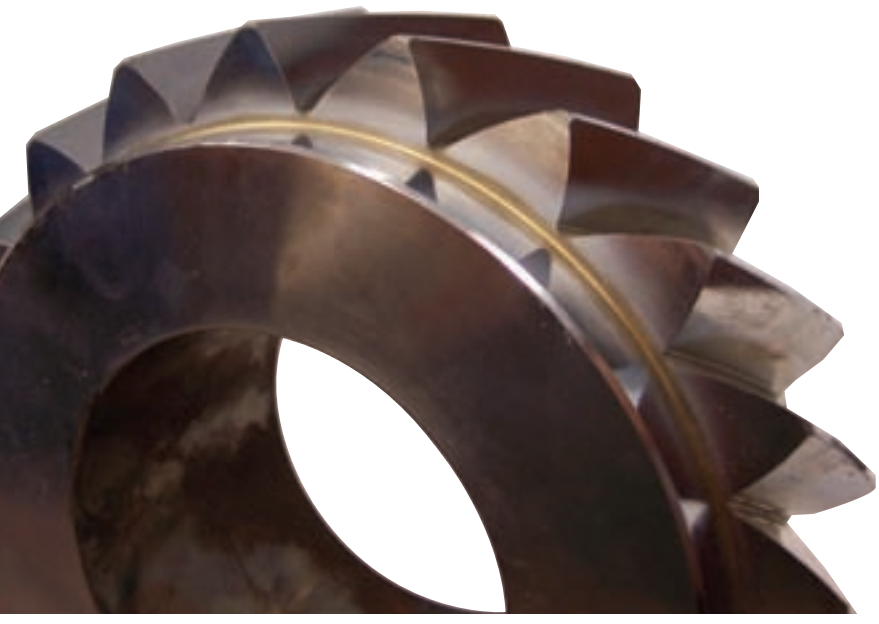
Longer Fatigue



With

MEGAGEARS (top) and UNIMEGAGEARS (middle) from Power Engineering & Manufacturing Ltd. allow for greater horsepower and/or longer life than standard involute gears (bottom).

Life at Lower Cost

Saul Herscovici, President, Power Engineering & Manufacturing Ltd.

MEGAGEARS and UNIMEGAGEARS

Power Engineering & Manufacturing Ltd. was established in 1975, one of only a small handful of gear manufacturers in the state of Iowa. By 1977, we found that there was good demand for custom designed gearboxes, so we concentrated our full efforts into designing and manufacturing them.

At first, since we were a new company without experience or automated and efficient equipment, our prices were higher than our competition.

However, over time, we developed unique designs that have enabled us to compete in the marketplace. For example, one of our customers manufactured trench-cutting equipment for laying fiber-optic cable. Often, these trenchers would have to cut through rock, so they required extremely rugged gearboxes. At the same time, though, the customer wanted smaller, more efficient gearboxes.

Power Engineering and Manufacturing designed gearboxes with flywheels to provide inertia so the devices could be powered by a hydraulic motor rather than a diesel engine.

This customer—like many of our customers—required stronger gear teeth that wouldn't break, even under heavy shock loads. We researched how to increase the power density so that we could make a smaller, more efficient gearbox with an adequately long life.

This progress was very slow. We tested the concept of higher power density in small steps, but in the end, they resulted in our custom gear designs, called MEGAGEARS® and UNIMEGAGEARS®. Because of that research, we now know that we can get 35% more horsepower out of our MEGAGEARS, and about 45% more horsepower out of our UNIMEGAGEARS, than we could get out of a standard gear using the same amount of metal. Our designs allow us not only to compete, but also to manufacture a gearbox that has excellent durability and efficiency, and that uses less metal and labor.

