Design of Machines and Structures, Vol. 2, No. 1 (2012), pp. 5–14.
https://doi.org/10.32972/dms.2012.001

HEATING BEHAVIOUR OF SMALL PLASTIC GEARS

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Plastic gears are used in many areas of life. Designing and installing these types of gears often needs physical post-control due to the deficiency of the relevant standards and work-helps. In order to have real results by the control, we must use a kind of testing equipment, which is able to simulate exactly the stress as well as the typical problems. To be able to compile the right tests we must learn the types of these problems. Some of problems will be introduced in this paper.

1. Introduction

Heating of plastic gears is an important problem because the strength parameters deterioration of most base materials to be concerned is faster than that of steel gears. In classical design the main reason of heating is the friction between the teeth surfaces. In some design method the heating coming from the internal material friction is also taken into consideration but they cannot be used or only in a limited matter for small size plastic gears. In case of plastic gears it is especially important due to the material deformation induced by the friction caused heating. In this paper some characteristic problems are shown, which should be expediently taken into regard of design and control of such kind of gears.

Definitions:

- Small gears:
  Module < 1 mm (precision engineering, DIN 58405)
  Characteristic external dimension < 50 mm
- Micro gears:
  Module < 0,2 mm (VDI micro gears)
  Characteristic external dimension < 20 mm

2. Limitations of design methods

Overviewed the often used design methods for small size plastic gears and the problems of those methods (*Figure 1–5.*) [1.], it can be seen that from the four basic cases in three, the acceptable accurate determination of the heat process is not possible as a part of the design according to either the complexity and cost demand or there are no methods or enough data for doing the calculation. In use of classical design methods the standards and offers to be concerned can be applied in larger size ranges however, in case of smaller sizes, especially for micro driven-gear there are no documents. So, it is generally true, that in case of small size and micro driven-gear equipped drives the heating should be controlled by experiments.

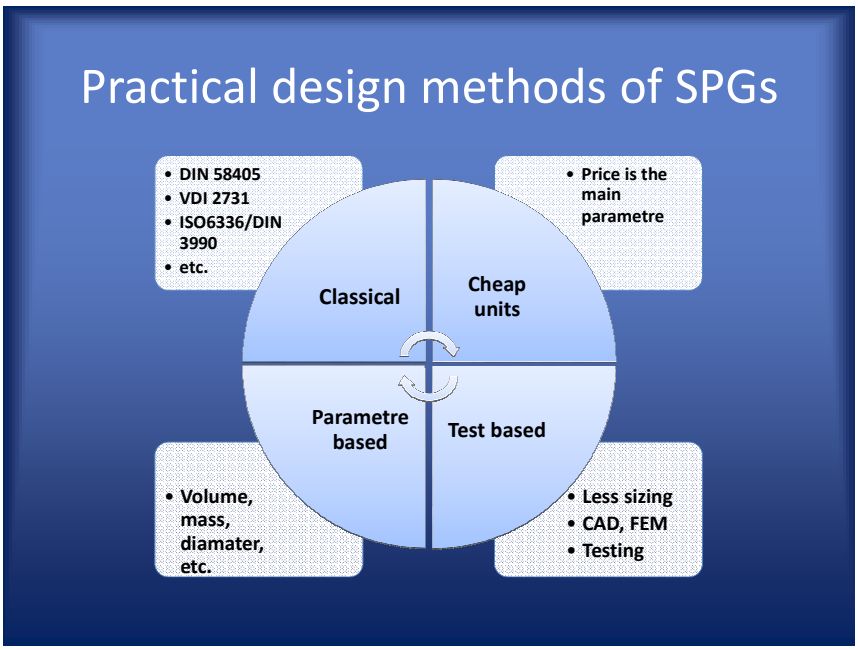


Figure 1.

