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The Yielding of Fasteners During Tightening

Wayne Wallace reminds us of Peter Gill's landmark 1975 Paper

Around 1985, I once remarked to Doc Morrow, then Stelco's head of fastener manufacturing in Canada, that structural bolts MUST be tensioned beyond yield. Was this all right, I asked, in his opinion? Doc was among the fastener greats at Stelco at the time, like Ian Park (in my opinion, the best self-taught fastener manufacturing metallurgist ever), Errol Alexander (the "Alexander" model for thread stripping), and others.

Doc, whom I never knew by any other name, showed me a paper written by Peter Gill of GKN Fasteners Ltd., for the answer. Peter was then a senior researcher at GKN, a very large British bolt manufacturer, and whom I have since learned, was internationally respected for technical application information on bolts.

In this landmark paper on the subject, probably written around 1975, Gill pointed out and proved that yielding of fasteners during tightening is, in fact, advantageous. Also, he not only proves the theory on paper, but he demonstrates it by means of devising a jig in which he torques a bolt almost to breaking and then applying external tension. The paper is elegant in its simplicity, and should be known and understood by anybody who wrestles with the sometimes perplexing questions surrounding bolting applications.

Rather than writing a new paper on this same subject, I thought it would be interesting for readers of *Link* to read or re-read Gill's paper, presented here in abbreviated form, along with a few comments of mine.

Here goes Peter Gill:

1. Introduction - In the design of load carrying parts, it is a generalrule to make sure that yielding will not occur under service loading. Usually, then, the yield load level of all-important parts is known or is closely estimated. The designer then ensures that these levels exceed the service loads by a suitable factor of safety so that the only deformations to be anticipated are the usual minute elastic ones, which are negligible.

In the.. . specification of tightening procedures, an important exception can be made to this rule. This is because shank yielding during tightening is not only allowable - it is in most cases, advantageous.

2. Retention of bolt load after yield at tightening - Some . . . fee/ that when a bolt is tightened we// beyond yield it loses its abi/ity to exert a clamping force on the joint members. We can show that this is not the case.

In Figure 1 line OYXU is the load extension graph for a bolt in a joint, and line OJ is the load deformation line for the joint members. We now imagine that tightening has been taken wel/ beyond yield point Y and up to a clamping force P where the bolt and joint member conditions are those shown at X and J respectively After tightening, the joint members can only lose compressive load by losing some of their compressive strain, i.e. by increasing in thickness. In order to increase in thickness they would have to push out against the bolt and nut and so increase the extension of the bolt. This would require a pushing load, which would have to be maintained at levels along the line XU. But the joint members cannot exert loads at these levels. They can only exert loads at levels along the lower line XF. This is because when their compressive strain decreases, their compressive load falls from J towards 0 and XF is para//e/ to JO.

It could be shown by a similar argument that the bolt of course cannot lose tension by squeezing the plates. Squeezing the plates requires an increasing load (arrow G), whereas the bolt can on/y exert a decreasing load (arrow H).

Thus, apart from small relaxation losses, a bolt tightened beyond yield is able to retain its induced tension.

Wallace again:

Note what Gill is saying here. Tighten a bolt WAY past yield, that is, almost to the breaking point, and it will exist in its environment as a stable system acting and reacting with and against the plates it clamps together. Note how clear is his explanation. None of those confusing bolt diagrams you see in many papers where the bolt stiffness and the clamped joint stiffness are represented by intersecting lines forming a triangle. Gill presents the bolt/joint clamp force/extension line (lines OYXU and OJ) on the same base line, as equal and opposite for true strain compatibility, which is of course the only logical way to present them. The two act as a system, after all.

Here is a summary of the other comments and conclusions Gill makes in this classic paper.

Under service load, the (yielded) bolt is able to perform as though it had never yielded at all.

Tightening beyond yield does not affect the ability of the bolt to withstand the effects of subsequent service loading on the joint.

High pretensions are good for joint performance because:

1. Improved resistance to bolt fatigue.

2. Shear loads will be taken by friction at the mating surfaces of the joint members.

3. Resistance to loosening.

4. Tightening to yield simplifies the tightening method ("If the bolt does not break during tightening it will not fracture in subsequent service").

