

Longer Fatigue Life at Lower Cost With MEGAGEARS® and UNIMEGAGEARS®

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ABSTRACT

Power Engineering and Manufacturing, Ltd. was established in 1975. At that time there were only two companies that manufactured gears in the state of Iowa, and we thought there was room for a third company. By 1977, we found that there was good demand for *custom designed gear boxes*, so we concentrated our full efforts into designing and manufacturing custom gear boxes. Since we were a new company without experience or automated and efficient equipment our prices for custom designed gear boxes were higher than our competition.

INTRODUCTION

We have developed a unique design, such as, gear boxes with flywheels to provide inertia when cutting rocks where the driving power is a hydraulic motor rather than a diesel engine. A hydraulic motor has a very small shaft which possesses an insignificant amount of inertia when compared to a diesel engine which has a big flywheel and crank shaft with a very powerful amount of inertia.

MAIN SECTION

In order to compete in the market and to make a powerful gear box that could resist shock loads that were generated while cutting rocks when making trenches for fiber optic wires and many other applications. We conducted a continuous research on how to make the gear teeth strong so that they wouldn't break due to heavy shock loads. Also to be competitive in the market we researched on how to increase the power density so that we could make a smaller, more efficient gear box with an adequate long life. This progress was very slow, we tested the concept of higher power density in small steps, and in the end they were all successful. Our research paid off handsomely as we now know that we can put in the same amount of metal used to make conventional gears about 35% more horsepower on our MEGAGEARS®, and about 45% more horsepower on our

UNIMEGAGEARS®. This allowed us not only to compete but also to manufacture a gear box that has excellent durability, efficiency, and uses less metal and labor.

At this point it is appropriate to define gear tooth profile.

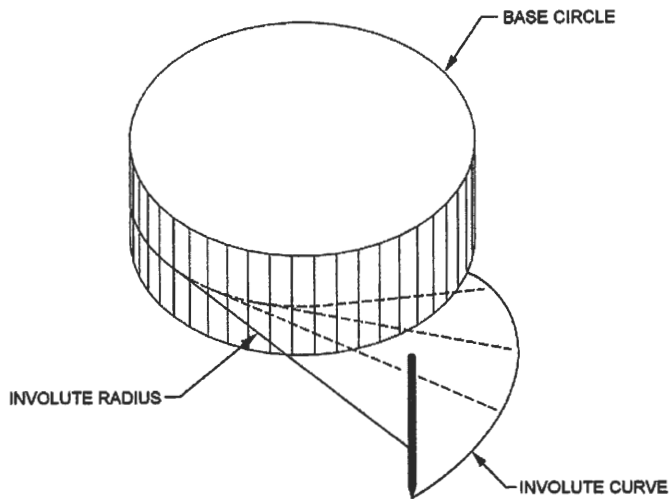
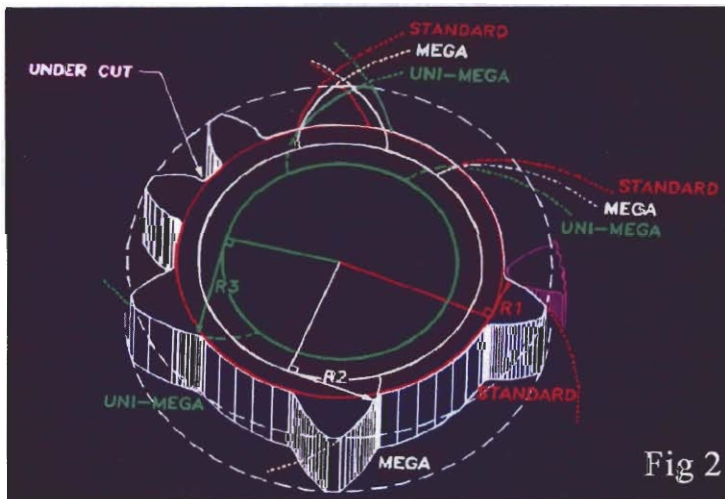


FIGURE 1 Development of the Involute Profile

Figure Number 1 shows how the involute curve is developed. If 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 scribes a line that is the involute curve. Austrian scientist Leonhard Euler (1707-1783), derived the involute mathematics that results in constant angular velocity. Any section of the involute curve can be used to form the gear tooth profile. The further away the bigger the radius of curvature is. This yields a larger contact between the teeth, thus reducing the surface compressive stress and increasing the surface fatigue life.



