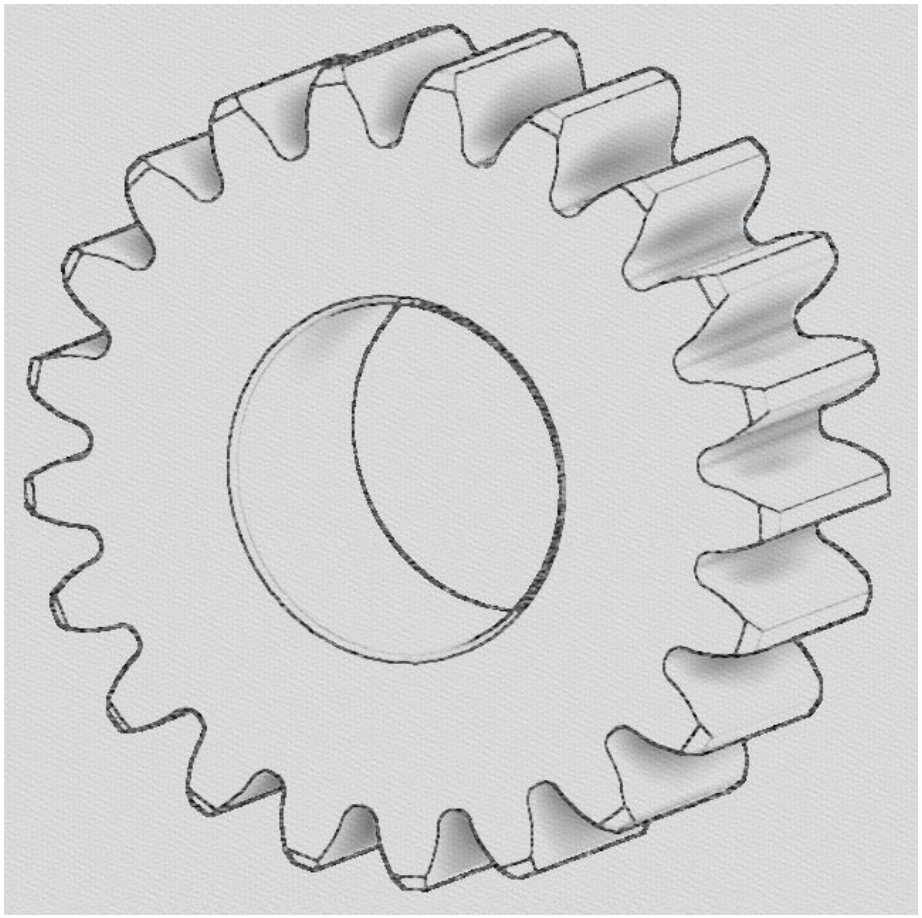
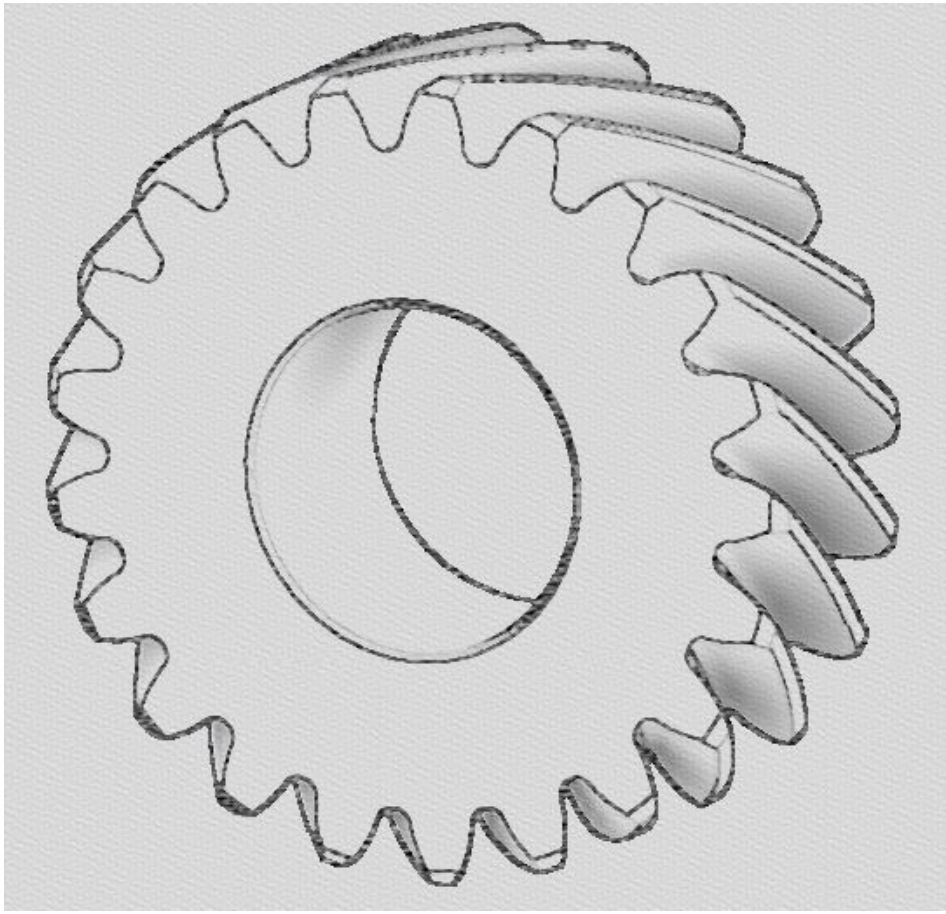