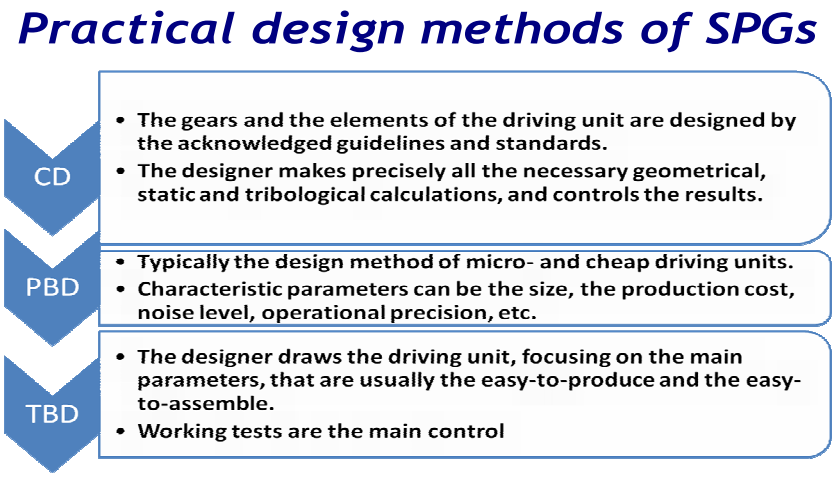


Figure 2.

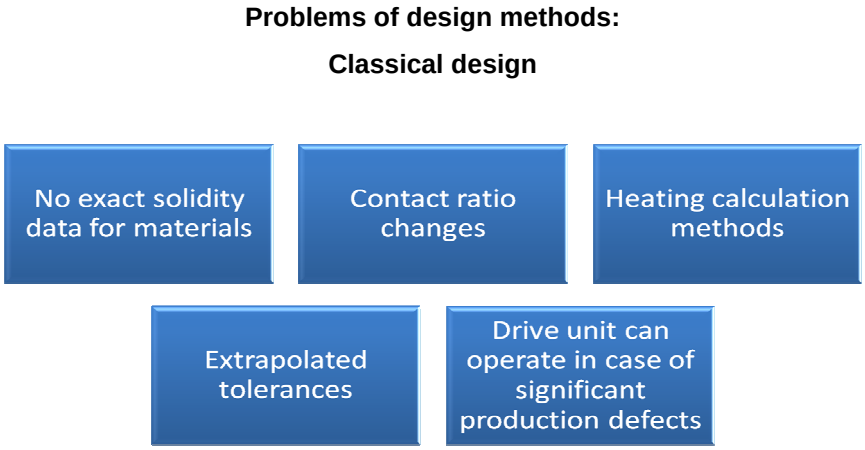


Figure 3.

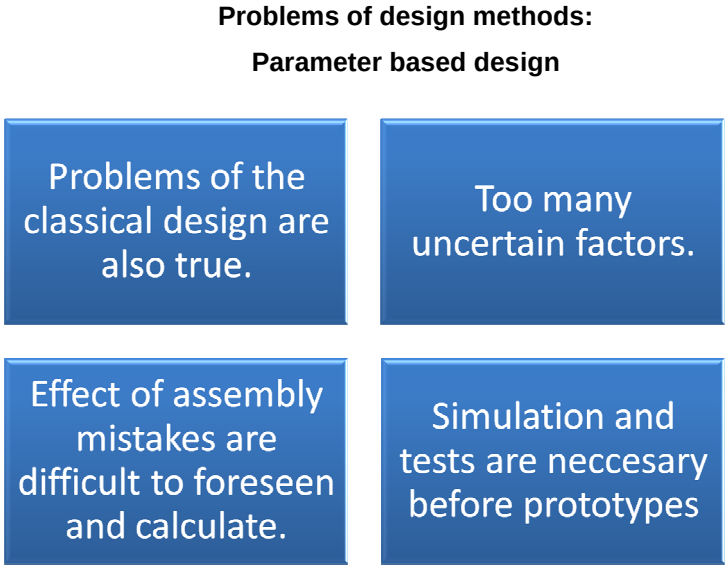


Figure 4.

