Single or double helical, which gear is better?

The question which is better, single or double helical gears is a question without a simple answer.

The earliest drives utilized spur gear teeth. Although modification to the addendum of spur gear teeth can improve the transfer of load from tooth to tooth smoothly, the introduction of a helix angle allows the transfer of load from one tooth to the next at a comparably slower rate. More than one tooth is in contact at any moment with which to share the load is increased, this is known as load sharing. Further modification of the gear tooth form, that is modification of the addendum, increases the contact ratio. This directly relates to smooth and quiet running gears. With the tooth form optimized this increases the tooth contact or bearing area of the gear rotor consequently increasing its surface load carrying capability, however the real gain in tooth strength is achieved by heat treating.

It is not a matter of design as much a matter of application and manufacturing techniques. Gears are subject to manufacturing errors functionally known as transmission error. In addition, the operating environment results in gear teeth which are twisting and bending during engagement. Also in higher pitch line velocity applications, high mesh velocities produce locally higher temperatures as gear teeth slide in and out of mesh. Also there are quenching losses as the oil and air are literally pumped axially along the engaging tooth flanks creating additional heat from the combination of the two. When operating PLV's exceed 100 mps (20,000 fpm) this heat produces notable distortion adding to the mechanical deflections referenced above. For even higher PLV's, around 130 mps this distortion can exceed the mechanical deflections resulting in the single most important segment to correct from the combined effects of all three.

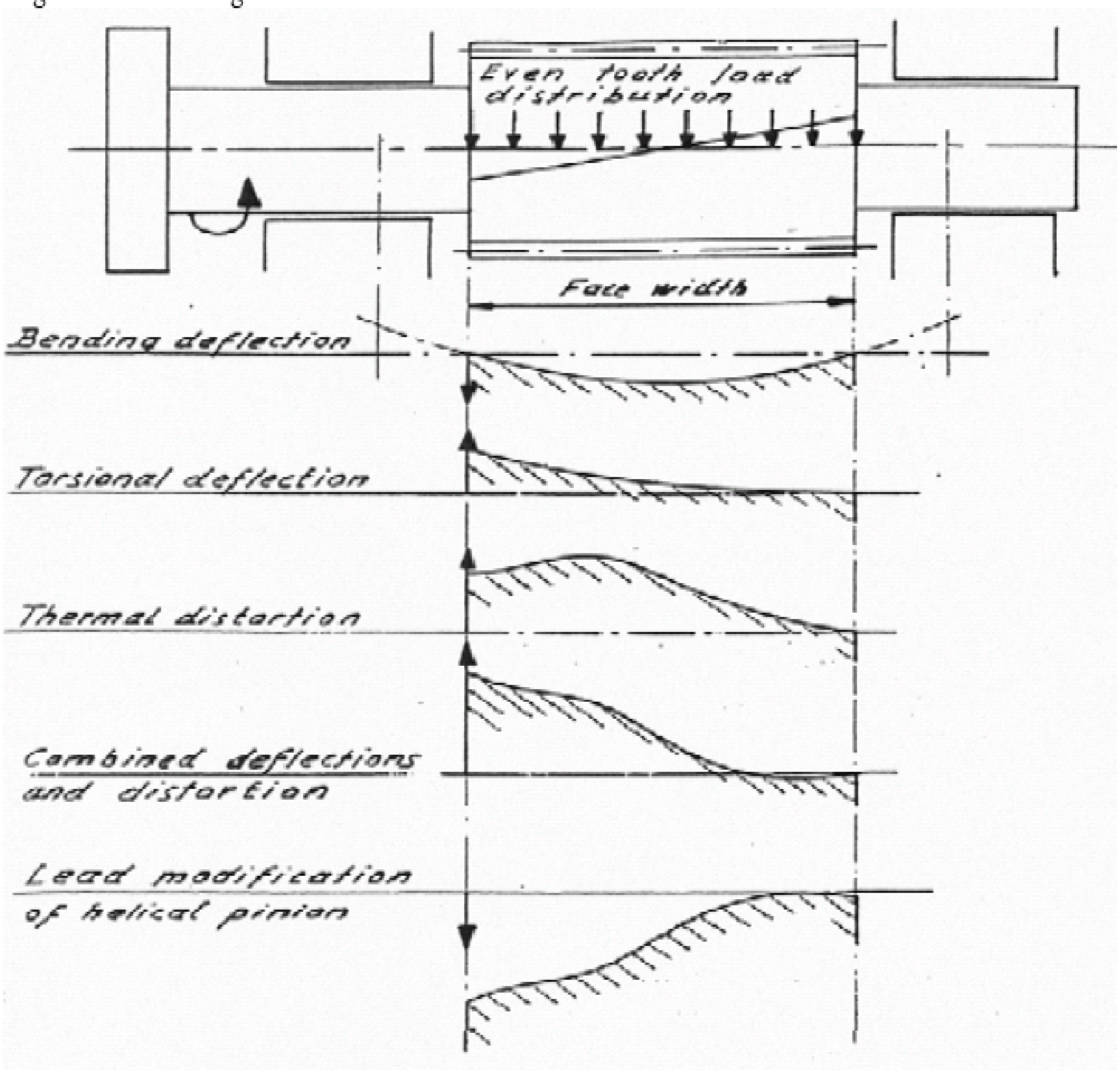
The predicted amounts of mechanical deflections can be calculated fairly accurately whereas the heat distortion developed in high speed gears is not so easy to define. The accumulation of data from past experiences and field results for many gear applications have produced a data base for which the heat distortion of gear teeth can be predicted empirically with some reasonable accuracy. The combined effects can be evaluated to create a lead and profile correction for any gear application to ensure the most even load distribution possible. Experience is needed to predict corrections which will result in even load distribution along the tooth flanks.

