The Use of Standards in Engineering Design: A Practical Example

ABET criterion 5 requires the use of standards in engineering design. This can be difficult to apply in senior design projects which often focus on developing an alpha prototype to prove a conceptual design. A common way to satisfy this requirement is to use NEMA or ISO standards for weather resistance if the product will be used outside. While this does expose students to the use of standards, it often contributes little to the design. The following pages contain a report showing how one of our capstone teams used standards in their design. I feel it is a particularly good example and want to share it with the engineering community.

> ## Criterion 5. Curriculum
>
> The curriculum requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The program curriculum must provide adequate content for each area, consistent with the student outcomes and program educational objectives, to ensure that students are prepared to enter the practice of engineering. The curriculum must include:
>
> a. a minimum of 30 semester credit hours (or equivalent) of a combination of college-level mathematics and basic sciences with experimental experience appropriate to the program.
>
> b. a minimum of 45 semester credit hours (or equivalent) of engineering topics appropriate to the program, consisting of engineering and computer sciences and engineering design, and utilizing modern engineering tools.
>
> c. a broad education component that complements the technical content of the curriculum and is consistent with the program educational objectives.
>
> d. a culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work.
>
> www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2023-2024/

In academic year 2023-2024 we developed a piece of service equipment for NAVAIR, an entity within the US Navy responsible for supporting and maintaining military aircraft. Our design had two threaded connections, one under high load and the other with minimal load. We used standards to determine the thread type for each application as described in the report below.

This example also clearly shows why exposure to standards is needed in engineering education. If standards were not utilized, the students may have created their own custom threads. Although they may perform well functionally, they would be difficult and expensive to manufacture. Thus, a redesigned would be required prior to production. The logic that the students used in their thread selection is also explained in the student report below.

Martin Tanaka

Martin L. Tanaka, PhD, PE is a professor of mechanical engineering at Western Carolina University (WCU). He has 11 years of experience designing commercial products in industry and an additional 14 years mentoring capstone teams at WCU. He is an ABET evaluator for Mechanical Engineering and serves as the director of the BS in Engineering program.

Technical Report

Dummy Input Quill Threads

Western Carolina University: Capstone Team 24

Colby O'Grady, Noah Robertson, Cole Holcomb, Matthew Hardison

Faculty Mentor: Dr. Martin Tanaka

January 24, 2024

Introduction

Helical threads can be observed in almost any system throughout modern engineering practice. Screw threads relate rotational movement to linear motion and are commonly used as fasteners to secure components in place. This type of jointing is extremely efficient, as components secured via fasteners are typically simple to remove.

Due to their versatility, there are many standards surrounding threads and their applications. An example of this would be Unified National Coarse (UNC) and Unified National Fine (UNF) threads. The main difference between these two threads occurs in their TPI, or "Threads per Inch". Coarse threads tend to have less TPI, but thicker overall tooth design. This characteristic makes UNC threads perfect for bearing large tensile forces. UNC threads are oftentimes chosen for components in mass production. Fine threads have more TPI, but a smaller cross-sectional tooth area. This limits its ability to withstand loads but tends to be tighter and more fluid resistant than UNC threads.

Application to Capstone

The Dummy Input Quill employs both UNC and UNF threads in its design. The UNC application occurs where the dowel pins interact with the inner pipe (*Figure 1*). UNC 5/8"-11 threads were chosen for this application as the dowel pins support most of the load, while also allowing the necessary degrees of freedom. With an inner pipe wall thickness of ½", the dowel pins will feature about five and a half engaged threads. This number was calculated from an engineering design table (*Figure 2*), by multiplying the threads per inch for UNC 5/8"-11 by the inner pipe wall thickness. Since there is a large amount of material to thread into, and a large load to support, UNC threads were the obvious choice for this application.

One downside of implementing UNC for the dowel pins is its lack of protection from fluid leakage. The inner pipe is likely to support a large quantity of engine oil, which has the potential to leak between the coarse dowel pin threads. To mitigate this risk, each dowel pin will be covered with pipe thread sealant. This sealant has a maximum operating pressure of 12,000 psi, and a maximum operating temperature of 450 °F. Both of which the quill will not experience during normal operation.