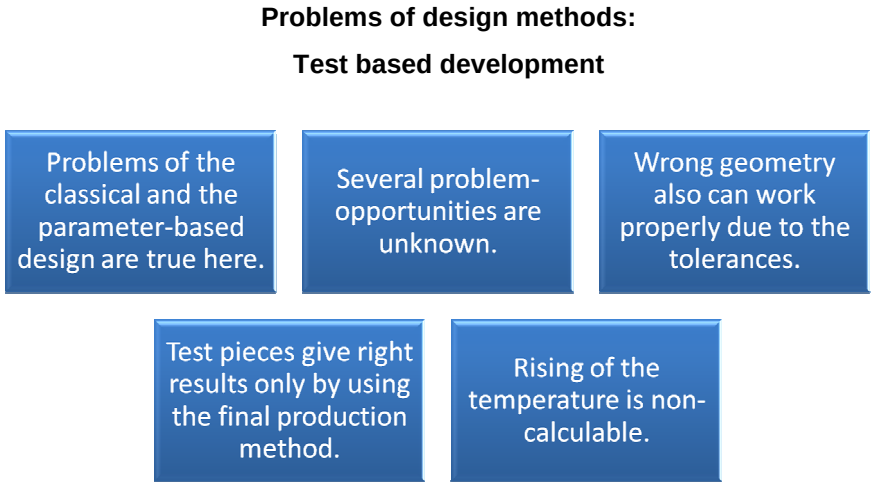


Figure 5.

In heating of plastic gears the deformation due to loading and the re-deformation due to unloading have an important role. This elastic deformation is always accompanied by internal friction. This kind of heating can be almost totally eliminated by determination of the strength requirements however, the system elements do not satisfy all the time the strength requirements in case of parameter based design, test-based development or design of cheap units. In such kind of situation only on base of element tests or knowledge of previous test results can be judged whether the strength of the gears is suitable or not.

3. Critical design positions from point of heating

The gear deformation can be induced more factors along the non-suitable strength property. For instance over-loading, non-optimal linkage of teeth and abnormal contact of surfaces, which have not been designed for that. The heating can be reduced in these cases as well by well selected lubrication. However, it should be taken into regard, that in the size range under investigation the characteristic procedure is the lifespan lubrication and the reinforced cooling of the lubricant never can be proceeded in practice.

3.1. The over-loading

The small size units involving driving gears often should be built in together with the electronic engine, which assures the propulsion. The designing possibilities are reduced due to the generally limited assortment of small engines and the power assortment scale is increased as much as by 50% steps. In micrometres the scaling is more robust. It can be easily happened, that only significantly higher power engine is at service, so the protective system for the drive cannot be designed neither at the power in way nor the counter-driven gear sides. So the increase of loading on the driven out-side it overloads the drive. In small measure the pollution of the moved structure on the driven out-side might be enough. This

is an unambiguous situation. The problem can be occurred if not the true conclusions are formulated in case of the damaged drive under investigation.

3.2. Geometrical faults of the gear-drive house and mounting errors

The cheap drives are generally built into the die casted houses. For reduction of costs the houses are generally made from more pieces and for the fastening of the house pieces to each other a few screw bonding is applied. Generally snap pits are used. The bearing axles and often the axles themselves are manufactured by using the same materials. Additional problem, that the assembly timing of such units is generally short. If the tools at service are not suitable then the probability of errors is higher.

