Mech 306

Lab #2
Strength of Fasteners

Group 35

Ratthamnoon Prakitpong

Jason Sled

Cole Stevens

Zishun Zhang

University of British Columbia
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Abstract

The maximum applied force of a fastener before plastic deformation can be obtained by applying torque on said fastener until the applied force begins to reduce as necking occurs. In this lab, we tested six different bolt types:

- Rolled UNC Unlubricated,
- Rusty UNC Unlubricated,
- Machined UNC Unlubricated,
- Machined UNC Lubricated,
- Machined UNF Unlubricated,
- And Machined UNF Lubricated.

As expected, the rusted bolt with coarse threads had the lowest maximum load, 1797 lbs, while the fine-threaded, unlubricated bolt had the highest maximum load, 4755 lbs. The factory-machined bolt with the rolled edge had a maximum load of 3990 lbs, which was the maximum of the coarse-threaded bolts which was expected due to the high quality threading from the factory. The lubrication in the coarse-threaded bolts had little effect on the maximum load allowed by the bolt; however, the fine-threaded bolts had a large difference in the measured values suggesting that the lubrication has a negative impact on the maximum applied load.

Introduction

One of the key components of most manufacturing processes is joining different materials together. A very common method for joining materials is to use mechanical fasteners. The greatest advantage to mechanical fasteners is that they are non-permanent, and they can be removed relatively easily without damaging the joining components. Due to their frequent use, fasteners are relatively cheap and easy to find.

The objectives of this lab are to evaluate the relationship between preload and torque for specific bolt types and determine their max operational strength. With these characteristics defined, an engineer could predict what bolts will be needed and to what torque specification they must be set for a given design. This lab also explores some other important factors, such as how lubrication and corrosion can change the mechanical response of the bolt.

Methods

We followed the procedure provided to us in the lab manual. To test the torque application required to cause plastic deformation and eventual breaking of the six different bolt types analyzed in this lab, we used a bolt force measurement device that is calibrated to display the load applied by tightening the bolts and a torque wrench that displays the applied torque for each turn. The results from tightening each of the six bolts were recorded in an Excel document. The measurements from each instrument were taken approximately every 20º until the bolts broke under the applied torque. The four machined bolts were developed during the lab using the bolts that had already broken as blanks for the die.

Results

Bolt Type	Preload vs Torque Slope Value [1/in]	Maximum Load
Rolled UNC Unlubricated	9.83	3990
Rusty UNC Unlubricated	7.6	1797
Machined UNC Lubricated	11.5	3930
Machined UNC Unlubricated	11.9	3934
Machined UNF Unlubricated	12.3	4755
Machined UNF Lubricated	18.3	4334

Table 1: All Bolt Preload vs Torque Slope and Maximum Load Measurements

Ranked by Largest Slope	
Bolt Type	**Preload vs Torque Slope Value [1/in]**
Machined UNF Lubricated	18.3
Machined UNF Unlubricated	12.3
Machined UNC Unlubricated	11.9
Machined UNC Lubricated	11.5
Rolled UNC Unlubricated	9.83
Rusty UNC Unlubricated	7.6

Table 2: Bolts Ranked by Largest Preload vs Torque Slope

Ranked By Largest Max Load	
Bolt Type	**Maximum Load**
Machined UNF Unlubricated	4755
Machined UNF Lubricated	4334
Rolled UNC Unlubricated	3990
Machined UNC Unlubricated	3934
Machined UNC Lubricated	3930
Rusty UNC Unlubricated	1797