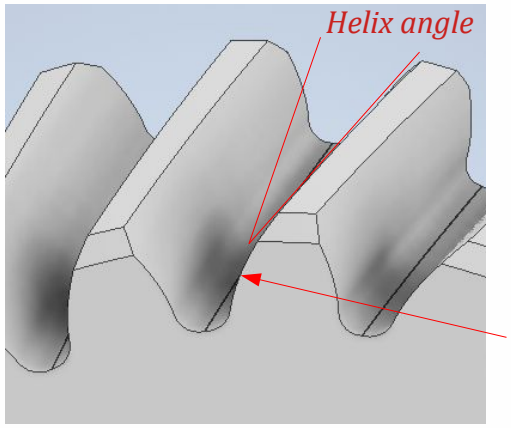


Straight cut gear or helical gear, which one is the best ?

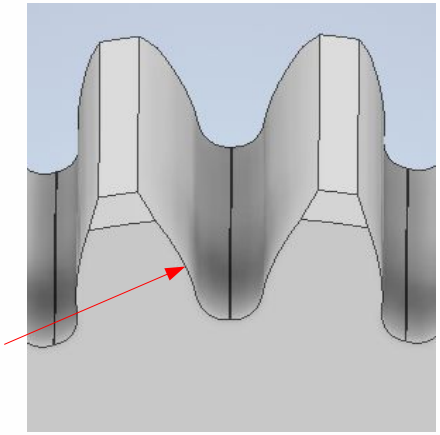
Abstract:
Every passionate about mechanical engineering has already seen that car gearboxes are made with helical gears whereas motorbike gearboxes are made with straight cut gears. In this paper, we will compare both geometries in order to understand why engineers are using one or the other depending on the application. There is no need to be a gear specialist to read and understand this paper as only the basics are explained. Happy reading!

BASIC GEOMETRY

First of all, let's compare the basic gear tooth geometry:



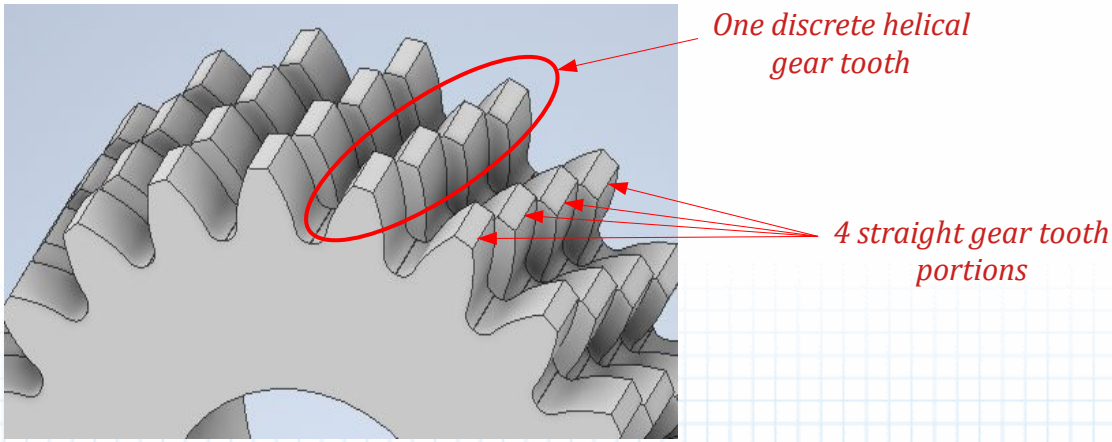
Helical gear teeth (20° helix angle)