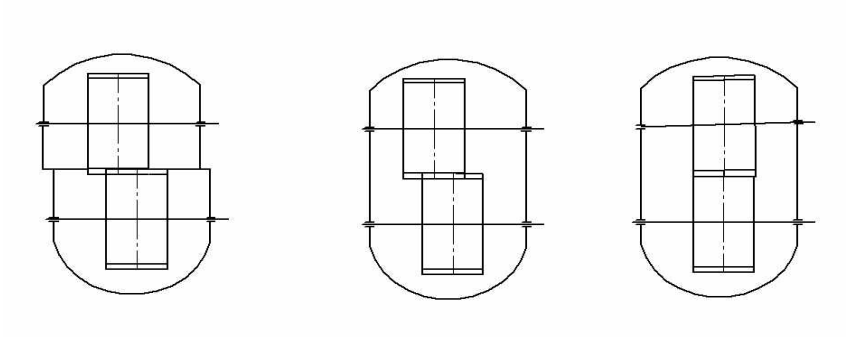


Figure 6. Bad drives

In *Figure 6.* there are examples for three typical problems. According to constructional reason not rare cross-spaced houses are used. The problem shown in the left side can be reason of either a mounting or manufacturing fault. The fault can be seen in the middle is an often experienced situation, namely the gear has no axial direction shoulder, they are mounted by extrusion to the steel axle and so the force transmission is assured by closed fitting. In this case the gear has been slipped on the axle due to assembly failure. On the right side the bearings are made with the house by one piece. If the tolerance ranges are prescribed badly then the distances of the bearings support can be relevantly different. In all of the three cases the loading is transferred on a smaller surface from one gear to the other then it would be necessary.

3.3. Incorrect tolerance determination of axle distances

In the small and micro ranges there are no standard tolerances [6], [7]. The tolerances can be prescribed by extrapolation of the ones valid in the larger ranges. Problems, connected with inconvenient selection of tolerances can be seen in *Figure 7.*

In situation of drafts 1 and 3 the axle distances are too big. In this case the bending on the tooth root is bigger than the allowable, and teeth jumping over might be occurred. In the draft 2 the axle distance is too short; one of the addendum circles reaches down into the dedendum circle of the other one, following deformation of teeth and gear.

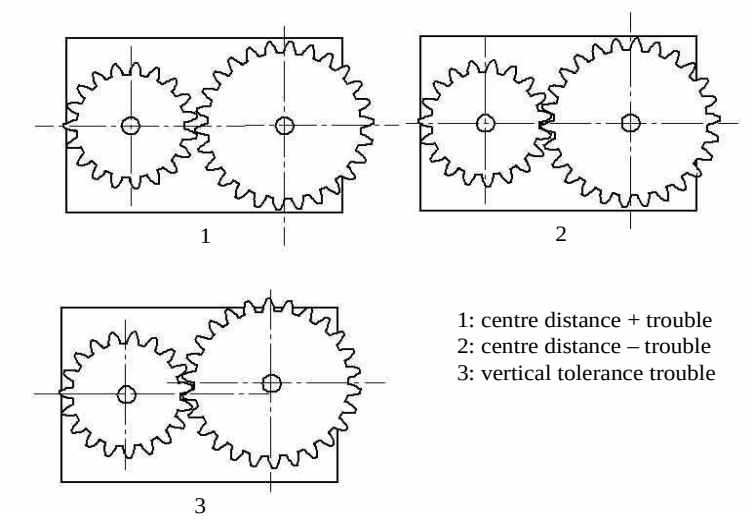


Figure 7. Centre distance troubles

4. Special design cases

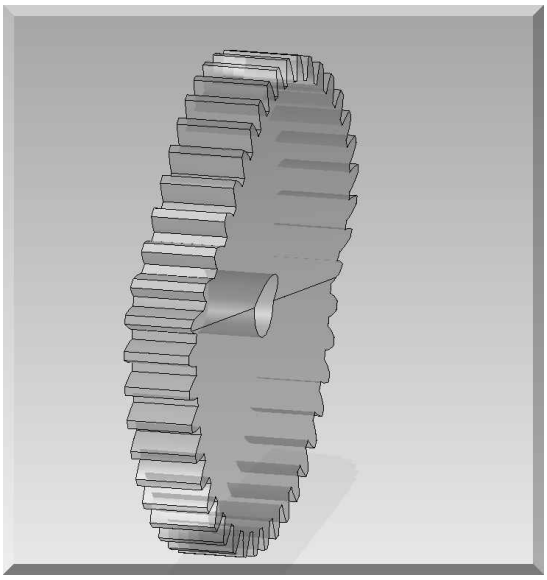


Figure 8. Narrow wheel body deformation at parameter based design

If the space is limited, so the wideness of the gear is small there might be deformation of the wheel body due to over-loading and axle distance failure. In this case the total wheel body is over-heated (*Figure 8.; Figure 9.*).