Table 3: Bolts Ranked by Largest Maximum Load

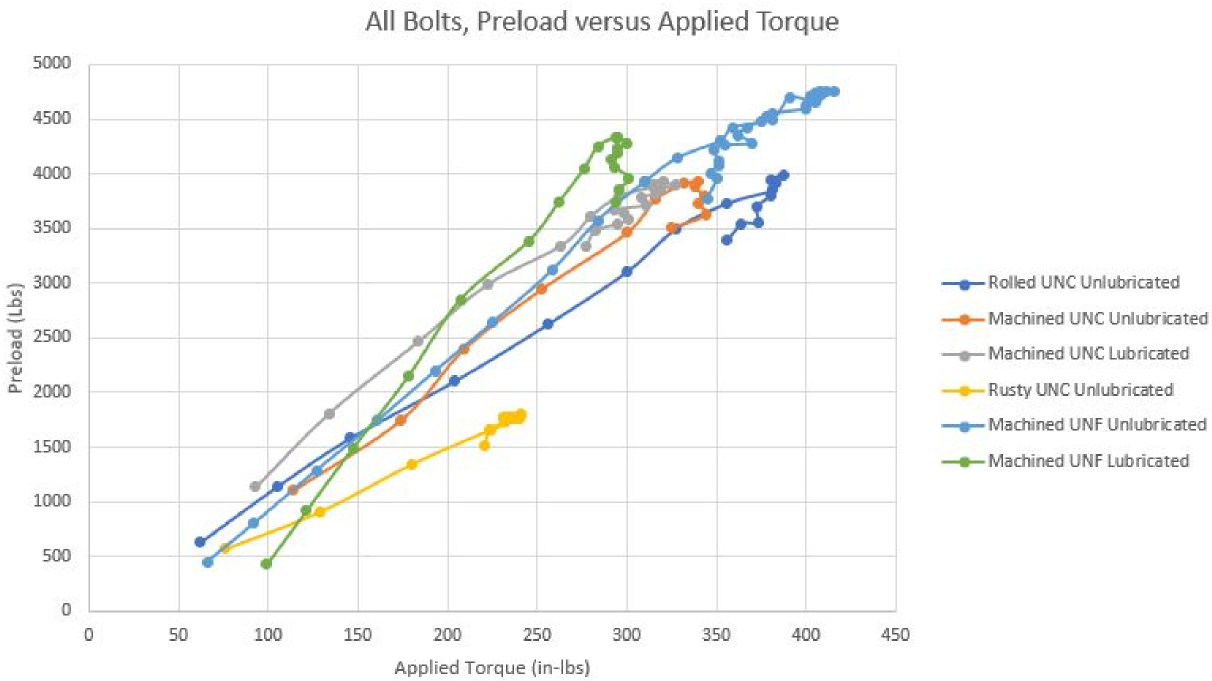


Figure 1: All Bolts, Preload vs Applied Torque

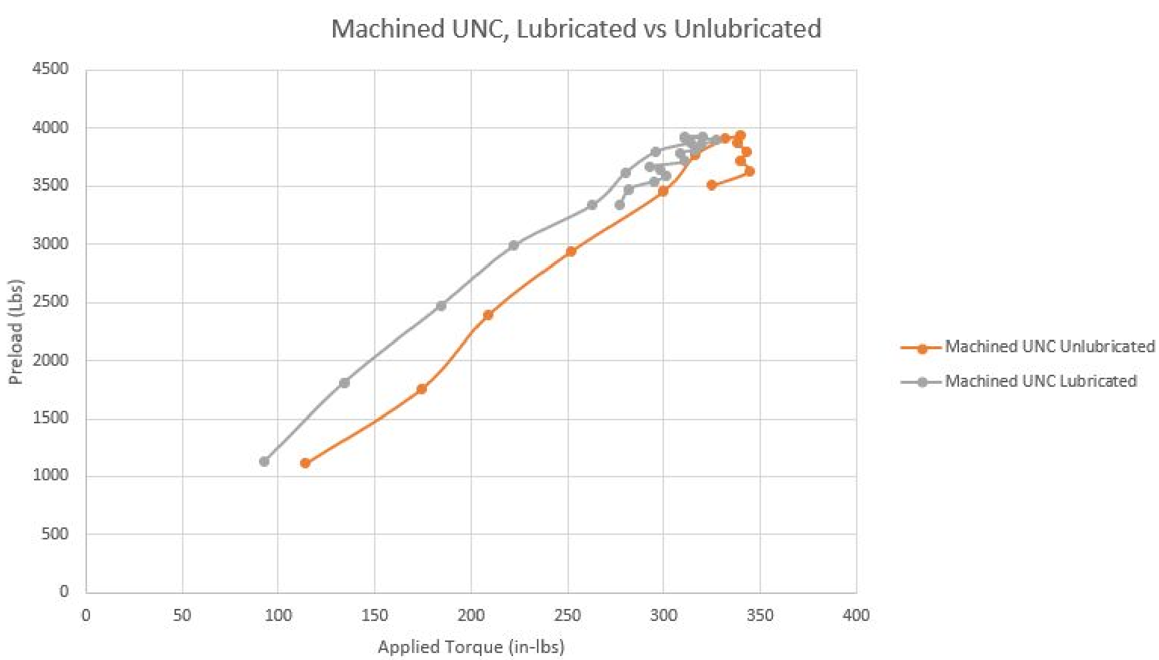


