Worm Gear - Helical Wheel Pair with Cylindrical Worm and Worm Gear-Helical Wheel Pair with Enveloping Worm.

Remarks

At times customers ask us why we don't substitute the normal worm gear with cylindrical worm with the corresponding enveloping worm (i. e. double envelope).

We advise against this solution on the basis of our own experience and we remark that in Europe and Japan the solution of the worm gear with cylindrical screw is the preferred one.

Without too many technicalities, we put forward some suggestions.

Double Envelope Worms

The special shape of the worm gear gives a theoretical contact of 3 - 5 teeth. This should provide a better behaviour when sudden load variations occur: in practice this advantage is not real because of difficulties in manufacture and assembly (fit).

To correctly fit an enveloping worm one needs to align correctly both the median axis of the wheel and the axis of the worm but, and this is even more important, **the median axis of the worm and the axis of the wheel.** One needs specific and costly equipment to correctly fit enveloping worm pairs: in practice the theoretical advantage of mating on more teeth is not attained.

A perfect lining up is required because enveloping worms suffer from errors in manufacture and fitting. Misalignments create limited zones of anomalous mating on which the load is concentrated and therefore there is the risk of pitting and abrasions on the wheel.

At any rate the mating area between wheel and enveloping worm extends radially for a small portion of the width of the wheel. As a consequence of this elongated shape, the difference between the sliding speeds of the upper and lower areas of the mating zone is high: rubbing increases with reduced output (Fig. 1).

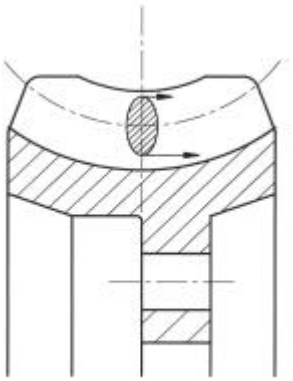

Fig. 1

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As seen from the manufacturer's point of view, materials mating is the consequence of technological limits: quite seldom it is possible to grind enveloping worm gears.
There is a limit in the use of hardened steels and in the lack of specialized equipment. The use of tempered and tempered steels causes high degrees of wear in the screw at high reduction ratios.

The surfaces cannot be ground and therefore the finishing of the tooth is obtained with a tool and by polishing. At any rate the surface presents a high level of roughness and the profile is not so precise.

A reduced tangential backlash is obtained through specific geometry and specialized workmanship.

Cylindrical Worm Gears

In the worm-wheel sets with cylindrical wheel, there are fewer teeth engaged at the same time but the contact area for each tooth is higher.
If we add up all mating areas at the same time, we remark that the sum is higher than the one of a corresponding enveloping worm gear.

The mating areas are located in the zone corresponding to the median diameter of the wheel and interest almost the full width of the tooth. The sliding speeds are identical on the borders of the mating zones and the resulting geometry creates a "hollow area" which transports lubricant into the mating area and creates a "mixed" or hydrodynamic friction (Fig. 2).

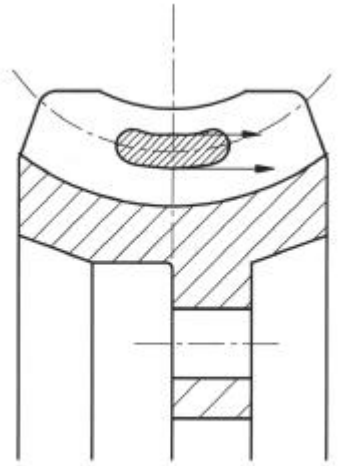

Fig. 2

In these conditions the worm gears with cylindrical screw work with a high dynamic output and with reduced ratios can be used also when gearing up.

The cylindrical screws can be easily ground and several machines are manufactured with this purpose. **The finish of the surface of the thread can be supplied with a roughness Ra=0,4.**

The material used for the worm gear is usually hardened steel with hardness Hrc 58 - 60: **the wheel is the weakest element.**

A more precise machining produces a more precise mating. With standard processes and limited costs it is possible to have worm-wheel couplings with tangential backlash of a few hundreds of a mm.

In the fitting process the only important adjustment is between the median axis of the wheel and the axis of the worm. The contact is controlled by means of a marking compound: **at the point of correct adjustment the mark must correspond to the mark on the certificate supplied by the manufacturer.**

The wheels of the worm gears are cut with hobs, which have a diameter slightly larger than the diameter of the wheel. Therefore they accept manufacturing errors without problems. In case of misalignments, these are compensated by the setting, which is higher than in the enveloping worm gears.

Wear of the cylindrical worm gears can be checked without total disassembly: one only needs to verify the angle backlash on the screw or on the wheel with the data supplied by the manufacturer.

Trade Consequences

Enveloping Worm Gears

The complexity in manufacture of these pairs requires long production times. The time required to cut the teeth and to control them are higher than when manufacturing worm gears with cylindrical worm. By consequence the costs go up for identical performance. Also the delivery time is longer than when ordering cylindrical worms: there are fewer manufacturers and there is no standard production, with the exception of North American factories.

There is also the risk that the machines, on which the enveloping worm gear is assembled, may stop for some time if the worm gear is not kept in stock. In addition there is the danger to have only one supplier.

To fit enveloping worm gears it is necessary to revert to specialize labour.

Conclusions

There is not much experience on the use of enveloping worms. The relevant design formulas are approximate and there is a limited number of working cases on which draftsmen can base calculations.

The worm gears with cylindrical worm and helical wheel are widely employed and therefore the design and the formula are based on a larger number of sets in use.
They are manufactured with ease and therefore their cost is low. The technology of the manufacturing process is often updated and new production machinery is developed.
The wheels are easily cut with the same tools used for cylindrical gears.

We think that the limited interest towards enveloping worm gears will not bring about a technical evolution (design and machines) comparable to the one of the worm gears with cylindrical worms.

A clear indication is the fact that the manufacturers of worm gears and reducers use only worm gears with helicoidal wheel and cylindrical worm.

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