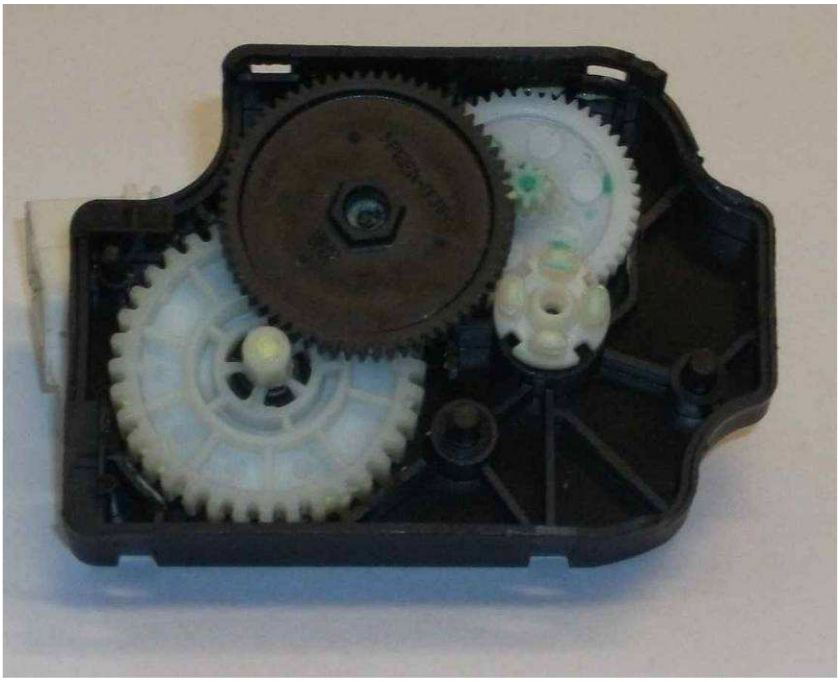


Figure 9. Thin wheel in a drive unit, with fibre-reinforcement reducing the deformation

In case of parameter based design due to geometrical limitations the small diameter gears body will be thin (*Figure 10.*). This kind of gears is generally fixed to the axle by cementation but the use of sintered joins is also not rare [5]. If the axle distance is too big, then not the tooth root deforms but the ribbon like gear body that is the teeth are diverged. If the axle distance is too small, then the head ribbon pushes the small gear teeth interval spaces so it is again the gear body that will be deformed. In this case the deformation can be occurred due to the over loading too.

Special loading state can be occurred in small tool machines and purpose oriented facilities. In *Figure 11.* a screw nail is wreathed by machine into chipboard. The hardness of the different structures is also different, so during the wreath the loading is also varying. For the loading variation an example is given by the diagram. The time of over-loading is very short and just only one-two teeth are involved.