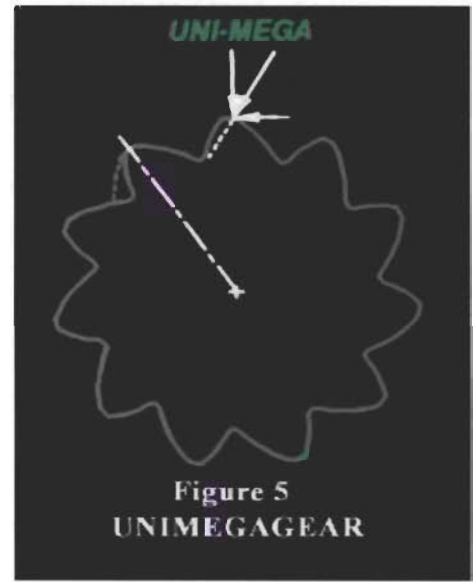
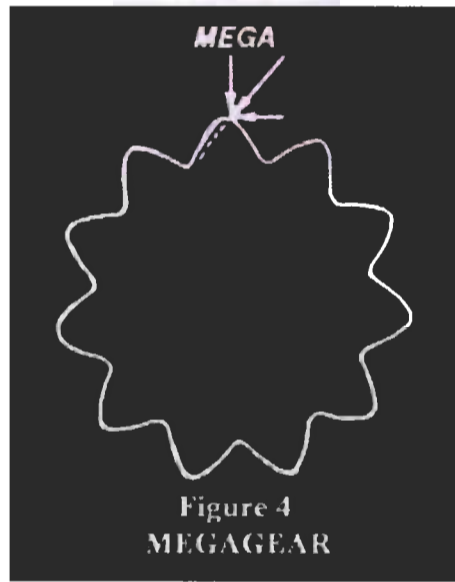
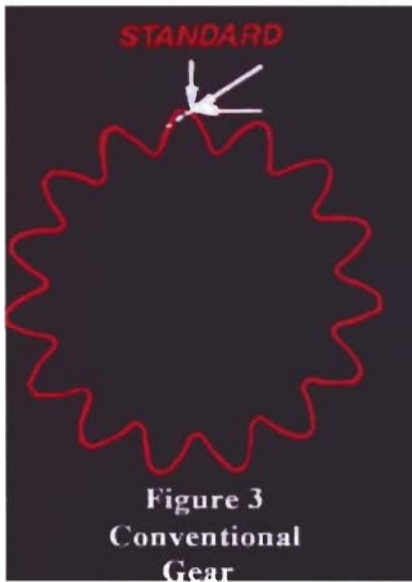
The gear blank in Figure Number 2 has a certain outside diameter that represents the amount of metal that will be used to make that gear. If we would cut a conventional gear tooth that we call standard you will see the tooth shape at the involute curve near the root diameter of the pinion is the most critical point for surface fatigue life. It can be seen that the radius of curvature at that point is R1, and that the radius is developed off the base circle (shown in the red). 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 active profile, enables us to have a larger area, of contact for better load distribution. When the same torque or force is spread over by 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, because the ratio of the initial higher surface compressive stress to the new one that its lower is raised to the exponent of 6.666, as can be seen on Equation Number 1.

$$\text{Equation Number 1} \quad \text{SurfaceFatigueLife} = \left(\frac{SCS @ SAP_1}{SCS @ SAP_2} \right)^{6.666}$$

$$\text{Equation Number 2} \quad SCS = \sqrt{\frac{E}{\pi(1+\nu^2)} \cdot \frac{T}{BR} \cdot \frac{\left(\frac{1}{r_1} + \frac{1}{r_2} \right)}{FW \cdot PCR \cdot 2 \cdot VF}}$$

For example, Equation Number 2 shows that if we are able to lower the surface compressive stress by the use of MEGAGEARS® or UNIMEGAGEARS® by 21 percent, the surface fatigue life is doubled.