Straight gear teeth

If you do a section of both gears, you will find almost the same involute profile. The difference is the location of this profile along the width of the gear.

There is an easy way to imagine a helical gear using a "discrete" representation. Let's replace the helical gear by the gear below.



Discrete helical gear - 4 portions

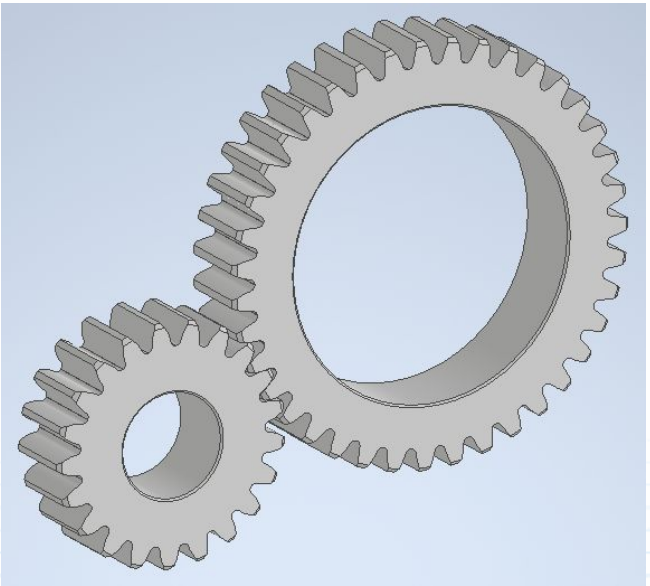
Let's name this gear "discrete helical gear". **A helical gear is basically a discrete helical gear but with an infinite number of portions so the behaviour between both geometries is similar**. This comparison is useful to understand some concepts that we will discuss later.

COMPARISON CRITERIA

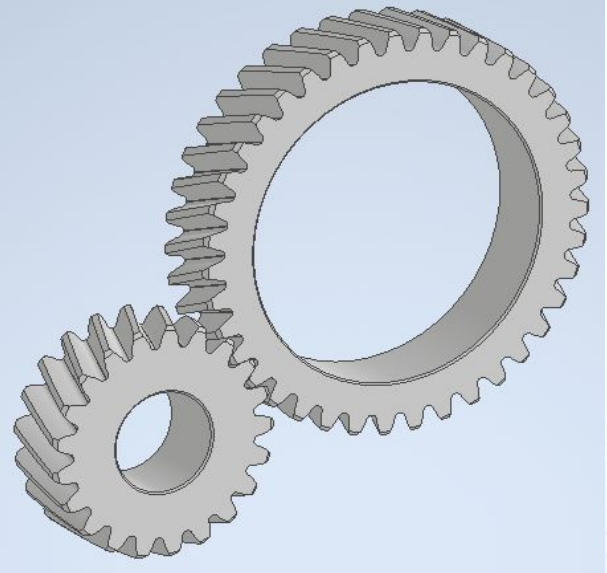
If we want to compare both geometries, we need to choose some comparison criteria. We will consider the following ones:

- Mechanical strength
- Noise and vibrations
- Bearing loads
- Efficiency

We could have used more criteria but those ones are the most relevant. To compare the performances, we are going to use two pairs of gears that have almost the same dimensions (width, diameters, tooth proportions) and the same material. The only difference between both meshes will be the helix angle. These are the gear pairs chosen:



Straight gear pair - 21x39 - transverse module 2.5mm



Helical gear pair - 21x39 - transverse module 2.5 mm – 20° Helix angle

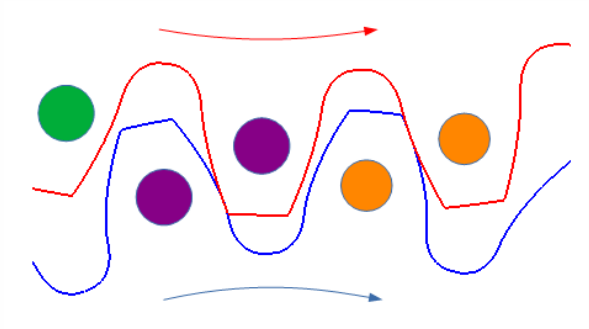
They could be a 2nd speed gear pair of a car manual gearbox.