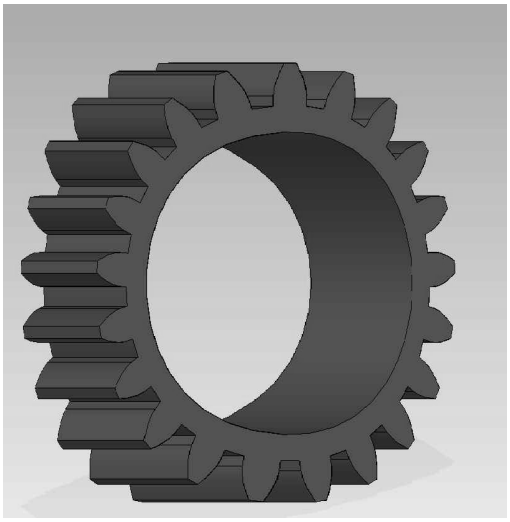


Figure 10. Deformation of narrow gear body

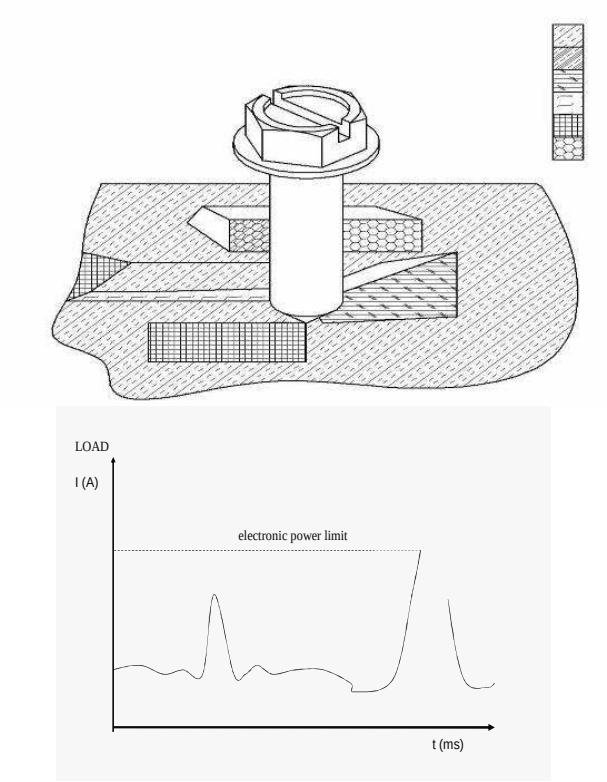


Figure 10. Momentary over-loading in case of chipboard screwing

According to the process can be seen in the diagram the drive is protected from the over-loading electronically (*Figure 10*.). Opposite, at over-loading some teeth can be deformed strongly, following local heating. Going round in case of badly determined tolerance these teeth can be reached down into the dedendum circle of the other gear or due to shrinkage they are not fitted between two teeth of the large gear. (*Figure 11*.)

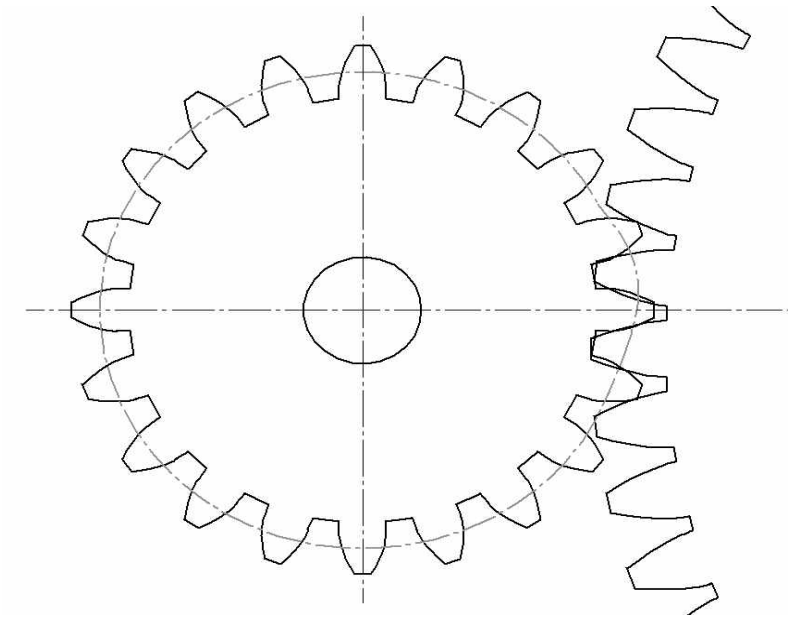


Figure 11. Effect of local heating

The same can be happened if a drive in standing position is taken out for a continual loading, then being started. This is a frequent situation at air technical equipment for baffle moving units. In these facilities the air stream tries to move continuously the baffle, which is kept many times in the right position only the propulsion. In this situation the force effect coming from the air stream loads only the linking teeth.

5. Summary

In determination of the small size plastic gears heating the effect coming from the teeth surface contact friction can be exceeded by that of the internal friction. Finding the failures is difficult because the small size plastic gears equipped by propulsions might have operating capability opposite to critical design, manufacturing and mounting errors. Additional problem is that the plastics have good vibration absorber property, so the noise of the propulsions does not deviate from the normal case. In consequence, in this size range the proceeding of the material and application specific test are absolutely necessary.

Acknowledgement

"This research was carried out as part of the TAMOP-4.2.1.B-10/2/KONV-2010-0001 project with support by the European Union, co-financed by the European Social Fund."

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