

# Study on the Ductility and Deformation of High Strength Fasteners in Tension

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## Procedure

- ASTM F606
- Proof washer is used in place of a wedge washer
- Thread length of the bolt is measured using digital calipers, and 5 different measurements of the diameter are taken before testing.
- The first bolt tested from each lot shall have zero threads exposed between the grips.
- The remaining bolts from the lot are tested with 2,4,6 ,and 8 threads exposed.
- Thread exposures obtained by running the fastener completely into the fixture and then unscrewing the amount of turns (2,4,6,or 8) as the thread exposure requires.
- After the fracture the thread length is measured and the maximum load is recorded.
- Data from the Tinius Olsen machine is imported into excel
- Bolt diameters of 5/8 " – 1 ¼ "
- Lengths of 3.25"-5"



Fig. 2: Bolt Fractures (From Top) 0 Threads to 8 Threads



Fig. 3: Installing the Bolts

## Results

- Bolts with zero threads exposed do not elongate as much as those with six or eight.
- Bolts with four or six threads exhibit more of the 45° shear fracture
- Eight threads exposed is not recommended as they tend to strip the threads with little to no elongation
- Richard model used to model data
- Based on the slope first part of the graph, the k or Stiffness
- And slope of the horizontal portion,  $k_p$  the stiffness after yielding (Fig. 5).

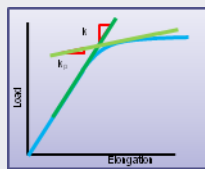


Fig. 4: Representation of Richard model

- Approximately 88% of all bolts tested fit the Richard model within 90% to 100%.
- Figures 5 and 6 show how the initial stiffness (k) and the stiffness after yielding ( $k_p$ ) varies by grade.
- Diameter and grade have no effect on the initial stiffness
- As diameter increases stiffness after yielding increases



Fig. 1: Testing Set-Up

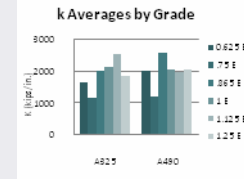


Fig. 5: Initial Stiffness (kips/in) by Grade and Diameter

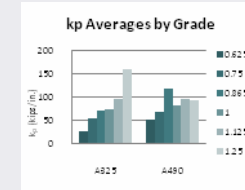


Fig. 6: Stiffness After yielding (kips/in.) by Grade and Diameter

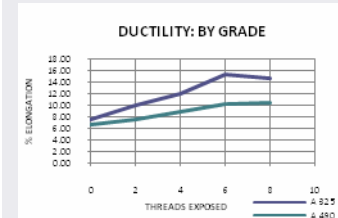


Fig. 7: Average Ductility: Elongation vs. Thread length

- Figure 7 shows the correlation of the ductility from the elongation measurements.
- The increase in ductility was considered to be linear due to the shape of the curve

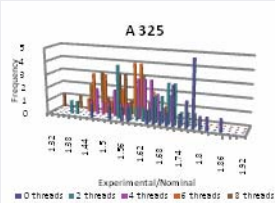


Fig. 8: Experimental / Nominal Frequency A325

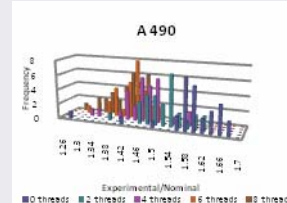


Fig. 9: Experimental / Nominal Frequency A490

- Fig. 8&9 show that as more threads become exposed in the grip of the bolt the closer the ratio gets to 1
- Fig. 10 & 11 show, from 0-8 threads, increase in frequency of elongations

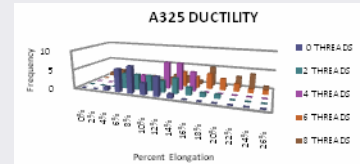


Fig. 10: A325 Distribution of Elongation With Respect to Thread Exposure

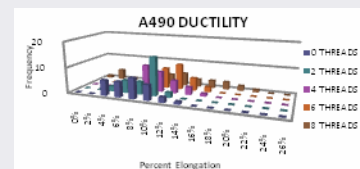


Fig. 11: A490 Distribution of Elongation With Respect to thread Exposure

## Conclusions

- The bolts tested exhibited behavior expected. As more threads were exposed, the more ductile the bolts were. As the bolts strength was decreased by the amount specified by AISC (90 ksi and 125 ksi, respectively).

### A325 Bolts

- The strength of the A325 bolts decreased as more threads were exposed. On average the strength decreased 3% per thread exposed with a standard deviation of 1.6%.
- Use of a wedge washer (ASTM F606 method) was not recommended for the bolts and the use of a proof washer was recommended for the bolt because of the increase in available thread length.
- It was found that A325 bolts on average were more ductile, with a standard deviation of 7%.

### A490 Bolts

- The ductility of the A490 bolts on average increased by 10% every two threads exposed (up until 8 threads) with a standard deviation of 8.41 %
- On average the strength decreased 3% per thread exposed with a standard deviation of 1.6%.
- On average, the A490 bolts were more ductile than the A325 bolts

- The length of the bolt does not affect the results.

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