The wave thread is a type of mechanical screw with total surface contact. It cannot be over tightened; the next threshold is to break the bolt. The total surface contact is an inherent seal. The lack of clearance space makes it resistant to vibrational loosening: The male and female surfaces cannot move separately.

What is very special about the wave thread is that it can distribute stress more evenly than a normal thread. Finite Element Analysis (FEA) has shown some models to be 25 percent stronger than standard threads.

This geometry will increase the strength of bolts or pipe across any material. Wave threads can create more resistance to side loading, pressure differentials in pipes, and thermal expansion than normal threads.

Threads are a root technology that connects the pieces of our infrastructure. Making threads on fasteners stronger, lighter, more resistant to corrosion or more useful makes the product they are used with safer, more durable, and better.

Wave threads have a variety of characteristics. The concave, conic and convex shapes are shown in Figure 1.

Each layer is rotated. The combined rotated stack renders the wave thread shape on the outer surface.

Aside from the shapes and length of the thread, the other characteristics that can be adjusted are leads, amplitude and period. There are also swells, overflows and nested leads, but these tools have not been tested.

Changes in these characteristics cannot be made independent of one another. For example, a pipe model would not screw together with a single lead, but it would with three leads. A smaller diameter bolt, with the same thread, needed two leads to assemble correctly. These are local clearance issues where surfaces interfere. It took multiple rapid prototype models to find parts that screwed together correctly. Changes in any of the characteristics can create local clearance issues that can be remedied with other tools.

The amplitude and period of the wave can increase/decrease at a constant or accelerating/decelerating rate. One of these models has increased its tensile strength 20 percent with a decreasing amplitude and increasing period. That model had its length increased, which reduced and leveled the stress on each thread, thereby increasing its strength even more.

Shapes

The shape is based on the diagram in Figure 2. There is a beginning radius and ending radius from a centerline and a length. Delta is the difference between the beginning and ending radius. The conix angle is between the length and delta. Changing the radii or length changes the conix angle. In the nut and bolt study, a 7/8 bolt was used with a 0.4375" radius. The

continued on page 2
conix angles tested were 10, 15 and 20 degrees. The beginning radius is changed, while the ending radius stayed the 7/8-bolt diameter.

Note that zero starts at the small end of the shape as shown in the Figure 2 diagram. All values to the right of this are positive.

There are three shapes: conic, concave and convex. Figures 3a and 3b are the concave and convex shapes overlaid on the cone shape so they have the same beginning and ending radius, conix angle and length.

A circular curve always has symmetry and is easier to determine its coordinates given desired properties. Technically, the curve can be elliptical, parabolic or hyperbolic if it serves a purpose.

**Wave Thread Construction**

Once the shape is determined, it is sliced up into layers. For rapid prototype models, layers of 0.003" thickness were used.

On the first layer, the desired amplitude and period of the wave for the shape circle are selected. In Figure 4, the number of waves is the number of periods. Here, there are four that are added to the shape circle.

This is wave thread basics. In Figure 5, the amplitude rises and falls at the same rate as the wave in Figure 4.

A single lead wave thread has the wave period equal to the shape circle circumference as shown in Figure 6.

In Figure 7, the single lead wave thread is shown as a circle. The first wave thread prototypes were constructed from a stack of cardboard circles.

The next aspect of the wave thread is that it has a second wave on the surface. Each layer of a single lead thread is shown rotating in Figure 8.

The next aspect of the wave thread is that it rotates at a constant or constantly changing rate. Figure 8 exemplifies this. This generates the wave on the wave thread. Its period is the completion of one of the lead periods. Figure 8 has one period. The amplitude is the same as the layer's amplitude.

The period and amplitude can also increase/decrease at a constant rate or constantly accelerating/decelerating rate, as demonstrated in Figure 9. Changing the amplitude is changing the generated wave height. Changing the period is either changing the spacing between the layers or keeping the layers constant and changing the degree of each layer's rotation. The following threads are a variation of the VP2D2 model used in Figure 9 and has the period doubling in size and the amplitude shrinking in half.

This particular combination distributes the load more evenly as compared to traditional threads as shown in Figure 10.

Stress concentration factors are a way to compare the tensile strengths of different threads. Figure 10 compares a standard thread with variations of the VP2D2 thread used in Figure 9. The comparison uses the same size nut. Due to how the wave thread changes its spacing, there are fewer threads than the traditional thread on the same size bolt. Other changes in period, amplitude and thread length shown in Figure 10 have a dramatic impact on how stress is distributed.

Extending the length of VP2D2 from 0.875" to 1.25" and changing its conix angle from 10 degrees to 15 degrees, lowers the stress per thread and even out the distribution. Decreasing the amplitude to 1/3 is size in VP2D3 lowers stress at the beginning and increases it at the end. There is a similar result by increasing the period from 2.0 to 2.5 in VP25D2. These are examples of how...
Having a longer thread will increase the utility of cheaper and lighter materials.

Conclusions

On the practical side of the wave thread application, they are faster to assemble because they have an initial penetration before thread contact; then they require fewer rotations to fully engage. Increasing the number of leads decreases the number of rotations and speeds up assembly.

The wave thread cannot be over tightened. Once its surfaces are engaged, the next threshold is to break the part, which will require considerably more torque than it takes to damage a standard thread.

The wave thread has six groups of variables: length, shapes, waves, leads, swells and nested leads. There are optimal combinations and some that will not work at all.

A systematic Finite Element Analysis study of the variety of combinations will create a knowledge base on which to predict properties. These tests include tensile strength, temperature variances, side loading for changes in elasticity and strength of the connected threads, and pressure differentials for tubing and different materials. Selective destructive testing will verify the FEA results.

This is a root technology with many applications. Standards have to be developed such as pipe threads for different wall thicknesses and diameters; and nuts and bolts for aerospace applications. This technology can be applied to a new type of valve.

In conclusion, the wave threads introduce various new characteristics to assemblies connected with nuts and bolts or tubes.

DALE E. VAN COR

Dale E. Van Cor invented three fasteners and new gears in two transmission systems. This includes developing the software to engineer and generate the Gcode for 5-axis machining. He owned a software development company for 15 years and created 57 turn key systems. To reach Dale, email him at dale@wavethread.com or call 603.239.4433.