The ability to have effective corrections first requires a gearset of high quality. These corrections while critical to avoid local tooth overload are really of a small magnitude. If the transmission errors are high the corrections are "lost" in the total tolerance range.

Corrections for mechanical deflections are not complicated however they are complex when corrections for heat distortion are required. The combination requires special consideration in the grinding technique. The optimized method involves a combined asymmetrical lead correction produced in the final grinding stage of the gearset. To do this with the highest accuracy and the minimum compromise demands use of a grinding machine capable of producing a true asymmetrical topological correction. Please see the following examples of single and double helical gearsets with referenced corrections.

These following diagrams are for reference only and are not dimensioned. Nevertheless the relating magnitude of the deflections and distortions are shown with the required corrections.

Single Helical with high PLV over 130 m/s



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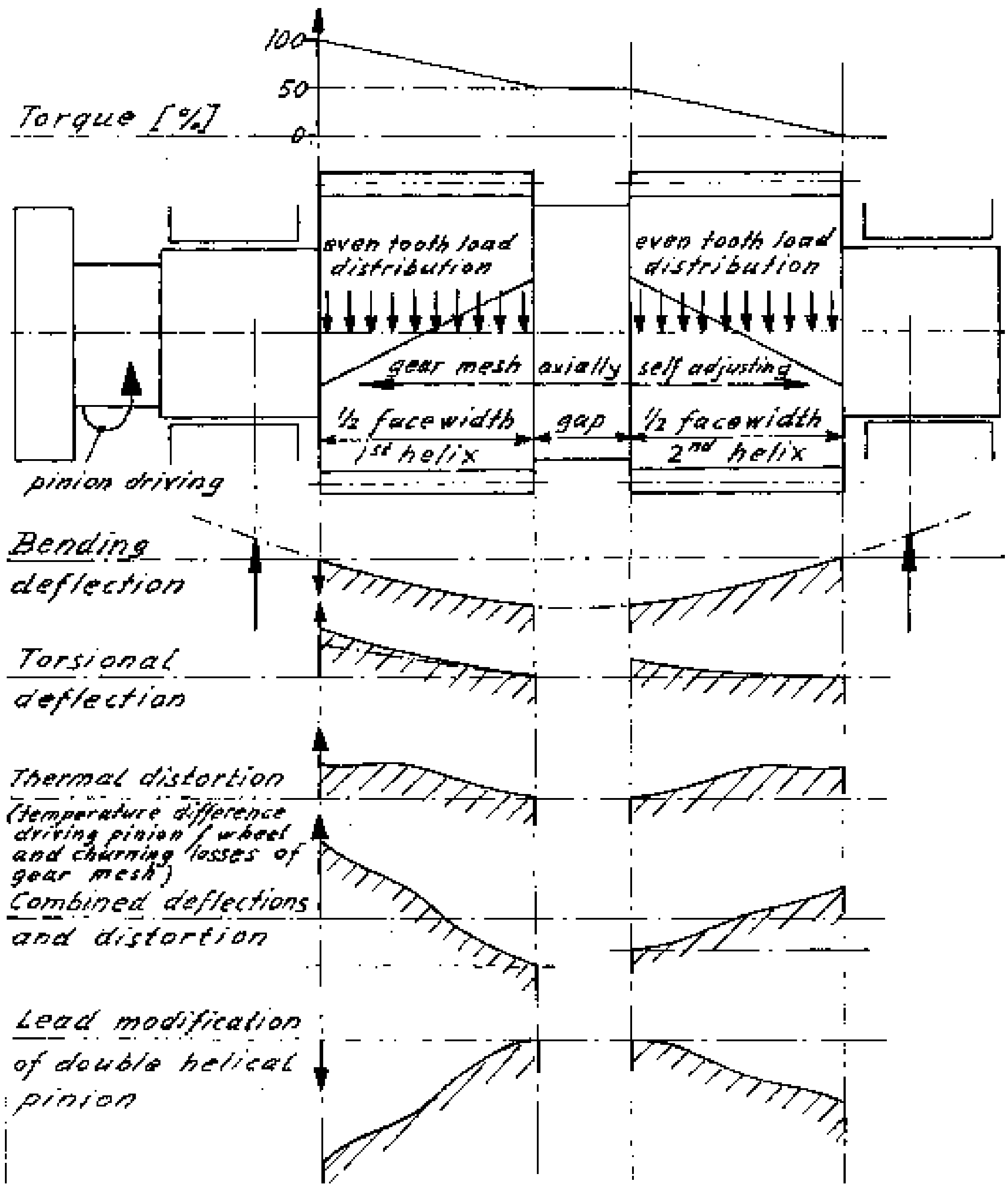
Double Helical Gear with high PLV over 130 m/s



The reader can readily see there are similarities in the mechanical deflections. The double helical gear is a little more complicated because the gap interrupts the continuity of the applied load. Comparison of thermal distortion is quite different. In single helical gears the amount of heat along the flanks result in a single accumulated distortion of greater magnitude.

The mesh and quenching losses for the double helical have half the distance of travel reducing the distortion amplitude for each helix. Also the helix angles are usually higher reducing the axial velocity of the pumped air/oil which also reduces the heat generated by that action. However the corrections are split and lack the continuous curve created by single helical gears.