MECHANICAL STRENGTH

In gear engineering, there are two main failure modes which are **tooth root failure** and **flank failure**. Even if gear failure modes can be very complicated and very different, **the origin of failure is almost always related to the load (force) applied to the teeth**. Therefore, to compare helical and straight gears, let's see if there is a difference regarding the load applied to the teeth.

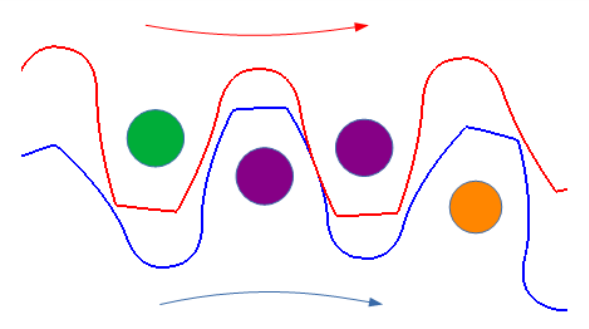
Teeth load in a straight cut gear

In a straight cut gear the load transmitted between a pair of teeth that are meshing together is **not constant along a mesh period**. To understand this, let's follow the **purple** teeth pair over a mesh period (the blue gear is driving):



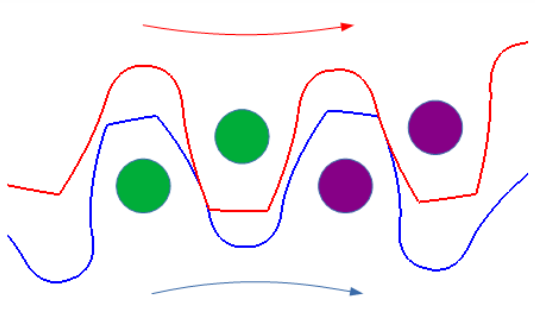
Beginning of the mesh between purple teeth pair.

Load shared between purple and orange teeth pairs.



Middle of the mesh between purple teeth pair.

Load only transmitted by purple - No contact between orange and green teeth pairs



End of mesh between purple teeth pair.

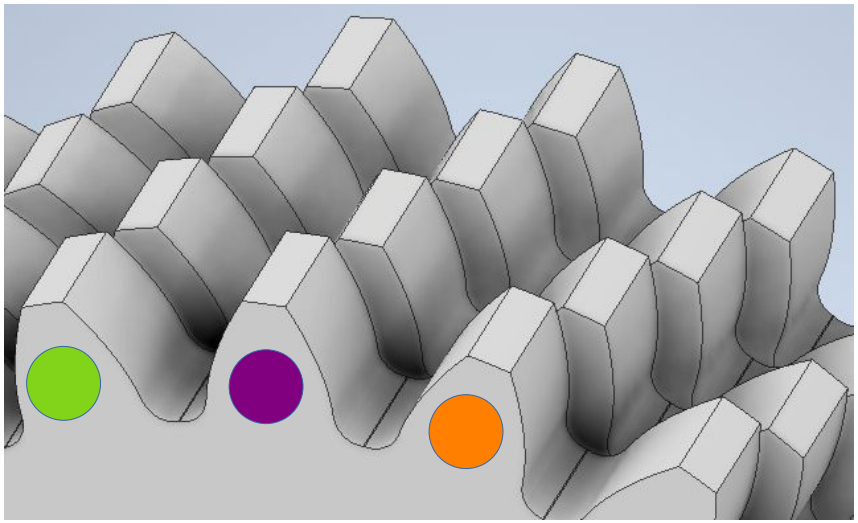
Load shared between purple and green teeth pairs

It is obvious that the load carried by the purple teeth pair is changing during a mesh period. It is basically doubled around the middle of the mesh period because only the purple teeth pair is carrying the load.

