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Angle torque cylinder head bolts

At one time cylinder head bolts were only replaced when the threads became worn or damaged. Engine rebuild instructions will now often require detailed cylinder head bolt tensioning procedures, demand new bolts at each assembly and cause seemingly perfect bolts to be thrown away. This bulletin explains the reason why this engineering design is now chosen by the majority of O.E. manufacturers.

The conventional method of tightening a cylinder head bolt is to use a torque wrench. However, this tool only measures a bolt's resistance to rotation and whilst this is related to clamping load, (the prime factor of importance), the relationship can be highly variable (Figure 1).

Such variation in clamping load is unacceptable for most modern engine designs, particularly those with light engine block construction, aluminium cylinder heads and/or multi-layer steel head gasket designs. As the action of tightening a bolt causes it to stretch and as the degree of stretch has a fixed relationship to clamping load, the solution has been to control the bolt stretch by specifying an angle of rotation. This is quite independent of the force or torque required to turn the bolt.

Whilst a bolt is within its elastic phase, a small amount of stretch gives a large change in clamping load (line OA in Figure 2) and the bolt's angle of rotation would have to be very accurately controlled. However, if the bolt is stretched beyond its elastic limit and into the plastic phase, the clamping load increases slowly for a large amount of stretch (line AB) and the accuracy of rotation is much less critical.

Unfortunately, once a bolt has passed its elastic limit, it is subjected to two conflicting internal conditions - its elasticity, which tends to return the bolt to its original length, and its plasticity, which tends to make it retain its new length. A bolt tightened to point B in Figure 2, if loosened, would return to zero clamping load along the line BE (parallel to AO). The partial return to its original length (line FE) is the elastic recovery and the deformation of the bolt (line OE) is the permanent set or permanent stretch.

If the bolt was now re-used, because of the permanent stretch, it would start from Point E, move along the load vs. stretch curve to Point B and then move towards Point C as it was turned through the specified angle of rotation. The bolt would then be in a most critical condition. Beyond Point C the bolt would start to neck and fail during assembly, which is perhaps the best situation, as at least the mechanic would know that a replacement bolt was necessary. At worst, the bolt would stop just short of Point C, only to fail later during operation as an expanding cylinder head stretched the bolt beyond the limit.

Some OE manufacturers (particularly in commercial applications) do specify the number of times an angle torque bolt can be re-used, which is essentially the number of times the permanent stretch of the bolt can be increased. Others on the other hand specify the minimum allowable bolt shank diameter at a designated location or the maximum allowable bolt length. Both methods compare the condition of the bolt against the known safe limit of plastic deformation for necking or stretch. However, unless the history of the bolt is known, re-use is not advisable. Angle torque or stretch bolts can usually be identified by the specified angles of rotation in the head bolt tension specification.

Be safe - always lubricate bolt threads and under bolt heads
always check block bolt holes are clean and threads are in good condition
always replace angle torque bolts
always follow the specified tensioning sequence, method and tensions.

Figures 1 & 2 over the page.

