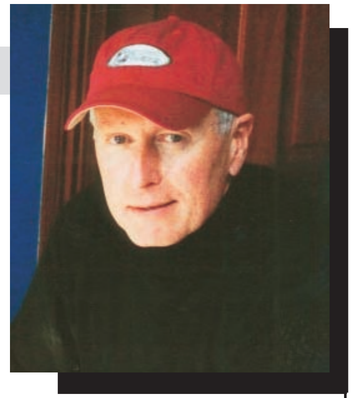
About the Author/WAYNE WALLACE



Wayne Wallace is the original founder, past president, and now VP and CTO of Applied Bolting Technology Products. Wallace is a past member of the Research Council on Structural Connections, and serves on the ASTM F16 Committee on Fasteners. In addition, Wallace is a fastener application consultant to major constructors, holds numerous patents on various styles of compressible washers used on bolts, and is a speaker and author on the practical aspects of bolting. Applied Bolting Technology manufactures both standard and Squirter® direct tension indicating washers from its base in Rockingham, Vermont. He can be reached by email at waynew@appliedbolting.com.

Retightening Wind Turbine Flange Splice Bolts

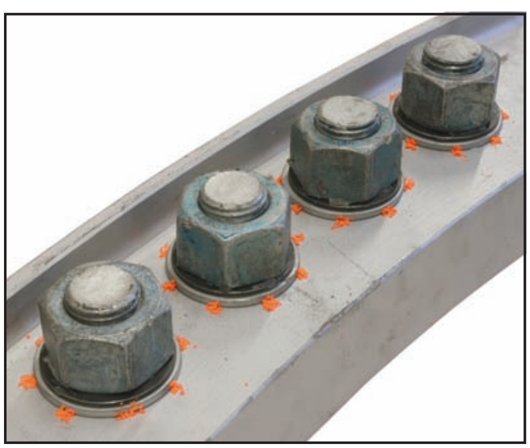
Inherent Problems With Installation and Retightening Using Torque Values

There's confusion among North American wind turbine generator engineers as to, firstly, how to install the tower flange bolts correctly, and, secondly, how to "retighten" them after some period of service as is required by European quality approval agencies.

The confusion is understandable since there's no North American structural steel connection design and erection code for metric bolts, and what codes exist only are written for bolts up to 1½" diameter. Wind turbines require flange splice bolts of M36, M42, M48, and soon-to-be M64 (!!) diameter grade 10.9 bolts. The turbine designers want a specific tension in the splice bolts, but their European colleagues have been specifying torques. Historically, torque installation has been the main technique in European codes, but nut fit, nut depth, coatings, and weathering all conspire to change the torque/tension relationship in unpredictable ways. It has been very well documented that specified torque values can produce tensions which vary +/- 30% in certain situations.

The present situation is this — the tower splice bolts are installed to a certain torque value, and then after a few months of turbine service, retightening flange splice bolts is undertaken, apparently because there has been some experience with bolts losing tension during the first period of service. I say apparently, because evidence of such bolt loosening hasn't been published, nor has a mechanism been postulated for such loosening. And, to make matters even more puzzling, no procedure has been specified for the retightening, so the general practice has been to simply re-apply the initial torque value to the bolt again. One presumes that retightening is intended to restore or at least improve the capacity of the bolted splice joint after some indeterminate bolt preload deterioration.

Four Bolts Tested



Typical Flange Bolted With Squirter DTIs

But does retightening really improve the joint?

Multiple tightening of higher strength structural bolts, and specifically galvanized bolts, is something frowned on by structural engineers in North America — to be avoided if at all possible. There is research[1] which shows that repeated installation of A490 bolts (similar to property class 10.9) produced the required tension only on the first and maybe the second cycle, and after that subsequent cycles showed a *sharp decrease* in induced tension. There's also evidence from this same research which shows the presence of galvanized coatings *sharply reduces the ductility* of the bolt assembly. "Sharp decrease" in tensions, *"sharp reduction in ductility"* — these words should alert wind engineers to be very careful when specifying a retightening process for flange bolts.

