Failure of an M24 Engine Mounting Bolt

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Inadequate preload can result in fatigue failure from joint movement and eventual self-loosening of the fastener.

An M24 property class 8.8 bolt was used to secure one of four engine mounts to the chassis of a bus. Following the introduction of the bus into service and some operational experience, reports started to be received that bolts were occasionally found loose, and on a number of occasions, the bolts were failing.

To prevent what was perceived to be a loosening problem, a split pin was introduced that passed through the bolt thread immediately below the nylon insert nut to prevent the possibility of the nut backing off. This fix proved to be only partially successful and instances were still being reported that the nuts continued to back off, leading to the split pin being completely sheared off in some instances.

Fatigue failures continued to be experienced. A failed specimen is shown in **Figure 1**, **Figure 2** and **Figure 3**. In this example, the fatigue failure occurred in the runout region of the thread. **Figure 2** displays the failed section of the bolt, indicating that the failure could be attributed to bending fatigue. **Figure 3** shows the nut had backed off resulting in the split pin being partially sheared.

Fig. 1 — Specimen of failed bolt from bus chassis.

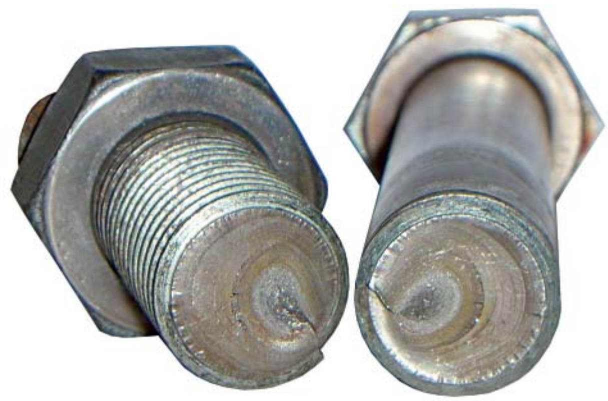

Fig. 2 — Failed section of the bolt indicating that the failure could be attributed to bending fatigue.

Reasons for the Failure

The tightening torque that had been specified by the design department was 660 Nm (487 lb-ft). This torque was achieved on the prototype test vehicles, but it proved to be difficult to achieve on production vehicles and also in service by maintenance staff. This was due partially because of space constraints and partially because of lack of appropriate equipment. Following investigations, the tightening torque actually achieved was closer to 400 Nm (295 lb-ft).

A section through the joint is shown in **Figure 4**. As can be seen, the joint consists of several sections, some of which are steel and others aluminum. The forces acting on the joint comprise both dynamic axial loading from the weight of the engine and lateral loads as a result of braking, acceleration and cornering forces.

An investigation and analysis of the joint was completed. The several layers of the joint contributed to a loss of preload as a result of embedding (plastic deformation of the contact asperities subsequent to the completion of the tightening process). A joint analysis was completed and indicated that when the scatter from the tightening process was included, a proportion of the joints would fail to provide sufficient preload to resist the forces applied to it. The preload requirement chart as a result of this calculation is shown in **Figure 5**. Because of this, in such joints small lateral displacements could be anticipated to occur. Repeated lateral displacements would have two effects:

- The fastener would be subjected to a moment resulting in bending stresses being induced into the bolt. Repeated application of such stresses is the probable cause of the fatigue failures experienced. The runout region of the thread is prone to fatigue when subjected to bending stresses since usually the thread is often poorly formed in this area and hence a high stress concentration is present.
- **Junker** and other researchers have shown that repeated lateral (shear) displacement of the joint is the prime cause of self-loosening of threaded fasteners.

Fig. 3 — Backed-off nut resulted in the split pin being partially sheared.

The bolt failure that is illustrated in **Figure 1**, **Figure 2** and **Figure 3** exhibits the two effects of self-loosening and fatigue.

A joint analysis indicated that achieving the correct tightening torque would ensure that a preload would be reached that would be sufficient to prevent joint movement that was considered to be the root cause of the problem. However, it became apparent that on production assembly and when vehicles were being maintained in service, that consistently achieving the 660 Nm (487 lb-ft) tightening torque would be problematic.

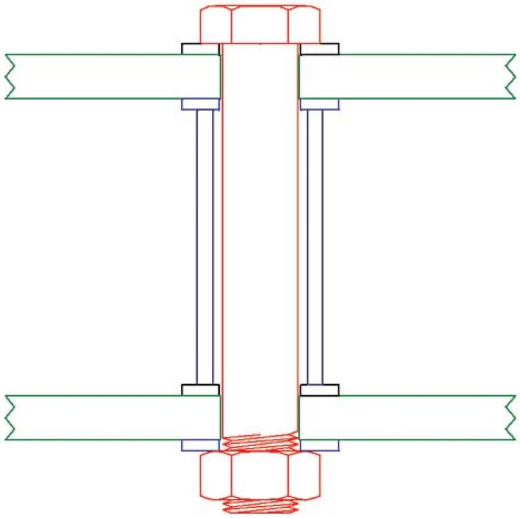

Fig. 4 — Section through the joint showing several sections, some of which are steel and others aluminum.