Having shown that yield is allowable in the shanks of bolts it follows that it is also allowable in other elements of the fastenings, i.e., the bolt head, the washer, and the nut...The amount of yield movement can be gauged or measured to inspect that the desired load has been reached. In the better-designed devices a considerable yield movement can occur at substantially uniform load and this removes the need for critical inspection methods.

Wallace again:

Note what Gill is saying here. The presence of (say) a DTI, which deforms plastically as the bolt is tightened, improves or "softens" the bolt response to external load because it assures beyond yield tightening, and is easily inspectable because of the relatively large deformation as the DTI bumps compress.

Gill again with his final conclusions:

Several advantages are obtained when the fastening is designed in this way, i.e., with yield occurring in the nut, washer. or head rather than in the shank.

1. The reduction in fastener stiffness reduces the fatigue loading to which the bolt is subjected under repeated joint service loads.

2. Any desired level of bolt pre-tension can be obtained irrespective of bolt yield strength.

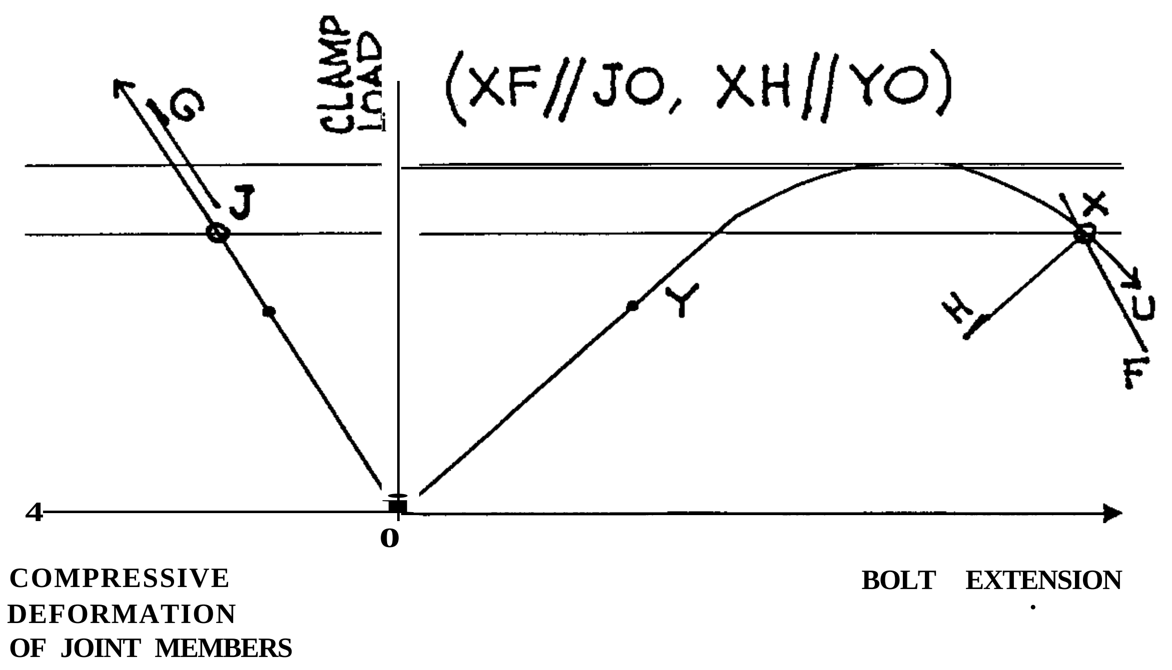
3. Although the "turn of nut" method is simple to use, subsequent inspection for correct bolt tension can be difficult. In the case of a compressible element inspection is easy. and only involve gauging the height of the bumps ... edited by Wallace.

4. Yielding of the shank is sometimes undesirable, e.g., when repeated tightening is anticipated.

5. Over-yield tightening means a low factor of safety during tightening but a high factor of safety in subsequent service.

6. Tightening below yield means a high factor of safely during tightening, but a low factor of safety during subsequent service.

Write or e-mail wallace@appliedbolting.com if you want a copy of Peter Gill's entire paper. O



GILL: FIGURE 1