanics found the nuts had fractured and failed – just 14 hours after tightening. They were worried. If the nuts had not failed during overhaul, they would certainly have failed in service. What if the engine was fitted to a single-engined aircraft, ready to take off with maximum load on a short runway?

The engineers sent some of the broken nuts to the ATSB for analysis. Scanning electron micrographs showed the failure was a result of hydrogen embrittlement.

It only takes a tiny amount of hydrogen to make steel brittle. As little as a few parts per million will do it.

When high-strength steel with traces of hydrogen is stressed in tension, it will fail at stress levels much lower than the designed strength. The higher the strength of the steel, the more susceptible it is to hydrogen embrittlement.

**Protection:** There are two ways to minimise the chances of hydrogen embrittlement. One is to produce porous plating by using higher current densities or by adding small amounts of titanium into the process. Porous coatings allow hydrogen to escape more easily.

The second method, which is more popular, involves baking the steel straight after coating. Coated parts are heated to 175–205°C for 3–24 hours, depending on factors like the thickness of the coating, size and geometry of the part and the strength of the steel. Most of the hydrogen escapes during baking, while some of it is diffused into the steel. The material properties of the base metal are largely restored.

If manufacturers' recommended procedures are not properly adhered to before and after plating, hydrogen might remain trapped in the steel, leading to embrittlement. Parts can fracture and fail at room temperature under stresses much lower than they were originally designed to handle.

**Another threat:** At higher temperatures, another threat to cadmium coated steel comes into play – "liquid metal embrittlement".

Whenever cadmium comes into contact with steel at high temperatures, the molten, non-diffused cadmium tends to attack the grain boundaries of the steel, weakening the steel in a way similar to hydrogen embrittlement. Liquid metal embrittlement accelerates with higher stresses and elevated temperatures.

The aerospace industry is a major consumer of cadmium plated nuts and bolts. They are used in engines, major structural members and landing gear and as fasteners for aluminium sheet. The reason is simple: cadmium plating helps to prevent bimetallic corrosion between high-tensile steel fasteners and aluminium alloys.

Coating has a high efficiency throwing power, meaning that intricate recesses, threads and key-ways can be coated with a good, even deposit.

Cadmium coating can be applied by mechanical plating, vacuum deposition or metal spraying but deposition through electroplating remains the most popular way.

As long as the plating or baking process is done correctly, it is safe to use cadmium plated nuts and bolts made from high-strength steel. They should be used in engine-cold sections.

But because of the danger of liquid metal embrittlement at higher temperatures, you should avoid using cadmium plated steel nuts and bolts in engine-hot section parts at critical locations.

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