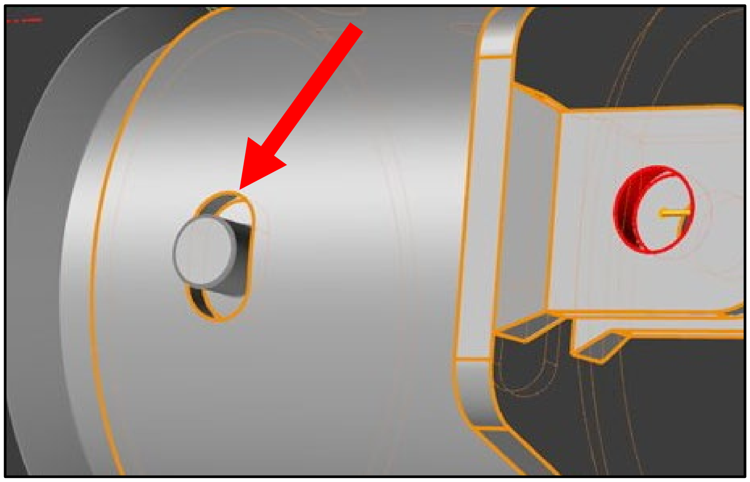

Figure 1: Dowel Pin Interface

Major Diameter (in)	Threads per inch (tpi)	Major Diameter		Tap Drill Size (mm)	Pitch (mm)
		(in)	(mm)		
#1 - 64	64	0.073	1.854	1.50	0.397
#2 - 56	56	0.086	2.184	1.80	0.453
#3 - 48	48	0.099	2.515	2.10	0.529
#4 - 40	40	0.112	2.845	2.35	0.635
#5 - 40	40	0.125	3.175	2.65	0.635
#6 - 32	32	0.138	3.505	2.85	0.794
#8 - 32	32	0.164	4.166	3.50	0.794
#10 - 24	24	0.190	4.826	4.00	1.058
#12 - 24	24	0.216	5.486	4.65	1.058
1/4" - 20	20	0.250	6.350	5.35	1.270
5/16" - 18	18	0.313	7.938	6.80	1.411
3/8" - 16	16	0.375	9.525	8.25	1.587
7/16" - 14	14	0.438	11.112	9.65	1.814
1/2" - 13	13	0.500	12.700	11.15	1.954
9/16" - 12	12	0.563	14.288	12.60	2.117
5/8" - 11	11	0.625	15.875	14.05	2.309
3/4" - 10	10	0.750	19.050	17.00	2.540
7/8" - 9	9	0.875	22.225	20.00	2.822

Figure 2: UNC Thread Chart

The UNF application occurs near the bottom of the proprotor gearbox plate, where the oil jet plug restricts the leaking of fluids (*Figure 3*). UNF 1”-12 threads (*Figure 4*) were selected for this design as the proprotor gearbox plate sports a thickness of only 0.295”. If UNC threads were selected for this application, there would only be two engaged thread teeth, when normally three locking threads characterize a successful mating. By selecting UNF threads, the team will be able to increase the amount of locking threads to just under four, keeping the design above the suggested thread minimum of three complete threads.

The increased thread count decreases the likelihood of oil leakage and allows for an even more compressed fit due to UNF’s tight tolerances. In this case, the team desired a tighter fit to better compress the O-ring towards the surface of the plate. As with the dowel pins, this area of the quill will be subject to large quantities of engine oil. However, since UNF threads were employed for the plug, it is more difficult for oil to pass. An o-ring seal is also utilized which eliminates the need for pipe thread sealant on this removable cap.

As the plug's main purpose is to seal back an unpressurized fluid load, the threads will not be subject to any severe loading. Since there are very minimal forces acting on the plug, UNF threads are even more practical.

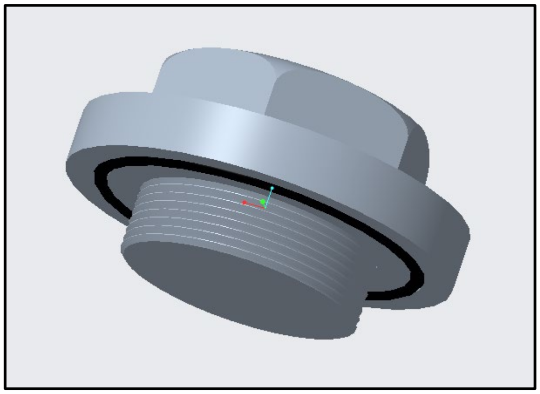

Figure 3: Oil Jet Plug

Major Diameter (in)	Threads per inch (tpi)	Major Diameter		Tap Drill Size (mm)	Pitch (mm)
		(in)	(mm)		
#0 - 80	80	0.060	1.524	1.25	0.317
#1 - 72	72	0.073	1.854	1.55	0.353
#2 - 64	64	0.086	2.184	1.90	0.397
#3 - 56	56	0.099	2.515	2.15	0.453
#4 - 48	48	0.112	2.845	2.40	0.529
#5 - 44	44	0.125	3.175	2.70	0.577
#6 - 40	40	0.138	3.505	2.95	0.635
#8 - 36	36	0.164	4.166	3.50	0.705
#10 - 32	32	0.190	4.826	4.10	0.794
#12 - 28	28	0.216	5.486	4.70	0.907
1/4" - 28	28	0.250	6.350	5.50	0.907
5/16" - 24	24	0.313	7.938	6.90	1.058
3/8" - 24	24	0.375	9.525	8.50	1.058
7/16" - 20	20	0.438	11.112	9.90	1.270
1/2" - 20	20	0.500	12.700	11.50	1.270
9/16" - 18	18	0.563	14.288	12.90	1.411
5/8" - 18	18	0.625	15.875	14.50	1.411
3/4" - 16	16	0.750	19.050	17.50	1.587
7/8" - 14	14	0.875	22.225	20.40	1.814
1" - 12	12	1.000	25.400	23.25	2.117
1 1/8" - 12	12	1.125	28.575	26.50	2.117
1 1/4" - 12	12	1.250	31.750	29.50	2.117

Figure 4: UNF Thread Chart

References

UNC and UNF - Unified Inch Screw Threads. (n.d.). Www.engineeringtoolbox.com. Retrieved January 22, 2024, from https://www.engineeringtoolbox.com/unified-screw-threads-unc-unf-d_1809.html#gsc.tab=0

What are UNF Threads and UNC Threads? | Difference Between UNF and UNC Thread | CNCLATHING. (n.d.). Www.cnclathing.com. https://www.cnclathing.com/guide/what-are-unf-threads-and-unc-threads-difference-between-unf-and-unc-thread-cnclathing