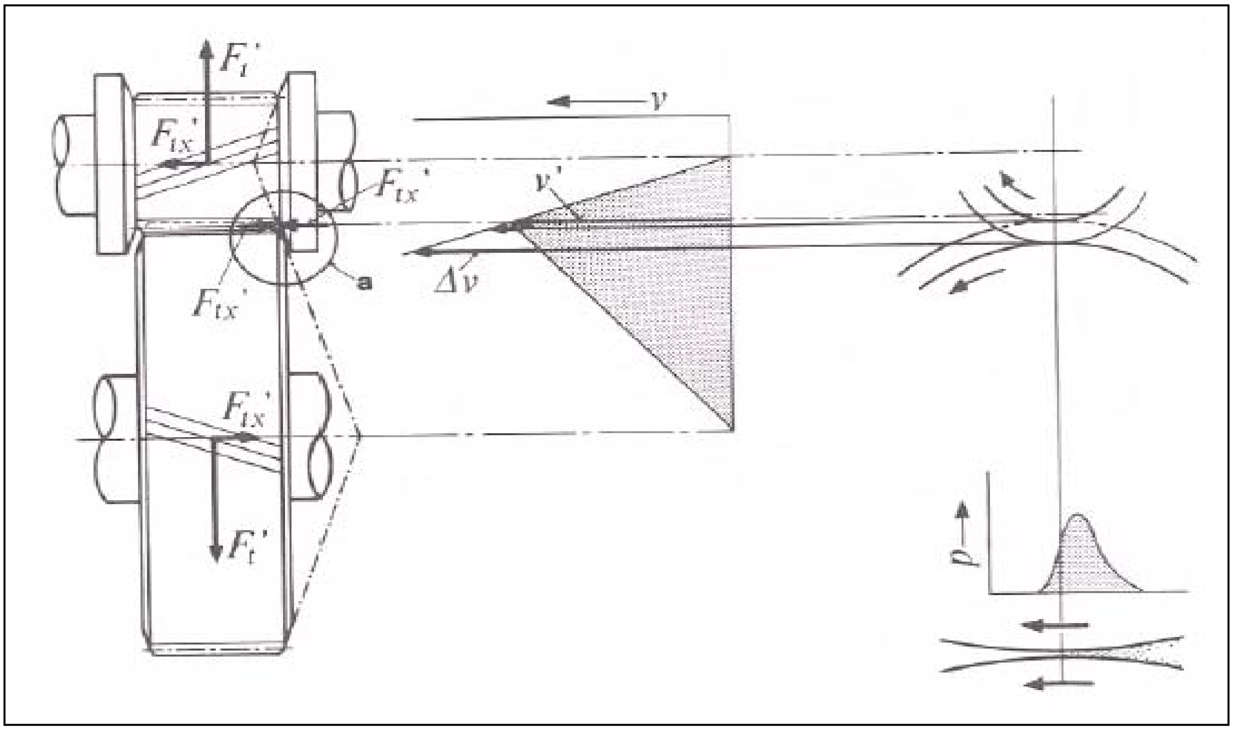
In both cases the optimum correction requires an asymmetrical shape. This can only be done by single flank zero degree point grinding of the gear tooth. Also it requires a grinder that can be programmed to produce the complex shape of the correction curve. Form grinding cannot produce this shape. It is important to recognize that the amount of correction for either single or double helical gears is not as important as producing a correction as accurately as possible.

Among many gear manufacturers form grinding is preferred because of their speed. This reduces grinding time and therefore manufacturing costs. These manufacturers typically prefer using double helical gears for high speed applications to reduce the complexity of the lead correction. Form grinders have a single flank generating mode which permits some correction capability in the direction of the lead. However it is not asymmetrical and therefore they average the correction as best as possible. While this is reasonably effective it is not optimum.

As mentioned above the corrections for thermal distortion have been empirically developed. When a unique application for a gearset requires a new calculation; i.e. speeds, power and layout configuration will sometimes result in a combined correction that may not be as optimum as it should. A field inspection of the mesh alignment is very important. If an adjustment is necessary it is much easier to achieve in a single helical gearset by simply adjusting a single bearing or inducing some rack into the housing. This will shift the contact pattern appropriately. In double helical gears this becomes a matter of judgment to compromise the two helices as best as possible. This becomes limited to the quality of the gears with low transmission error. It is not uncommon to inspect a gear unit after many years of operation only to discover changes in foundation or alignment will require a realignment of the mesh by the methods described above. In compensating for the installation problem if the demand for correction is too extreme it is not possible to optimize the load for one helix without unloading the load of the other in double helical gears. Therefore they can only be truly corrected by regrinding of the gearset whereas in single helical gear units further adjustment can be facilitated by adjustment of a bearing or racking of the housing which will shift the contact pattern in place.

In mechanical drives the "unique" design required for powers, speeds, configuration and environment are ever present making single helical gears more practical. However there is a price in efficiency which increases operating costs, size of lube oil consoles and extra spares for bearings. Where there are remote and difficulty issues to address for unique applications such as offshore platforms, remote and isolated areas of the world, the single helical provides an ease of reliable field adjustment. Double helical gears designed with low transmission errors are a good solution where 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 demands for the highest efficiency is desirable. Gas turbine to generator gears are a prime example where double helical is a preferred solution. The gearset corrections have been optimized by earlier constructed gears of the same requirements and minimum power losses are important in the long term.