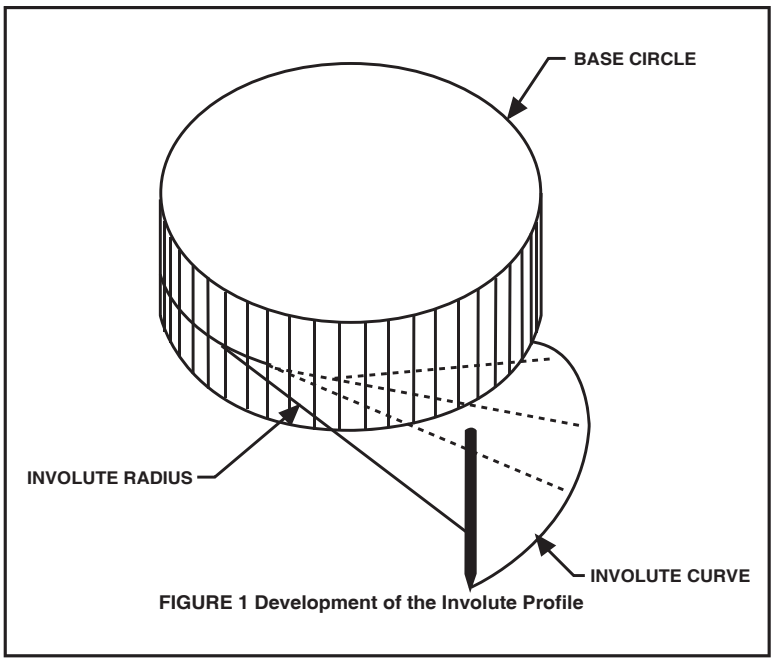


FIGURE 1 Development of the Involute Profile

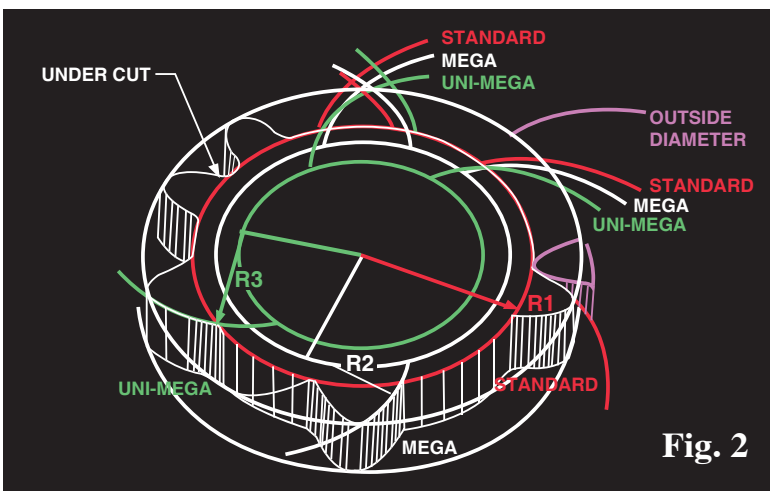


Fig. 2

How Do They Work?

At this point, it is appropriate to define the gear tooth profile, which is most often based on an involute curve. Figure 1 shows how the involute curve is developed. In the example, a pencil is tied to a string that is connected to a drum whose diameter is the same as the base circle. When unwinding the string, the pencil draws a line that is the involute curve.

Any section of the involute curve can be used to form the gear tooth profile. The secret to MEGAGEARS and UNIMEGAGEARS is moving the involute tooth profile farther away from the base circle, or more practically, using a smaller diameter base circle for the same sized gear. This creates a bigger radius of curvature on the tooth profile, which yields a larger contact area between the gear teeth. The larger contact area reduces the surface compressive stress and increases the surface fatigue life of the gears.

The gear blank in Figure 2 has a certain outside diameter, representing the amount of metal that will be used to make the gear. For any gear, the most critical point for surface fatigue life is the point on the involute curve closest to the base circle, where the radius of curvature is its smallest. If we cut a standard gear tooth, the radius of curvature at that point is R1, which is developed off the base circle (shown near the root diameter).

If we intend to cut the teeth of MEGAGEARS, we can see that the radius of curvature at the critical point designated as R2 is larger because the base circle diameter is smaller. The same is true of UNIMEGAGEARS because the base circle diameter is even smaller and thus the radius R3 becomes larger.

The larger radii of curvature, particularly at the pinion start of

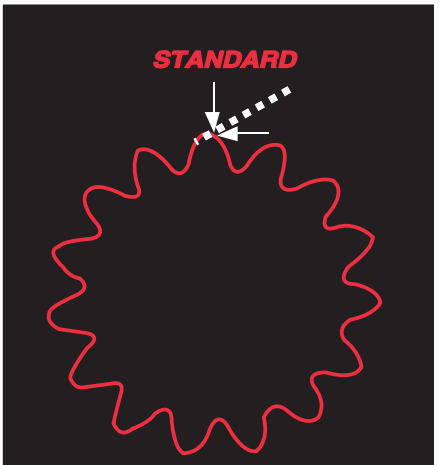


Fig. 3
Conventional Gear

active profile or profile contact ratio of 1.0, enables us to have a larger area of contact for better load distribution. When the same torque or force is spread over a larger area, the surface compressive stress is lower and, therefore, the surface fatigue life becomes higher. Lowering the surface compressive stress has an enormous influence on increasing the surface fatigue life.

When we overhaul gearboxes with conventional gears of 20° or 25° pressure angles and replace them with MEGAGEARS or UNIMEGAGEARS, we usually more than triple the surface fatigue life.

As can be seen from Figures 3, 4 and 5, the most damaging force—at least with regard to shock loads—is the force that acts perpendicularly at the tip of the tooth. A certain volume of metal is required to absorb the energy of a shock load or a heavy load. There is danger that the tip of a conventional tooth could be sheared because the force (described by an arrow) goes through the addendum of the tooth.