Figure 2: Machined UNC, Lubricated vs Dry Bolt, Preload vs Applied Torque

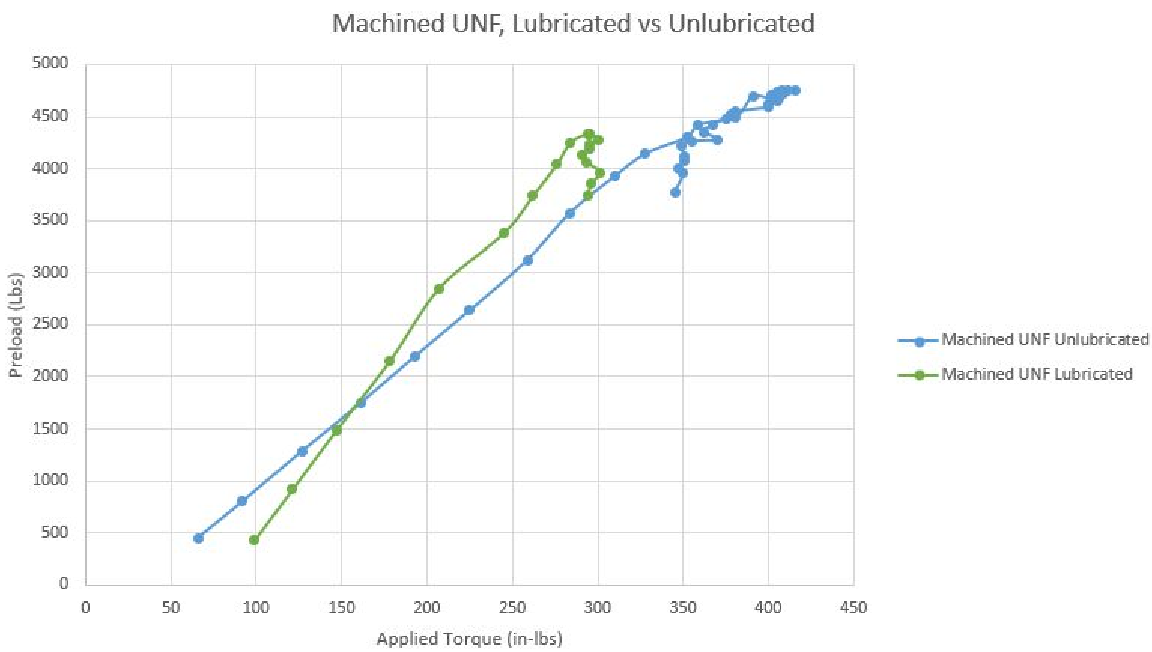
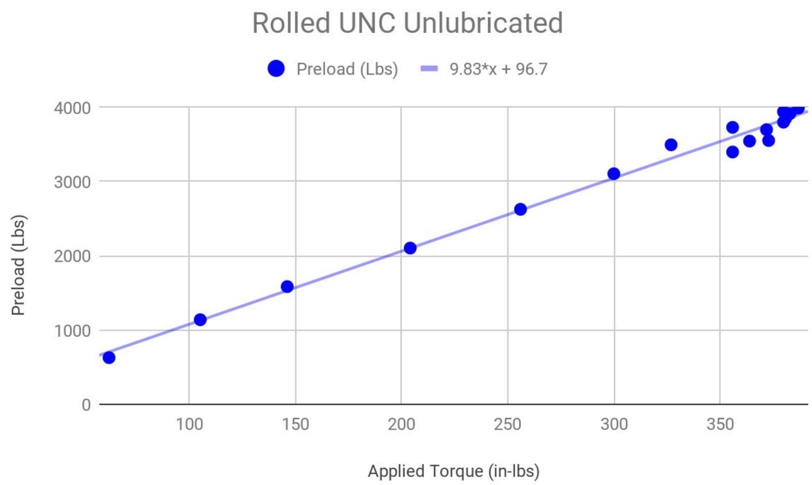
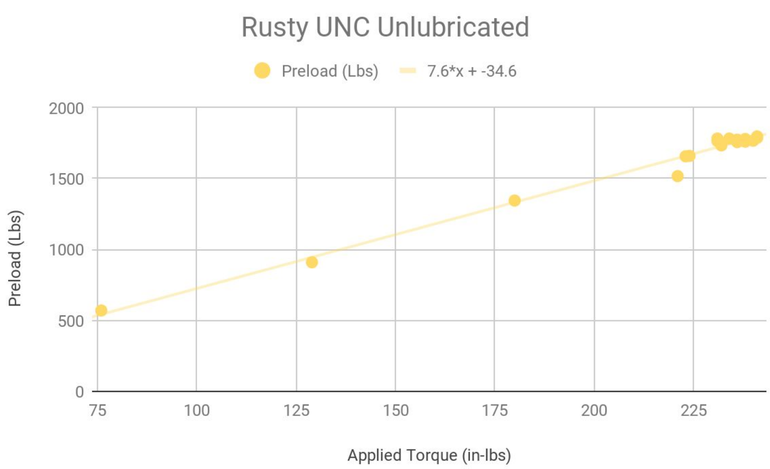