This means that, in a straight cut gear, there is always an amount of time during which only one pair of teeth transmits the entire load.

Teeth load in a Helical gear

The contact in a helical gear is different. To explain it, we use the discrete helical gear.



Each portion of the tooth is not at the same moment of the mesh period – Ring gear not represented

Each portion of the purple tooth behaves exactly the same as a straight cut gear. However, those portions are not at the same moment of the mesh period. Whichever the moment during the mesh period, there is always at least one portion of the purple tooth which shares the load with another teeth pair portion (orange or green pairs).

Therefore, in a well designed helical gear, the entire load is never carried by only one teeth pair whenever during the mesh period. Moreover, the more the helix angle, the more load shared between teeth.

Conclusion

Helical gears are stronger than straight cut gears because the maximum load per tooth is lower. Back to our gear pairs, the helical one can transmit roughly **30% more torque** than the straight one.

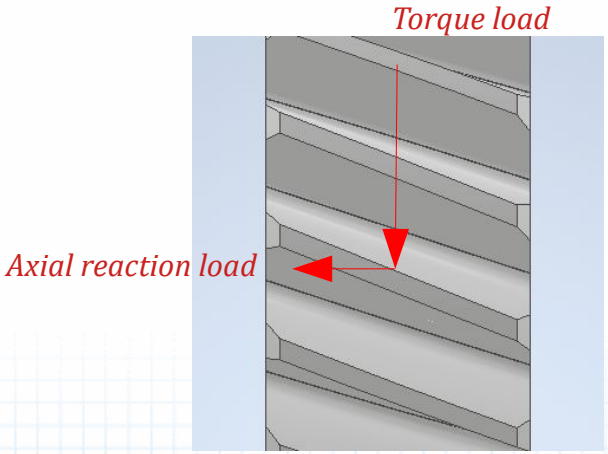
NOISE AND VIBRATIONS

Here again, there is a big difference between straight and helical gears. We have said that, on straight cut gears, the load is doubled at the middle of the mesh period. Now imagine that the gear is rotating at 4000 rpm, it means that the load is doubled 1400 times in a second for a 21 teeth gear. In our example, at moderate torque, this load varies from 400kg to 800kg and the mesh period is less than 1ms. Basically it acts like a hammer knocking a teeth pair every 1ms from 400 kg to 800kg force. This leads to massive vibrations which are then converted to noise by the housing.

On the contrary, we have seen that the load variation is much smoother on a helical gear because the load is shared with other teeth, therefore the vibrations are much lower. **Here again the helical gear is better.**

BEARING LOADS

Following what we said so far, we could think that we should use helical gear everywhere, every time. However, there is a major drawback of using helical gears. Indeed, because of the helix angle, the contact between teeth leads to an axial load.

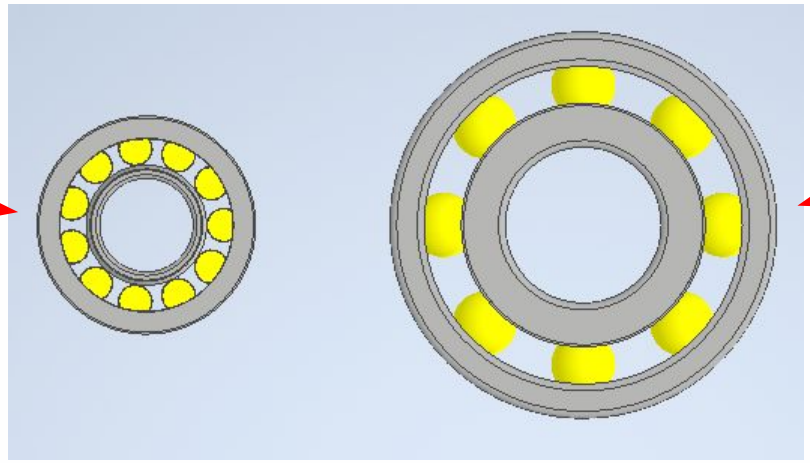


Pinion gear - 20° Helix angle

The helix angle leads to an axial reaction load. In our example, with a torque load of 800 kg, the axial reaction is 300 kg.
The bigger the helix angle, the bigger the axial load.

This axial reaction load has to be handled by the bearings and the housing so they have to be designed according to this. Basically, the bearings have to be bigger and the housing thicker. This is a big issue because the gearbox will be bigger and heavier.