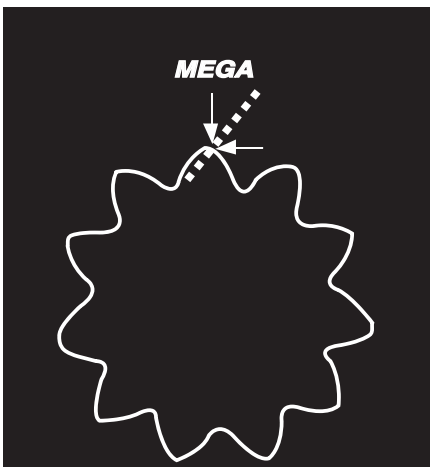


Fig. 4
MEGAGEAR

If we look at the MEGAGEARS and UNIMEGAGEARS, we can see that the perpendicular force at the tip of the tooth is pointing inside the tooth towards the root diameter. The MEGAGEARS and the UNIMEGAGEARS have a much larger volume of material to absorb the energy of a shock load or heavy load. We also have eliminated the possibility of shearing the tip of the tooth.

Not Just Theory

The technology of MEGAGEARS and UNIMEGAGEARS has been proven at Power Engineering and Manufacturing. We have more than 6,000 gearboxes working successfully with MEGAGEARS, and we have several hundred gearboxes working successfully with UNIMEGAGEARS.

To prove that the MEGAGEARS have a larger load carrying capacity, we had fatigue life tests done at the Design Unit at the University of Newcastle-Upon-Tyne in England, which is headed by professor Dieter A. Hofmann. This laboratory is very technically advanced, efficient, and extremely accurate.

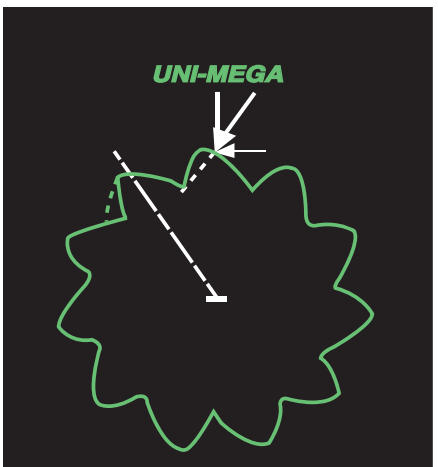


Fig. 5
UNIMEGAGEAR

Figure 6—Standard gear, 23 teeth, 4.233 NDP, 20° PA, 30° helix angle; showed surface damage after 50 million load cycles at 1,264 hp.

Figure 7—MEGAGEAR, 19 teeth, 4 NDP, 35° PA, 30° helix angle; looks unused after 50 million load cycles at 1,264 hp.

Figure 8—MEGAGEAR, 19 teeth, 4 NDP, 35° PA, 30° helix angle; showed some wear after 50 million load cycles at 1,686 hp.

For the tests, we used steel from the same melt to manufacture the standard gears and the MEGAGEARS. We will be again using steel from the same melt to test UNIMEGAGEARS at a later date.

Figure 6 shows the standard gear, 20° pressure angle, that was tested for 50 million load cycles and 1,264 hp until it started to score and have surface damage.

Figure 7 is a MEGAGEARS that was tested under conditions identical to those used for the conventional gear—50 million load cycles and 1,264 hp. Grinding marks are still there, and the gear looks as if it wasn't used, with the exception of some polish at the start of active profile. When the university laboratory testing personnel saw that the MEGAGEARS did not exhibit any fatigue or score marks, they increased the horsepower to 1,686 in order to make a successful fatigue test.

Figure 8 shows that there are some score marks and damage to the surface. However, the MEGAGEARS had to have 33 percent more horsepower in order to show fatigue similar to the conventional gear. The MEGAGEARS offers the advantage of increased power when substituting for conventional gears.

The UNIMEGAGEARS offer the advantage of power density that is even higher than that of the MEGAGEARS. We have used UNIMEGAGEARS to replace standard gears in hundreds of applications, and in some cases, we have been able to increase power density by 45 percent or more. In the cases where higher horsepower is not necessary, we can increase the surface and bending fatigue life by three fold or more by using MEGAGEARS or UNIMEGAGEARS.

An important additional feature of the MEGAGEARS or UNIMEGAGEARS is that the oil film thickness is greater because the area of contact between the gear teeth is larger and more oil gets trapped between the teeth. It is desirable to have a thicker oil film for the simple reason that hydrostatic load transfer is very desirable and advantageous because it increases the surface fatigue life. The mechanical load transfer on the high surface finish is reduced or eliminated; therefore, the force distribution on the tooth's surface is more uniform.

Note on Figures 4 and 5 that the MEGAGEAR and UNIMEGAGEAR teeth have a fairly big triangular shape with a large thickness at the root diameter. This tooth shape provides a very low bending stress at the root diameter, as it is extremely difficult to break a tooth at the root diameter. In fact, the bending stress is so low that the amount of tooth deflection is also very small, and for that reason, the MEGAGEARS and UNIMEGAGEARS run much more quietly than conventional gears. ■

Power Engineering & Manufacturing will be exhibiting at Gear Expo Booth #547.

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