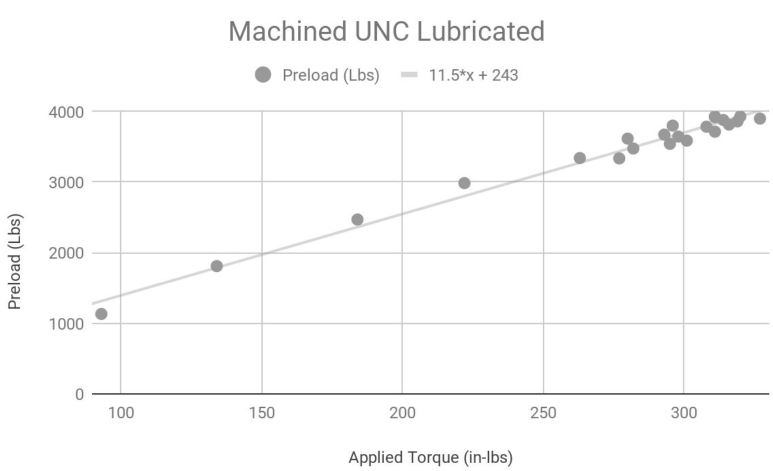


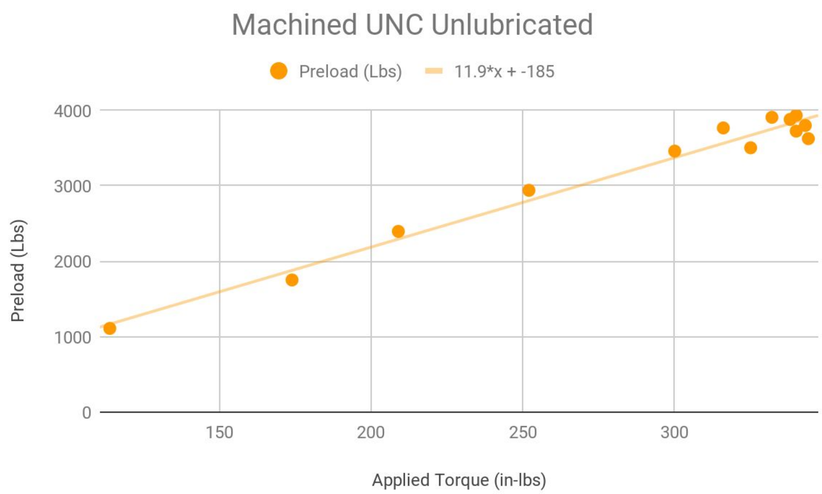
Figure 3: Machined UNF, Lubricated vs Dry Bolt, Preload vs Applied Torque