Here is the bearing size comparison in our example. Because there is only a torque load in a straight cut gear, we can use a roller bearing. However, because it has to handle both torque and axial load, the bearing need to be a ball bearing in a helical gear train.



Bearing size comparison – Same torque on the gear train

The torque carried by both meshes is the same but the size of the bearings is much bigger for the helical gear. **Regarding bearing load, the straight cut gear is better.**

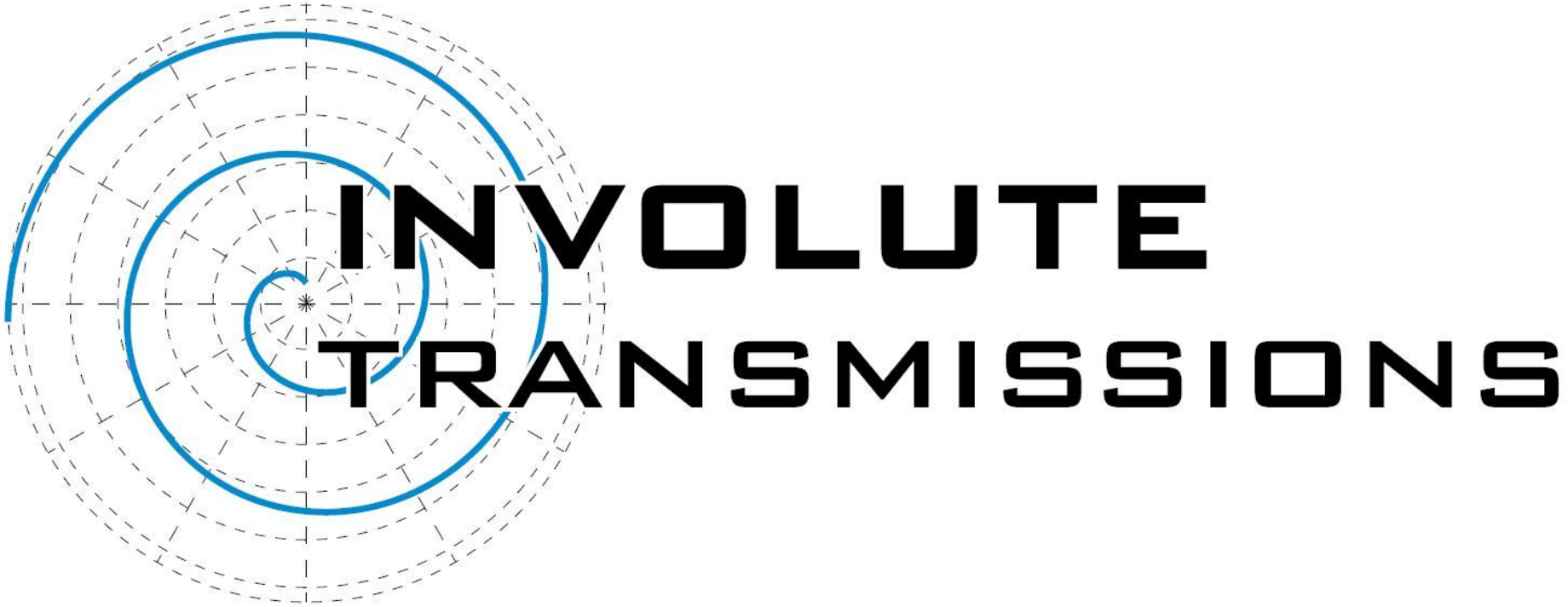
EFFICIENCY

The mesh efficiency is very similar between helical and straight cut gears. But if we look at the complete gearbox efficiency, the power losses in the bearings will be bigger with helical gear train because the bearings are bigger and the bearing loads are bigger too.
At the end, we can say that straight cut gear train efficiency will be better especially for high speed gearboxes.

WHICH ONE IS BETTER?

None is better than the other. It will depend on the application. **If you are looking for low vibrations, low noise, and high tooth strength, helical gears are better. If you are looking for low size, low mass, and efficiency, straight cut gears are better.** To sum up, helical gears can handle the high torque of passenger car Diesel engines while being quiet. On the contrary, straight cut gears allow for small and light gearboxes in motorbikes.

Written by Lionel Bauduin on behalf of:



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