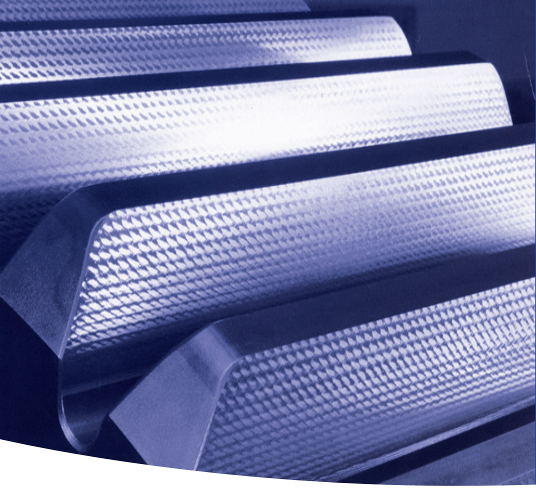

Single vs. double helical gears

Selection Depends on Operating Conditions and Gear Characterisitcs

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John B. Amendola, Sr.

Artec Machine Systems

Selection of helical gears involves specifying whether the gear should be single or double helix (Figures 1 & 2). Often, turbomachinery operators make this decision based on past experience or the traditions followed in their engineering firm. But the "best practice" in helix selection involves a deep understanding of the two technologies and gear operating conditions (Table).

Operating conditions can distort gear tooth contact, requiring field adjustments.The ease which these adjustments can be carried out on single and double helical gears affects the choice of single and double helical gears. While double helical gears generally have higher efficiency, single helical gears may be the appropriate choice for state-of-the-art applications that could require corrective action in the field.

Gear adjustments

During operation, gear teeth undergo mechanical distortions through twisting and bending. High mesh velocities cause thermal distortion from the heat generated (see archives in www.turbomachinerymag.com for a temperature vs velocity chart) as gear teeth slide in and out of mesh. Quenching losses — due to the oil and air being pumped axially along the engaging tooth flanks — create additional heat.

When operating Pitch Line Velocities (PLVs; the tangential speed of the gear rotors measured at the pitch circle) exceed 100 m/s, the heat produced creates notable distortion, increasing mechanical deflections. At higher PLVs — about 130 m/s — thermal distortion dominates.

Mechanical deflections can be calculated fairly accurately whereas thermal distortion developed in high-speed gears is not so easy to define. The accumulation of data from past experiences and field results from many gear applications help manufacturers predict thermal distortion of gear teeth empirically with reasonable accuracy.

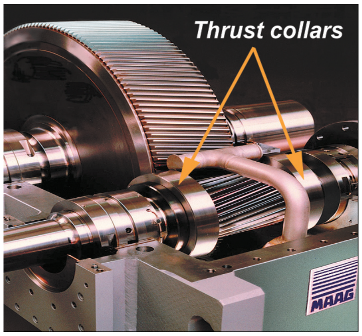
The combined effects can be evaluated to create a lead-and-profile correction to ensure even load distribution under design operating conditions.The ability to have effective corrections first requires a gearset of high quality – defined as the total manufacturing tolerance and specified by the American Gear Manufacturers Association (AGMA) and the American Petroleum Institute (API).

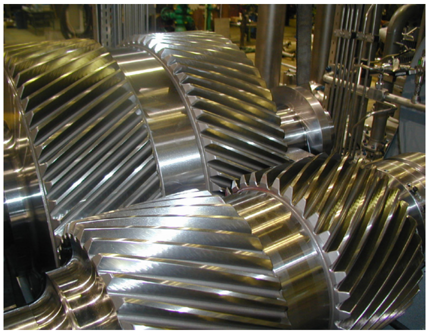
These corrections, while critical to avoid local tooth overload, are of a small magnitude. If the transmission errors (measured by the tolerance range) are high, the corrections are "lost" in the total tolerance range.

Corrections for mechanical deflections are not complicated, unlike corrections for thermal distortion. The optimum correction is typically a combined asymmetrical (three dimensional) lead correction (Figure 3), produced in the final grinding stage of the gearset (see box).

When a state-of-the-art application for a gearset requires a new calculation involving speed, power and layout configuration, field inspections of mesh alignment become important.

If in the field a tooth contact adjustment is found to be necessary, single helical gears provide a simpler means to do so by adjusting





Figures 1 & 2: Single helical gears (left) require some external support to compensate thrust created within mesh. Double helical gears (right) compensate thrust created by the mesh within the two helices.