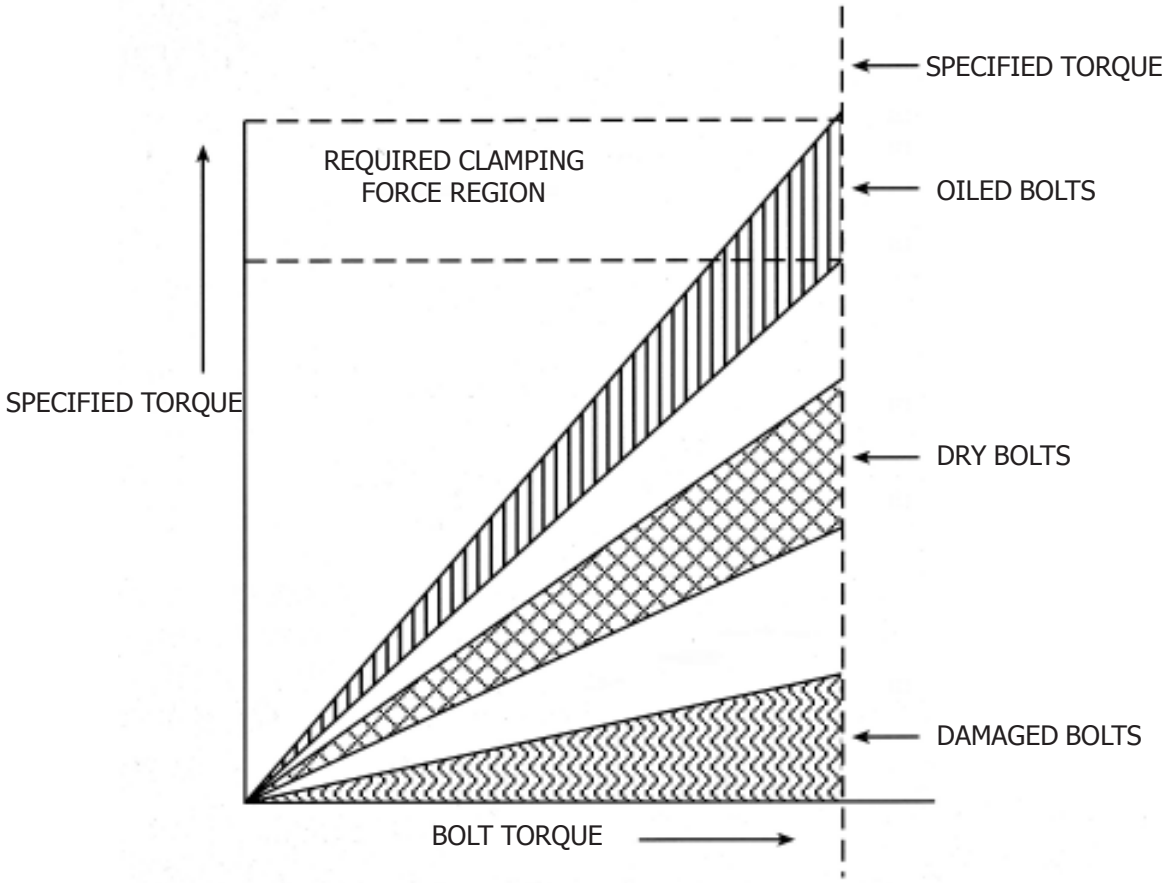

FIGURE 1: VARIATION OF CLAMPING FORCE WITH BOLT CONDITION FOR SPECIFIED TORQUE VALUE.

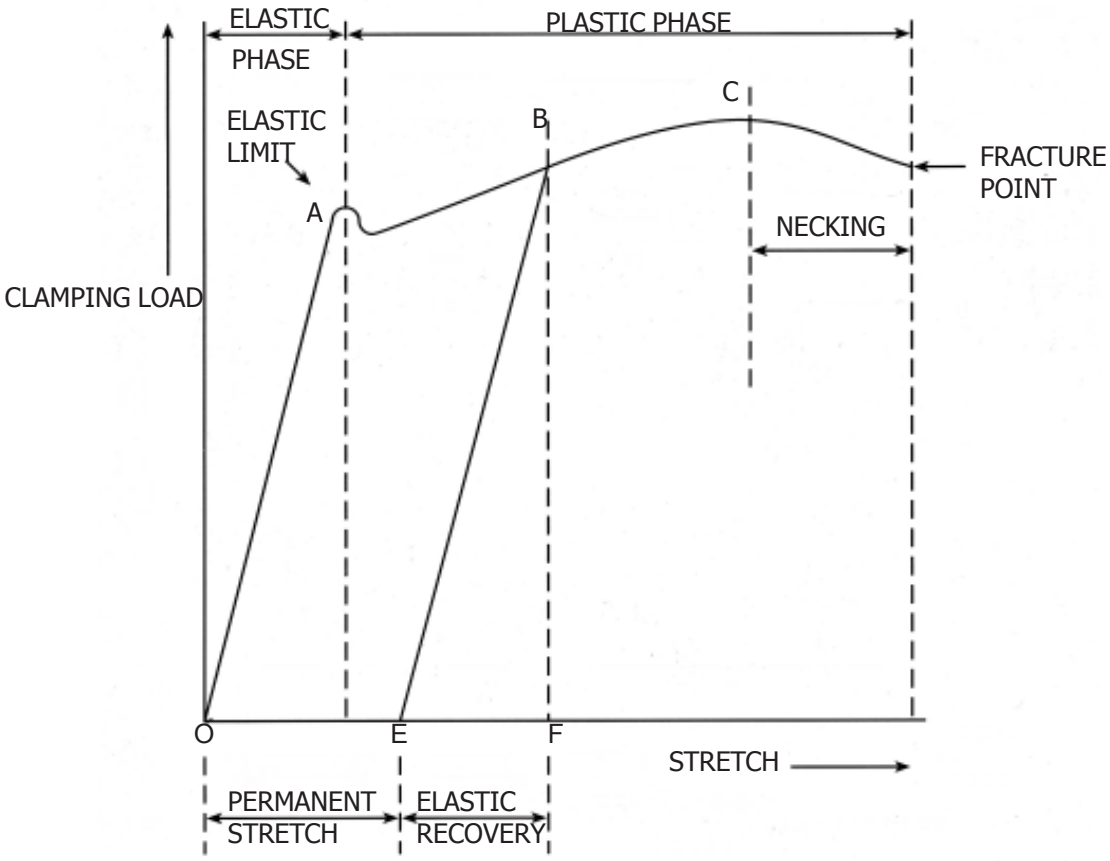

FIGURE 2: CLAMPING LOAD VARIATION WITH BOLT STRETCH.