PO.016

Predictant

An Integrated Machine Learning and Signal Processing Pipeline for Bolt Tension Measurement using Bi-wave Ultrasonics

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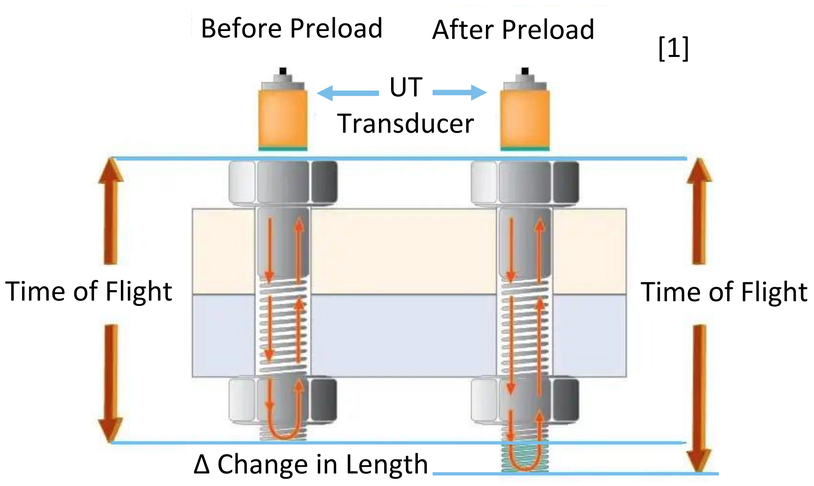
Predictant LLC

Accurate bolt tension measurement with bi-wave ultrasonics and machine learning

THE PROBLEMS WITH ELONGATION METHODS



Traditional bolt tension ultrasonic (UT) measurement systems measure the elongation in a bolt by comparing the time of flight (ToF) of the UT wave before and after applying tension.

REQUIRES UN-TENSIONED BASELINE LENGTH MEASUREMENT FOR EVERY BOLT

The accuracy of elongation measurements are dictated by how accurately the following impact variables are measured.

- Bolt geometry
- Material properties
- Temperature
- Clamp length
- Bolt bending
- Assumed coefficients

REQUIRES EXTENSIVE CALIBRATION

Compounding errors!

THE PREDICTANT APPROACH

1) Uses both longitudinal and shear waves
2) Utilises machine learning to correlate changes in the impact variables with bolt tension.

Benefits

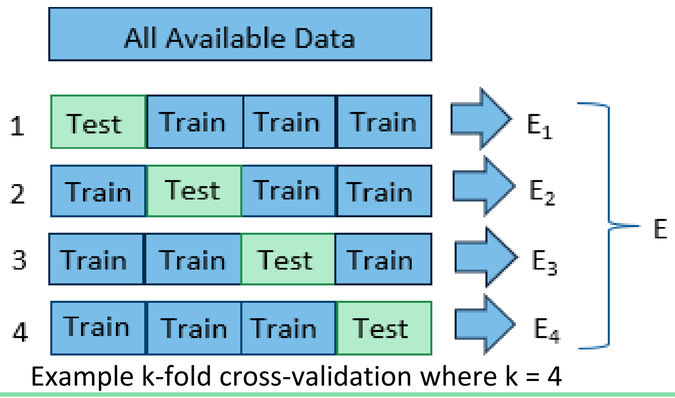
1) No in-situ baseline measurements
2) No calibration for new or in-situ bolts
3) Less impact from material and environmental variances

Ensuring Quality Data

1) Eliminate user variation during measurements.
   - Magnetic clamp removes variable hand pressure
   - Transducer centering mechanism
   - Thermal sensor embedded inside transducer
   - Solid UT couplant

Predictant's Bolt iQ

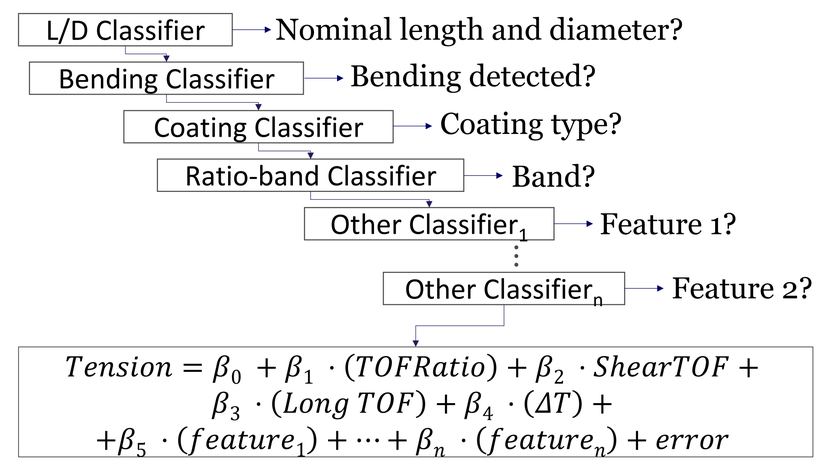
2) Software only accepts high quality data
   - Signal amplitude threshold
   - Signal to noise ratio (SNR) threshold
   - Outlier detection
3) K-fold cross-validation
   - More than 30,000 samples
   - 27,000 features analyzed per waveform



Example k-fold cross-validation where k = 4

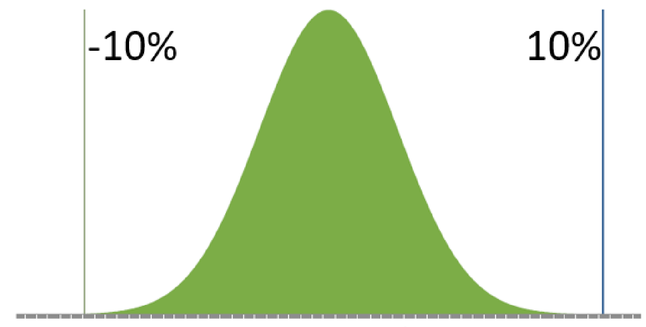
STACKED MACHINE LEARNING MODELS

Combination of several base models to get a final tension measurement with better performance



Verified Accuracy

Error of ± 5.00% of Yield Stress (940MPa) with 93.32% CI
Error of ± 5.5% of Yield Stress (940 MPa) with 95% CI
Error of ± 8.00% of Yield Stress (940MPa) with 99.73% CI



Includes data from different bolt/stud lengths, diameters, temperatures, tensioning methods, clamp lengths, head end/tail end measurements, and up to 4° of bending.

Verified by DNV

References

[1] Advanced Torque Products. (2025). *How do Ultrasonic Measurement Work?*. https://advancedtorque.com/ultrasonics#:~:text=An%20ultrasonic%20signal%20is%20sent,measurement%20(unloaded%20fastener%20length

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