	Single helical	Double helical
External thrust	No influence on gearing	May overload one helix leading to possible damage
Couplings	Any coupling may be used	Toothed coupling should be used with caution
Gear teeth thrust	Compensation by thrust bearings or thrust collars	Equalized within the gearing
Gear errors	Minimum	Different on two helices, leads to unequal load sharing
Axial vibrations	None	Axial vibrations brought on due to possible assymetrical pitch errors.
Field adjustment of gear tooth contact pattern	Possible with one adjustable bearing or casing adjustment	Very limited possibilities. May have to compromise. Re-grinding maybe necessary.
Gear tooth modification	Good control even for assymetrical corrections	Assymetrical on two helices. Requires more manufacturing control to produce the same quality
Transmission errors	Low	More than single helical. More noise is typical for lower quality gears

Table: The choice of single and double helical gears depends on their properties and their impact on gear operating conditions.

'ZERO DEGREE' GRINDING

Users should be aware of the manufacturing capabilities of gear suppliers, as this determines the technological quality of gears supplied by the vendors. For instance, to carry out an asymetrical correction to the gear profile accurately, vendors should be capable of performing "zero degree" grinding. In this, the grinding wheel is parallel to the vertical. Only one point of the grinding wheel is in contact with the gear tooth, so that an asymmetrical curve can be produced along the flank of the tooth, and tooth contact can be ensured. The grinder should be programmed to produce the complex shape of the correction curve.

Mesh and quenching losses for the double helical are spread over half the distance of travel, reducing the distortion amplitude for each helix. Also the helix angles are usually higher in double helical gears, reducing the axial velocity of the pumped air and oil, which also reduces the heat generated. However, the corrections are split and lack the continuous curve created in single helical gears. It is important to recognize that the amount of correction is not as important as producing a correction as accurately as possible. Some manufacturers induce an angle relative to the vertical on the grinding wheel so that more of the grinding wheel is in contact with the gear tooth. This reduces manufacturing time but does not produce the required correction. A few other manufacturers employ form grinders, whose wheels have contours on the cutting face with a mating fit to the desired form. These grinders can grind the loaded flank independently, permitting correction capability in the direction of the lead. However, the correction is not asymmetrical and therefore the manufacturers average the correction as best as possible. While these corrections are reasonably effective, they are not the optimum solutions.

Manufacturers who use form grinders prefer double helical gears for high-speed applications to reduce the complexity of lead correction. But the double helical gear may not be the optimum choice for that application.

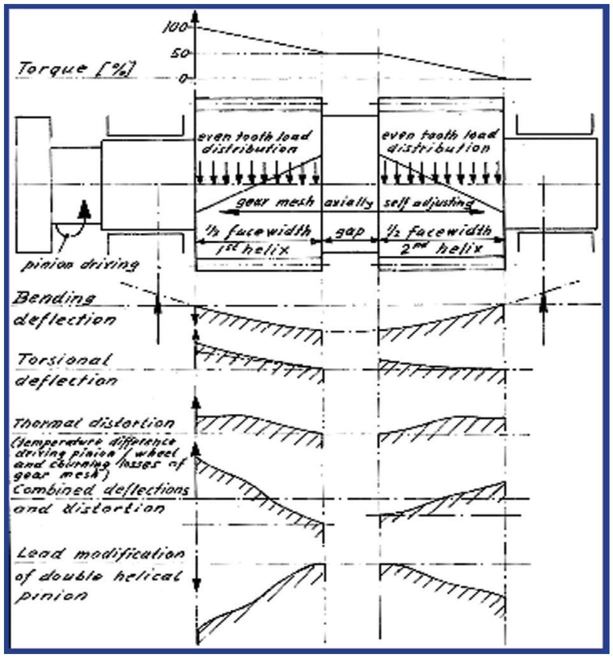


Figure 3: Lead correction is required on a double helical gear (pitch line velocity of 130 m/s) due to bending, torsion and thermal distortion. Experience is required to predict corrections.

If in the field a tooth contact adjustment is found to be necessary, single helical gears provide a simpler means to do so by adjusting a single bearing or housing. This will shift the contact pattern appropriately. In double helical gears, it becomes a matter of judgment to compromise the effect on the two helices.

