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Nondestructive Testing (NDT) of Residual Tension on Wind Tower Flange Bolts

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BACKGROUND

When large structures, such as wind turbines, that employ flange bolts are erected, each bolt should be torqued until it meets a specified design tension. It is common for these bolts to loosen over time, however, due to vibration, joint relaxation, bolt fatigue, and the like. When residual tension of a flange bolt falls below the design tension, the flange bolt can be subjected to excessive fatigue and break, compromising the structural integrity and stability of the structure. It is therefore critical to ensure that the residual tension in the bolts remains sufficient to meet design specifications. The proposed method addresses this issue.

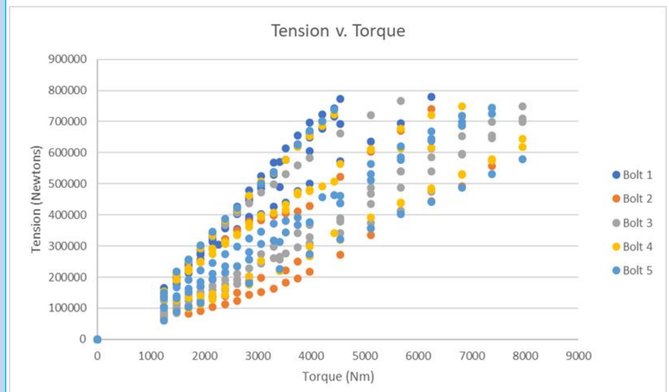
OBJECTIVE

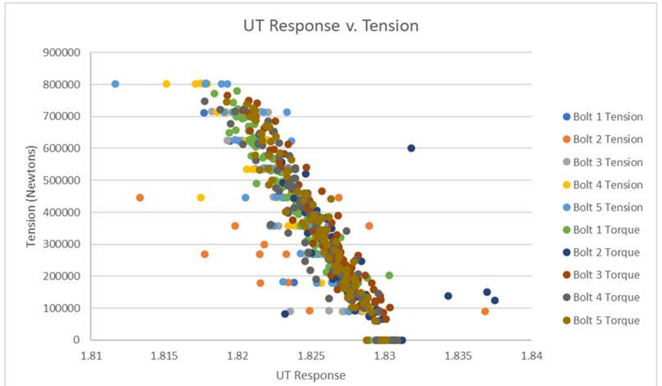
1. Develop a method for estimating residual tension in flange bolts
2. Develop a method that does not require length or pre-installation measurements
   a) User should be able to walk up to any installed flange bolt and estimate tension using method
3. Reduce cost of wind farm maintenance
4. Increase maintenance process safety
5. Increase tension estimation reliability

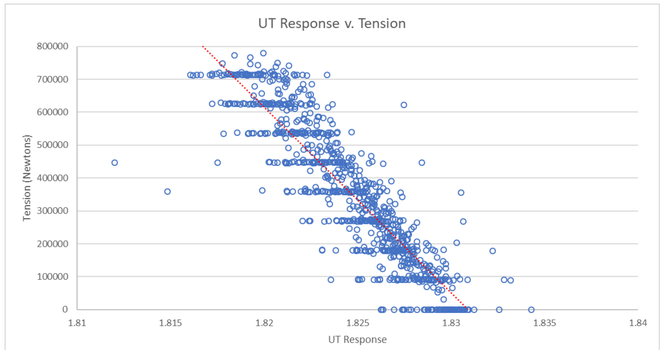
METHODS

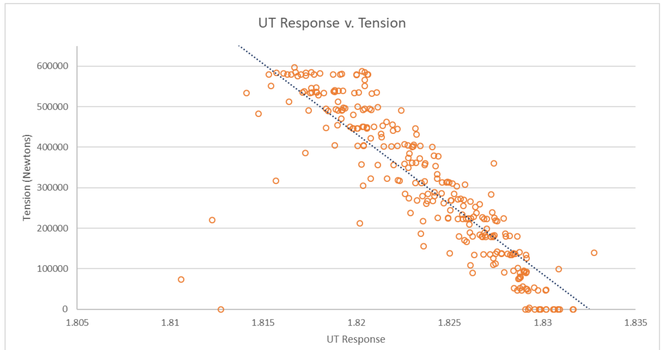
- A mock wind turbine flange was constructed.
- Grade 10.9 M42 bolts were installed in the flange and incrementally tightened from 0-780,000 newtons (180 kips) using a torque wrench. UT data was collected at each tension increment.
- Grade 10.9 M42 bolts were incrementally tightened from 0-780,000 newtons (180 kips) using a hydraulic jack. UT data was collected at each tension increment.
  - Process was repeated for M42 bolts from two different manufacturers.
- The above process was repeated for 205mm grade 10.9 M36 bolts from 0-600,000 newtons (130 kips) and 415mm grade 10.9 M64 bolts from 0-1800000 Newtons (405 kips).

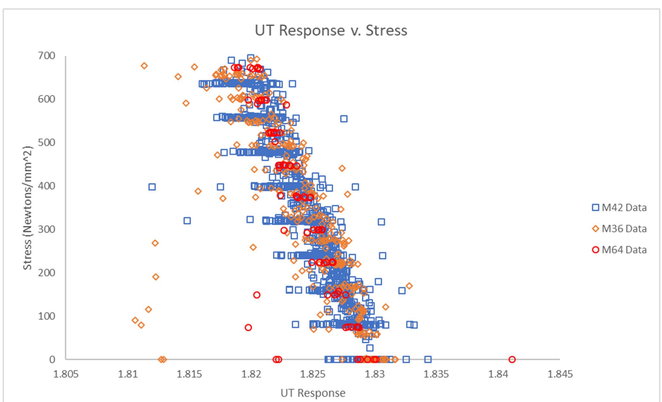
RESULTS











Top Left: *Depicts the torque-tension relationship for five M42 320mm bolts*

Middle Left: *Depicts the UT response-tension relationship for M42 bolts of length 241mm-387 mm that were torque tightened and tightened with a hydraulic jack*

Bottom Left: *Depicts the UT response-stress relationship for M36 and M42 bolts ranging from 205mm-387mm in length*

Top Right: *Depicts UT response-tension relationship for the same 5 320mm M42 bolts as seen in the top left figure. These bolts have been torque tightened and tightened with a hydraulic jack*

Bottom Right: *Depicts UT response-tension relationship for 205mm M36 bolts that have been torque tightened and tightened with a hydraulic jack*

*** Patents pending for this method***

Left*: Image of FDH mock flange*

Right: *Torque wrench on wind turbine flange bolts*

CONCLUSIONS

- Using torque to predict bolt pre-tension is unreliable as the relationship varies greatly from bolt to bolt and within a bolt over a series of load cycles
- The UT response is consistent regardless of whether the bolt is tightened with a torque wrench or a hydraulic jack
- There is a strong relationship between the UT response and Tension
  - The relationship is consistent in M42 grade 10.9 bolts regardless of bolt length or manufacturer
  - The relationship exists in both M36 and M42 grade 10.9 bolts
- The relationship between UT response and stress is the same for grade 10.9, M36, M42, and M64 bolts regardless of manufacturer or bolt length

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