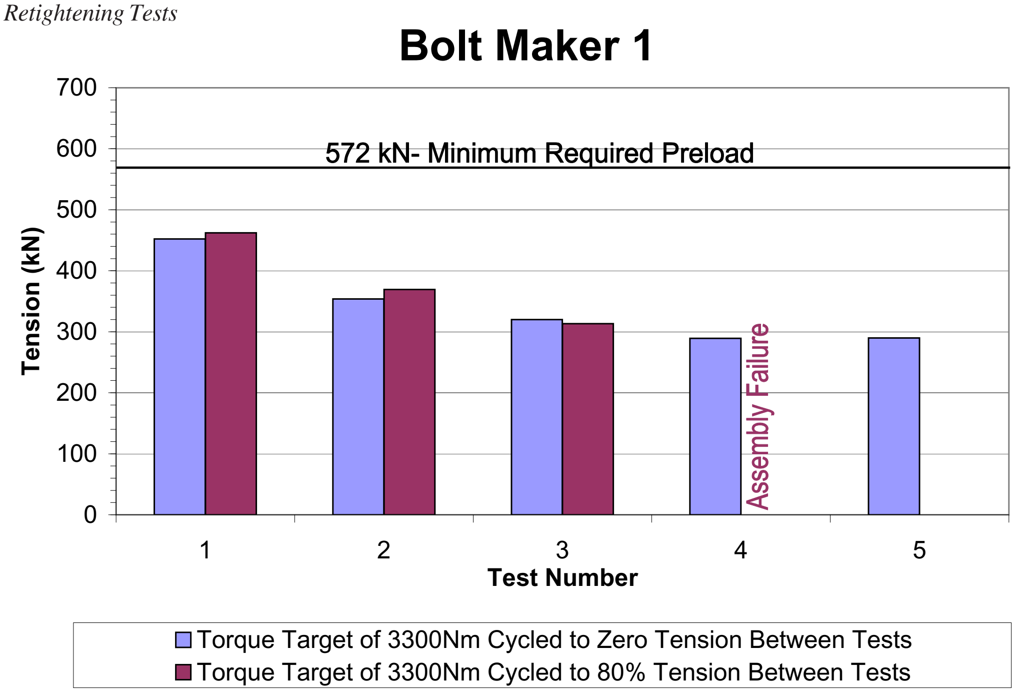
As a simple experiment, Applied Bolting tested two M36 x 140 galvanized 10.9 bolt assemblies, from two manufacturers, intended to be installed to 572 kN using a torque value of 3300 Nm. In experiment one, each of the two different manufacturer's bolt assemblies was tightened to 3300

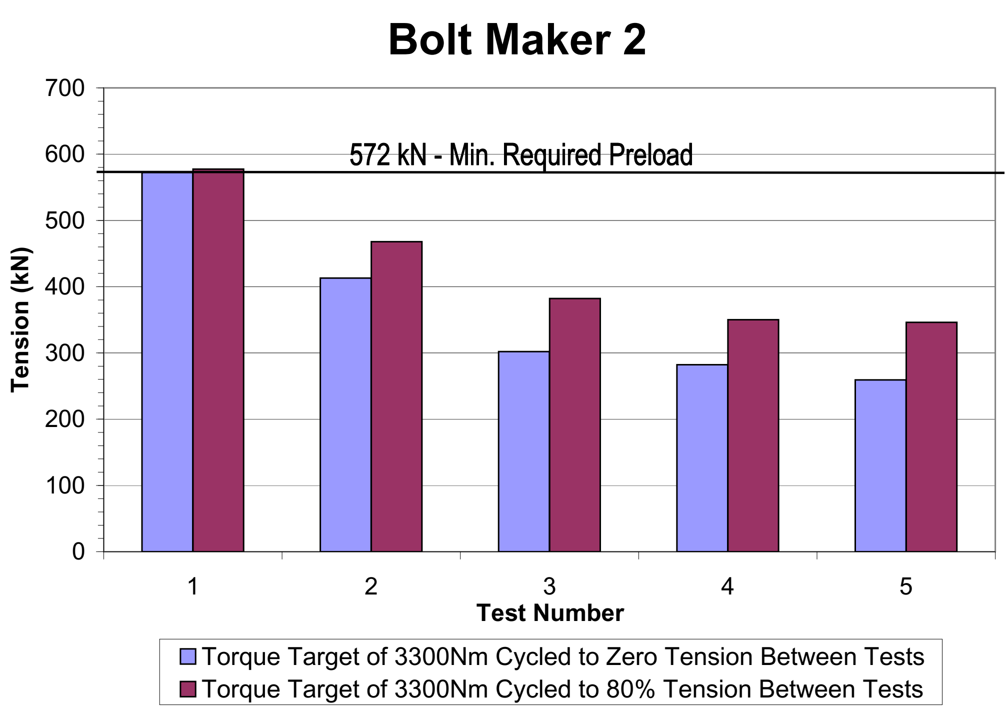
Nm, then unloaded to zero, and then retightened to 3300 Nm again, repeated five times. In experiment two, each of the two different manufacturer's bolt assemblies was tightened to 3300 Nm, then unloaded to only 80% of the tension achieved, and then retightened to 3300 Nm again. This cycle was repeated five times. The attached charts show the results of the (admittedly small) sample tests.