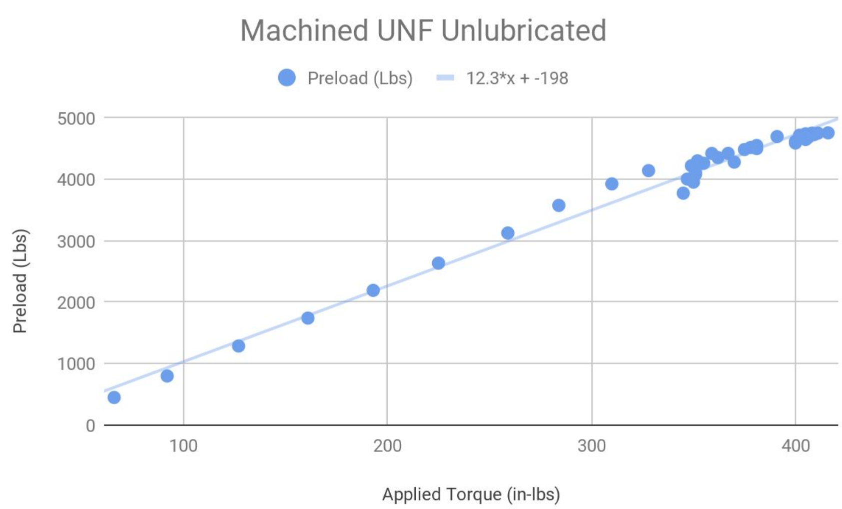
Individual Bolt Plots with Best Fit Lines:

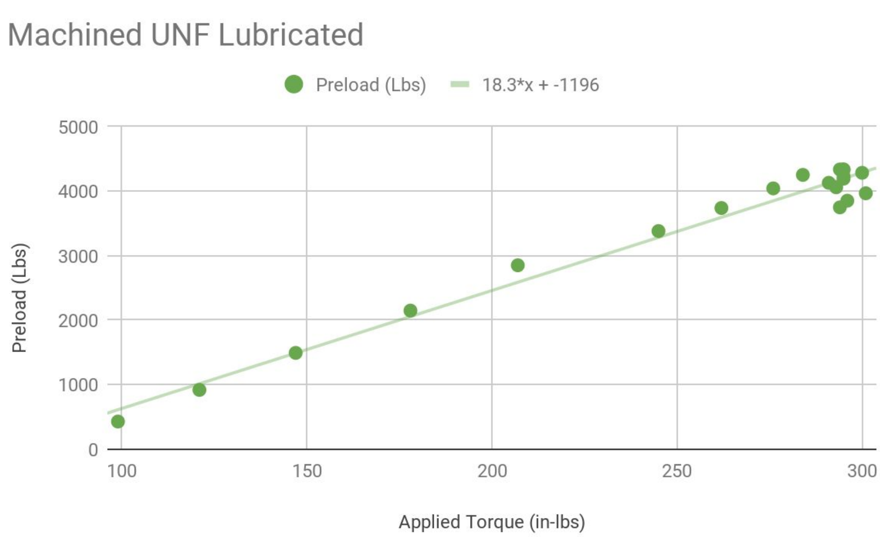







Machined UNC Unlubricated
Preload (Lbs)
11.9*x + -185
4000
3000
2000
1000
0
150
200
250
300
Preload (Lbs)
Applied Torque (in-lbs)