It is not uncommon to inspect a gear unit after several years of operation only to discover that changes in foundation, bearing or alignment will require a realignment of the gear mesh by the methods described above.

In some cases, compensating for installation problems may require extreme corrections. And in the case of double helical gears, it may not be possible to optimize the load for one helix without unloading the other. Therefore the double helical gears may likely require correcting by regrinding the gearset, whereas in single helical gear units, further adjustment may be facilitated by adjusting a bearing or the housing.

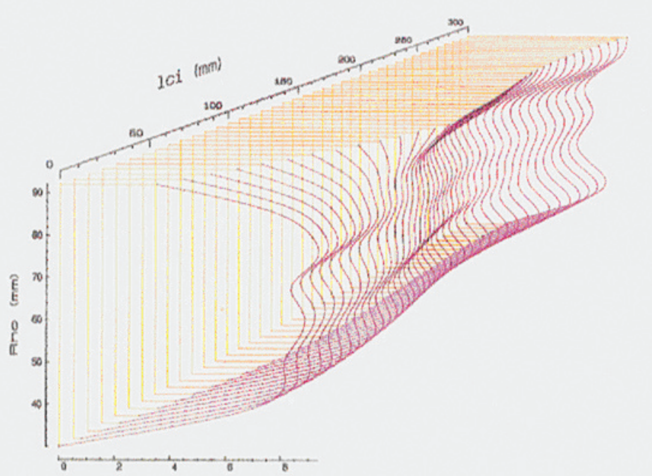


Figure 4: Assymetrical Topological Tooth Flank Curve

Weighing choices

Single helical gears are more suited for mechanical drives in which each application requires a "unique" design for powers, speeds, configurations and environment. For remote, difficult-to-access applications, such as offshore platforms, single helical gears provide easy and reliable means of adjustment in the field. However, there is a price to be paid in efficiency, affecting operating costs.

Double helical gears designed with low transmission errors (AGMA A3 as defined in ANSI/AGMA 2015-2-A06 or ISO 3 as per ANSI/AGMA 1328-2) are the appropriate solution if the gear unit is installed in a well-designed, controlled environment and the gear is a duplicate of prior designs with known speeds, power and layout and where efficiency is a key requirement. Gears for gas turbine-driven generators are prime examples where double helical is the preferred solution. The corrections have been optimized by previous gears, and minimizing power losses is an important requirement.

For single helical gears, axial forces that are developed can be absorbed by a thrust collar. At each side of the pinion, a collar is shrunk on. The inner faces of the collar are ground slightly conical.

The wheel is beveled on both sides to correspond. There is little slip between the collar and the bevel surface on the wheel, and at the pitch circle there is no relative velocity. The conical surfaces form a load-carrying oil film.

Toothing of single helical gears provide a more convenient means to adjust than those of double helical gears. It is easier to adjust two instead of four mating tooth flanks. Tolerances on the tooth form of one continuous tooth can be tightly controlled, which may not be the case with two teeth of different hands of helix and greater total length.

In a double helical rotor set, one of them, usually the larger of the two, is axially fixed and the other is free to move. Thus the latter adjusts itself axially, so that the opposed gear forces of the two gear halves reach equilibrium.

The double helical gear eliminates internal thrust without introducing a thrust bearing, while maintaining a helical design for load sharing and smooth transfer of load from tooth to tooth. However, this style of gear is subject to a mismatch of the helices between the pinion and the gear. In the case of a single helix, the pinion can be corrected with respect to the gear whereas in the case of two helices a compromise must be settled for the left and right-hand helices. This is because mismatch is not necessarily symmetrical but accumulative.

With the double helical gear there is a certain error of the apex formed by the helices, commonly referred to as apex wander that results in an axial runout over one revolution of the rotor. This causes a shuttling of the pinion axially with respect to the gear during operation, producing an axial vibration. The condition is particularly evident during a No Load Full Speed mechanical run test when the pinion is unstable and subject to its gear errors (see API 613 5th para 4.3.2.2.10). Without any load to dampen or stabilize the pinion, the gear's inherent manufacturing errors take over and exhibit themselves as vibration. Hence, the No Load Full Speed mechanical running test can help users evaluate gears effectively.