Both sets of bolt assemblies were tested in the as-received condition. You can see immediately that neither of the manufacturer's assemblies reached the minimum specified 572 kN tension on first tightening using 3300 Nm. Nothing should be read into this other than that the lubricant on the nut was apparently not sufficient to get the bolts up to the correct tension on the first tightening. DIN and EN bolting specifications specify that lubricants should be applied to bolt assemblies in a batch process so the entire lot can be considered uniformly lubricated, so we tested the bolts in the as-received condition and to NOT add lubricant.

As the charts clearly show, the second and subsequent tightenings, either unloaded to zero between

Retightening Tests





tightenings or only slightly unloaded to 80% of the previously achieved tension, certainly demonstrated the *"sharp decrease"* in induced tension referred to in the above research. In fact, the decrease in bolt capacity in only a few cycles was alarming, especially when retightening is intended to bring the bolt tension up to the original minimum value and therefore improve or restore the capacity of the joint.

Even more alarming, the same research points out that the yield point of the bolts degrades with each loading/unloading cycle, in approximately the same way the achieved tension degrades in the attached charts. And since it is the intention for the bolts in this application to remain below the yield point, retightening may not be advisable, in fact it may be deleterious to the bolt assembly and to the capacity of the joint.

If tower flange splice bolts loose tension during service, after the initial embedment losses occur in the first few minutes, is it possible that the bolts were never correctly tensioned in the first place? And then, because of inadvertently low initial tension, external prying loads cyclically ratchet the bolt preload and yield point down to where the bolt was at zero tension or close to zero as our simple experiment showed?

To make sure we have an adequate connection, the tower flange splices should be first bolted together in such a way that it is known that the initial preload is correct, and then any loss of bolt tension during service be monitored using ultrasonics. If bolt tension loss during service is still seen to occur, the overall adequacy of the bolted splice joint should be reviewed.

Getting the bolts up to minimum preload on first installation, regardless of torque resistance, is of course where Applied Bolting's Squirter® DTIs come in handy as a cost-efficient, visual, and accurate tool. Added to the bolt assembly they provide a belt-and-suspenders tension check on every bolt, and take the bolt's individual torque resistance out of the equation.

Applied Bolting Technology now produces Squirter DTIs with specific compression strengths to match the bolt tensions wind turbine designers need in their flange splice bolts. Germanischer Lloyd, a German wind component approval agency, has audited Applied's M36, M42, and M48 sizes, and has certified that they will produce tensions as specified +/- only 10%, to a 97.7% confidence factor.

Is it possible that retightening of these bolts is a self defeating exercise at best, or potentially damaging at worst?

Squirter DTIs can guarantee the tower flange splice bolts will get tensioned correctly, regardless of the torque/tension relationship of the bolt assembly, when the bolts are tightened the first time.

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[1] *"Guide to Design Criteria for Bolted and Riveted Joints," Kulak, Fisher, Struik, second edition John Wiley, 1987.*

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