Machined UNF Unlubricated
Preload (Lbs)
12.3*x + -198
5000
4000
3000
2000
1000
0
100
200
300
400
Preload (Lbs)
Applied Torque (in-lbs)


Machined UNF Lubricated
Preload (Lbs)
18.3*x + -1196
5000
4000
3000
2000
1000
0
100
150
200
250
300
Preload (Lbs)
Applied Torque (in-lbs)

Analysis and Discussion

Our predictions were verified by the results in Table 2. The machined lubricated UNF bolt has the largest slope since preload is higher for the same amount of torque in a lubricated bolt. The only irregularity is where the machined UNC unlubricated bolt has larger slope than the machined UNC lubricated bolt (11.9 vs 11.5). However, the values are so close that the error could just be a result from our machining. Using rolled bolts, our value would likely follow theoretical trends.

In Table 3, the UNF bolts have a higher maximum load than the UNC bolts. This is expected because the fine threaded bolts have a larger area for absorbing the shear stress than the coarse threaded bolts. Additionally, the rolled unlubricated UNC bolt has higher values for both measurements than the machined unlubricated UNC bolt; while both are UNC bolts, our machining is likely less precise than the factory's, which adds surface friction that increases slope and maximum load values. The rusty unlubricated UNC bolt has the smallest value for both measurements, due to having largest friction from the rust.

There are two ways to preload bolts as discussed in the lab: torque method and turn-of-the-nut method. Torque method requires the calculation of torque for wanted preload, then using a torque wrench to apply that precise amount of torque on the bolt. Turn-of-the-nut method turns the bolt into a snug fit, then by reading from a table that accounts for bolt geometries (such as the ratio of bolt length to diameter), the assembler turns a specified angle further passed snug to get the right preload.

Torque method can specify a more precise preload for the bolt, while turn-of-the-nut only considers the minimum preload tension for the specified bolt in slip-critical condition. However, torque method requires more calculations and more expensive equipment (such as a torque measurement device), compared to just a pen for marking where the snug fit is located when using the turn-of-the-nut method.

As shown in both Figure 2 and Figure 3, a major difference in the bolt analysis is that the lubricated bolts require less torque for the same amount of preload. This occurs because lubrication reduces friction, so that the same amount of torque can apply more tension. In other words:

$$T_{in} = F_P \left(\frac{P}{2\pi} + \frac{\mu_t r_t}{cos(\beta)} + \mu_n r_n\right) \text{ [Equation 1 given in the lab manual]}$$

Keeping T_{in} the same and reducing μ_t and μ_n by using lubricant will increase the value of F_P, the preload force.

There are advantages and disadvantages to lubricated and dry bolts. For example, lubricated bolts are advantageous when the machine needs to be serviced often. Lubrication removes friction from the bolt when inserting, as well as reducing the amount of required torque for the same amount of preload; both of these factors make it easier for lubricated bolts to be removed.

On the other hand, friction factors have little variation when the bolt is dry, as opposed to highly varied values depending on the type of lubrication used. This increases consistency between assemblers, and reduces the possibility of accidentally using the wrong lubricant and applying more torque than required for the preload, thus warping the bolt.

Conclusion

We investigated the relationship between applied torque and tension in a bolt, and our data shows that tension is proportional to the torque used to tighten the bolt. Theoretically, the six plots should pass the origin because there is no tension in the bolt when we apply zero torque. The experimental errors may be resulted from the the torque loss during the transmission from torque wrench to other fasteners. To be specific, there is also tension created in the washer and spacers so our data best fit lines do not pass the origin. We also compare how surface condition affect tension vs. torque relationship. Figures 2 and 3 basically verify the assumption that it requires less torque to generate the same preload in lubricated bolts since it has smaller friction factor. With the same surface condition and machining, our experiment determines how UNC and UNF threaded bolts affect overall fastener strength. Table 3 suggest that UNF bolts have higher strength than UNC bolts and the result also satisfy the tension vs. torque equation. Fine thread has smaller thread lead (P) so it requires higher preload to reach the maximum failure torque. In practice, lubricated UNF bolts can withstand higher load and requires less torque to reach a required preload which is more safe.