Classes of Fit in Screwthreads

As noted in *A Brief History of Screwthreads*, Joseph Whitworth's major contribution to screw-thread technology was the development of a set of equations defining the "fit" between male and female threads. This advance was so significant that many texts ascribe the development of the modern practical screwthread to Whitworth. I disagree with this for several reasons, but I understand the reasoning behind such claims. Whereas it had been understood since early in the 17^{th} century that cylindrical fits were proportional to the circumferences involved, this did not lead to properly fitting screwthreads. Whitworth's leap was to understand how this had to be modified for screwthreads.

The basic equation for a male thread takes the form:

Maximum Pitch Diameter = Basic Pitch Diameter - Factor_1*√Nominal Major Diameter]; and
Minimum Pitch Diameter = Basic Pitch Diameter - Factor_2*√Nominal Major Diameter] – Factor_3*√Pitch]

While the equation for a female thread takes the form:

Maximum Pitch Diameter = Basic Pitch Diameter + Factor_1 * √Nominal Major Diameter]; and
Minimum Pitch Diameter = Basic Pitch Diameter + Factor_2 * √Nominal Major Diameter] + Factor_3 * √Pitch]

This insight is the foundation of modern screwthread success. Factor_1 and Factor_2 as used in the equations above establish the *allowance* – clearance that lets a nut spin quickly onto a bolt. Factor_3 establishes the tolerance for manufacturing – based solely on the pitch of the thread. In more modern standards, the Factors are actually complex functions based on materials, processes used in manufacture, and width of the engaged threads. When the factors are negative, the result is an interference fit screwthread. These are rarely used today as localized distortion of female threads are used to create a controlled positive required assembly torque.

Allowances and tolerances for screwthreads are **always** unilateral. I.E. a male thread may be as large as the basic pitch diameter (a zero-allowance condition), but are allowed to be smaller than that value. Similarly, a female thread may be as small as the basic pitch diameter (a zero-tolerance condition), but are allowed to be larger than that value. This assures that any Class of male thread will successfully mate with any Class of female thread (excepting interference-fit Classes). The exception to this rule is that metric threads of a given size and pitch manufactured to different standards may not interchange. This is a result of the differing national standards that are still found today.

The Unified National Thread standard has four Classes, though Class 4 is rarely used today as it is the interference fit thread referred to above. A Class 3 thread has a small tolerance, but no allowance. This results in a close (potentially zero-clearance) assembly commonly used where high stresses and vibrations are encountered. A Class 2 thread has small allowances and tolerances applied to reduce the cost of manufacture and speed assembly while maintaining high strength properties. A Class 1 thread has relatively large allowances and tolerances that create a dirt-tolerant assembly fastener set. It should be noted that any surface conditioning, plating, or coating is included in allowances and tolerances and must be completed before measuring to qualify a screwthread.

Generally speaking, a Class 2 fit is easily made on machine driven and controlled set-ups. If you are hand tapping a hole, you should define it as a Class 1 fit. Class 3 fits require machine driven and controlled set-ups using close tolerance taps.

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