Old technology used gear elements constructed with softer, through-hardened material, with the pinion somewhat harder than the gear. This results in the pinion "working in" the gear during operation by wearing it in. This process wears down the unevenly loaded surface across the gear face width until even load sharing is achieved. Due to uneven loads, highly loaded and localized areas of the toothing begin to show pitting during initial stages, which can be exacerbated by today's requirements or high sliding velocities (typically 130 m/s).

Current technology universally uses carburized-hardened and ground gears, and, therefore, wearing in of the pinion to gear is not possible. Field adjustment of four mating tooth flanks, compared to two, is always a compromise.

In a single helical gear drive, each gear shaft bears against its respective thrust bearing or thrust collar. The external axial thrust, which acts on the gear shaft under load due to friction in the toothed coupling, cannot cause momentary overloading of one helix as is the case with double helical gears. External thrust has detrimental effects on a double helical gear due to the axial compensating shift produced because of tooth errors.

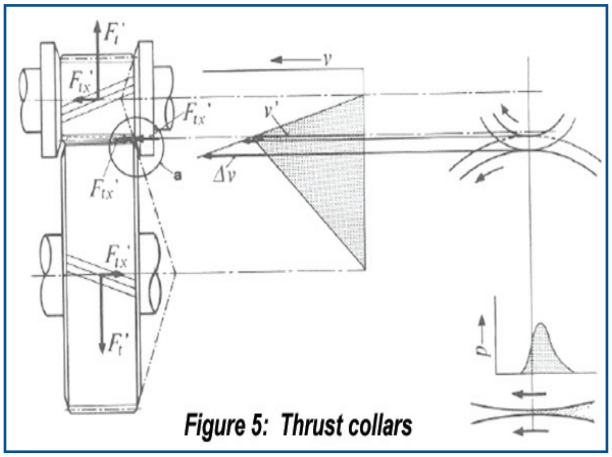


Figure 5: Thrust collars

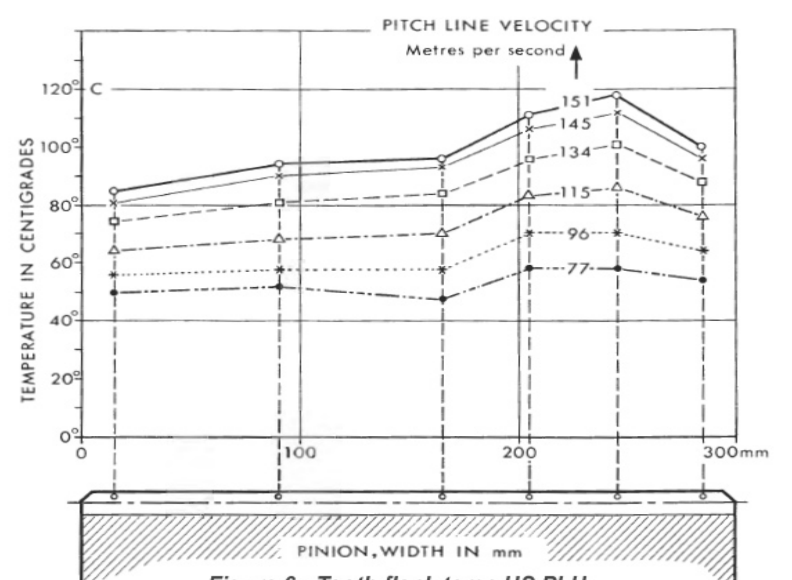


Figure 6: Tooth flank temp US PLU

Double helical gears have a higher overall unit efficiency than single helical gears without thrust collars. This also means lesser lube oil flow, resulting in a smaller lube oil system. Single helical gear units with thrust collars exhibit similar efficiency levels as double helical gears. Lubrication requirements for the thrust collars is relatively small.

Of grooves and spans

No center relief groove is required in single helical gears. Therefore the overall bearing span is shorter compared to double helical gears in which the gap between the two helices contributes to the bearing span. For the same effective face width and speed, the double helical gear will have a lower critical speed, due to its longer bearing span.

About the Author

John B. Amendola is the chairman of the board of Artec Machine Systems (www.artec-machine.com), the exclusive North American agent of Maag Gear. He is an active contributor to AGMA committees.

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Artec Machine Systems is located at: 26 Commerce Drive, North Branford, Connecticut 06471
Telephone: (203) 484-2002; Fax: (203) 488-2969 24-hr Line: (203) 589-6417
Email: sales@artec-machine.com; Website: www.artec-machine.com