If gear efficiency is the only criteria but the simplicity of single helical gears is desired, single helical gears with thrust collars (see below figure) are as efficient as double helical gears without the need for external thrust bearings.



The axial forces developed in a helical gear can be absorbed by a thrust collar. At each side of the pinion, a collar is shrunk on, the inner faces of which are ground slightly conical. The wheel is beveled on both sides to correspond. The relative speed between the collar and the bevel surface on the wheel is low and at the pitch circle is zero. The conical surfaces form a load carrying oil film. Losses are very low. Due to the large radii of curvature the Hertzian stresses are low.

Summary Comparison of Single and Double Helical Gears

- The teeth of single helical gears are much easier to adjust than those of double-helical gears. That is, it is easier to adjust two tooth flanks instead of four.
- It is easier to control the form of one continuous tooth than the forms of two teeth of different hands of helix and greater total length.
- When considering a double helical rotor set, one of them, usually the larger of the two, is axially fixed and the other axially free. Thus the latter adjusts itself axially so that the axially opposed gear forces of the two gear halves reach equilibrium.
- The double helical gear eliminates internal thrust without introducing a thrust bearing while still maintaining a helical design for load sharing and smooth transfer of load from tooth to tooth. However, this style 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 at best between left and right hand helices because mismatch is not necessarily symmetrical but is accumulative.
- With the double helical gear there is a certain error of the apex formed by the helices commonly referred to as apex wander resulting 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. It is particularly evident during a no load full speed mechanical run test. Under these no load conditions the pinion is most unstable and is subject to its gear errors. Without any load to dampen or stabilize the pinion, its own inherent manufacturing errors take over and exhibit themselves as a vibration. For this reason, the no load full speed mechanical running test is a better test than one in which a small load is imposed.
- Older technology was adapted to the advantages of double helical gears. These gears were usually constructed of softer through hardened material with the pinion usually 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 resulting from the mismatch created by the mechanical deformations until even load sharing across the gear face width is achieved. Since the load can be quite uneven, oftentimes highly loaded localized areas of the toothing begin to show some initial pitting. Due to the localized thermal deformation created by the higher sliding velocities of high-speed gears this pitting could become quite severe. However, as the pinion and gear wear in, this condition slowly heals itself and the gearset develops a high degree of polish. Early day manufactured double helical turbo-gears ran at lower speeds than what is demanded of today’s highly loaded designs and so this condition was not serious. Also, because of slower speed conditions, the shuttling of the pinion due to apex runout was not a serious concern and this too worked itself out under load as the gearset wore in.
- In a single helical gear drive each gear shaft is always against the thrust bearing. The external axial thrust that acts on the gear shaft under load due to the friction in the toothed coupling cannot cause momentary overloading of one helix as is the case with double helical gears. Needless to say, an external thrust can have detrimental effects on a double helical gear in connection with axial compensating shift due to tooth errors.

- Because no center relief groove is required, the overall bearing span in a single helical gear is shorter, thus giving less elastic deformations under load resulting also in higher critical speed.
- Considering the elimination of the thrust bearing, the double helical gear will operate with higher overall gear unit efficiency than single helical gears. This also means lesser lube oil flow resulting in a smaller lube oil system. Single helical gear units with thrust collars have the same as double helical gears. Lubrication requirements for the thrust collars is relatively small.

Consideration	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 couplings 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 share loading
Axial vibrations	None	Axial vibrations brought on due to possible asymmetrical pitch errors
Gear tooth contact pattern	Possible with one adjustable bearing or casing adjustment	Very limited possibilities may have to compromise, regrinding maybe necessary
Gear tooth modifications	good control even for asymmetrical corrections	Asymmetrical on two helices. Requires more manufacturing control to produce the same quality
transmission errors	low	more than single helical, more noise is typical