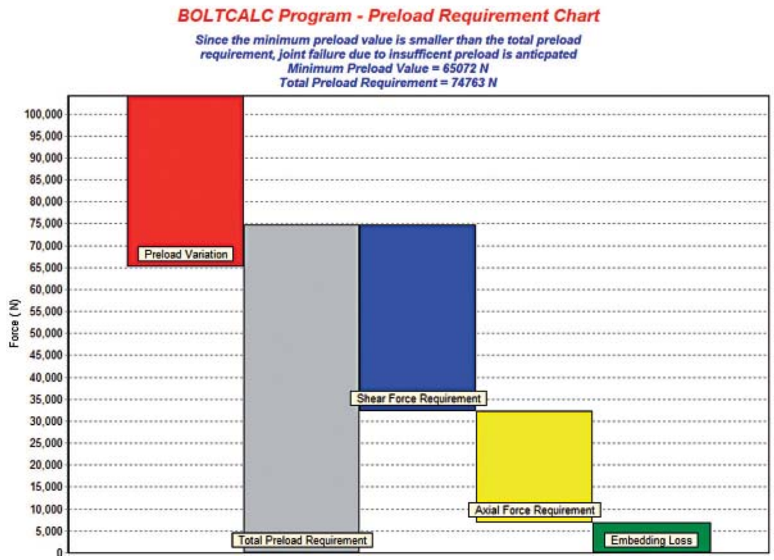

Fig. 5 — Preload requirement chart resuting from joint analysis calculation.

Solving These Problems

To resolve the issues of specifying a tightening torque that was achievable, given the tools and space limitations of this installation, while ensuring adequate preload, it was decided to reduce the size of the bolt and to increase the bolt's strength. As a result, an M16 flange headed property class 12.9 bolt was specified.

The greater length-to-diameter ratio of this bolt would reduce the preload loss due to embedding, while the bolt's smaller size would also reduce the torque requirement in order to achieve the required minimum preload.

Torque was specified at 380 Nm (280 lb-ft), which with torque was anticipated to produce a preload variation of between 86 and 137 kN (19,330 and 30,800 lbf). The minimum preload required was 78 kN (17,535 lbf), which is below the anticipated preload range for the modified design. For this reason, further fatigue and nut loosening issues were not anticipated. The preload requirement chart for the modified design can be seen in **Figure 6**.

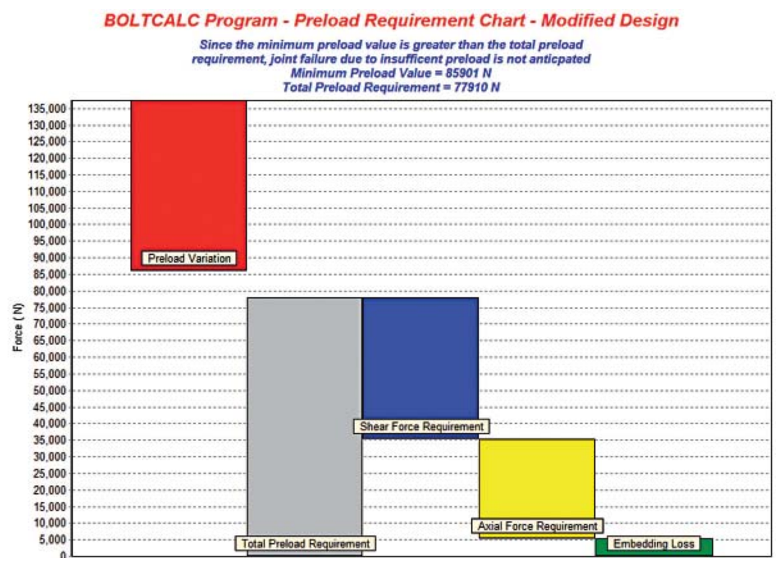

Fig. 6 — Preload requirement chart for modified design.

Conclusion

The bus chassis bolt failure described in this article illustrates two problems that can result from inadequate preload.

Fatigue failure is a common byproduct of inadequate preload; joint movement, because in this case the friction grip was inadequate resulted in stresses being induced into the bolt that it was never designed to sustain. This same movement, when the fatigue strength of the bolt is able to sustain the induced stresses, will result in the tendency for the fastener to self-loosen.

The importance of achieving and maintaining an adequate preload is often the crucial factor in ensuring that the structural integrity of the bolted joint is assured.

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