When we overhaul gear boxes which have conventional gears of 20° or 25° pressure angle and we replace them with MEGAGEARS® or UNIMEGAGEARS®, we usually more than triple the surface fatigue life.



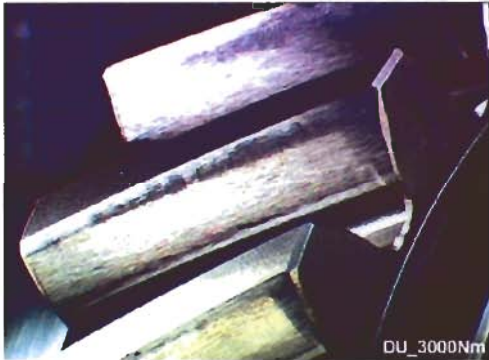
As can be seen from Figure Numbers 3, 4, and 5, the most damaging force is the force that acts perpendicularly at the tip of the tooth. It can be seen that on the conventional gear has a certain volume of metal can absorb the energy of a shock load or a heavy load. There is also a danger that the tip of the conventional tooth may be sheared because the **force (described by an arrow) goes through the addendum of the tooth**. If we look at the MEGAGEARS®, 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 amount 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.

The technology of MEGAGEARS® and UNIMEGAGEARS® has been proven at Power Engineering and Manufacturing, Ltd., because we have in excess of 6,000 gear boxes working successfully with MEGAGEARS®, and we have several hundred gear boxes 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 in 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. We also had the good fortune to obtain from The Timken Company steel that has been made from the same melt that tested the standard gears from which we made MEGAGEARS® and now we are in the process of making UNIMEGAGEARS® for a later dated test at the University of New Castle Upon Tyne.

Picture Number 1 shows the conventional or standard gear, 20° pressure angle that was tested for 50 million load cycles and 1264 HP until it started to score and have surface damage.



Picture 1.

Standard gear 23 teeth, 4.233 NDP, 20° PA, 30° HA
1264 HP at 3000 RPM, 50 million load cycles
SCS@PCR=231,000 PSI, 6.753 O.D.



Picture 2.

MEGAGEAR® 19 teeth, 4 NDP, 35° PA, 30° HA
1264 HP at 3000 RPM, 50 million load cycles
SCS@SAP=186,000 PSI, 6.813 O.D.



Picture 3.

MEGAGEAR® 19 teeth, 4 NDP, 35° PA, 30° HA
1686 HP at 3000 RPM, 50 million load cycles

Picture Number 2 is a MEGAGEAR® that was tested under identical conditions as the conventional gear for 50 million load cycles and 1264 HP, and it can be seen that the 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 personal saw that the MEGAGEAR® did not exhibit any fatigue or score marks, they increased the horsepower to 1686 in order to make a successful fatigue test. The test proceeded identically to the previous tests at 3000 RPM and 50 million load cycles. Picture Number 3 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 MEGAGEAR® offers the advantage of increased power density by as much as 35 percent or even more when substituting for conventional gears.

The UNIMEGAGEARS® offer the advantage of power density that is higher than that of the MEGAGEARS®. The UNIMEGAGEARS® can have an increased power density up to 45 percent or higher. In the cases where higher horse power is not necessary we can increase the surface and bending fatigue life by three fold or more by the use of 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.

Equation Number 1 shows that any reduction in the operating forces on the tooth surface has a major effect on increased surface fatigue life. The fatigue increases by the exponent of 6.666 of the ratio of the reduced surface compressive stress.

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 shape of tooth provides a very low bending stress at the root diameter as it is practically impossible to break a tooth at the root diameter. The bending stress is very low,

in fact it is so low that the amount of tooth deflection is also very small and for that reason, the MEGAGEARS® and UNIMEGAGEARS® run much quieter than the conventional gears.

CONCLUSION

Here is the conclusion paragraph.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

Here is the Definitions section. This is an optional section.

Term: Definition for the term