

New Findings on the Loading of Plastic Spur Gear Teeth

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ABSTRACT:

Plastic gears often break at the tip of the tooth. To the knowledge of the authors, there is no satisfactory explanation of that breakage mode yet. An hypothesis put forward in this paper to explain the tooth breakage at the tip is the interference on the back of the tooth. It is reported here how interference on the back of the tooth has been verified experimentally. Then it is explained how CAD software and plastic gear calculating software have been used to simulate the kinematics of a gear pair to predict and to localize the interference on the back of the tooth. The results obtained were then used with a finite element analysis to show that the maximum tensile bending stress shifts from the root of the tooth to a point above the pitch circle when there is interference on the back of the tooth. The conclusion is that the hypothesis of the back interference can realistically explain the particular failure of a plastic gear tooth at the tip, but it remains to refine the calculations to find more precisely the values of the loads that are applied on the tooth.

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NEW FINDINGS ON THE LOADING OF PLASTIC SPUR GEAR TEETH

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Introduction :

Tooth profile and tooth proportions for plastic gears are essentially the same as those used for metal gears. However, because plastic materials are much less rigid than metals, tooth deflection permits the contact between teeth to extend outside the line of action, thereby spreading the load between more tooth pairs than it is theoretically calculated [1,2]. Although load spreading has the beneficial effect of reducing the stress on each tooth pair, it causes interference on the working profiles, noise and wear. In plastic gears, wear acts as a regulating agent by reducing the length of contact outside the line of action [3]. As the gears run, wear progresses, redistributing the load among tooth pairs; eventually, an equilibrium state is reached between tooth deflection and wear. If the load applied on each tooth pair is not too high to cause tooth failure by a crack, the gear pair will eventually fail by wear. On the other hand, if the load redistribution is such that the tooth pair is too heavily stressed, the tooth will break by the propagation of a crack, thermal softening, pitting or other gear failure mode.

In metal gears, tooth breakage is associated with the root fillet section; breakage at other portions of the tooth are called random breakage [4]. With plastic gears however, in many cases it is observed that the tooth breaks by a crack that starts at a point above the pitch circle [5,6]. A typical example of such a breakage is shown in figure 1 that

represents a real gear pair in mesh without load. The left hand side gear is the driver gear and the direction of rotation is as indicated. It is seen in figure 1 that the driving tooth "a" shows a crack on its working flank that is initiated well above the root circle. A similar crack can be seen also on the following tooth "b". Eventually, these cracks will cause a failure of the tooth as shown in figure 2. That type of failure is observed too systematically to be attributed to a random process.

Figure 3 is an outline of the engaging tooth pairs a-a' and b-b' of figure 1. The line of action, the center line and the pitch circles of both gears have been drawn on figure 3 as well as the position of the cracks on teeth "a" and "b"; it is evident that the cracks on the tooth flanks are initiated above the pitch circle. One hypothesis to explain such a failure is that the back (the non working profile) of the driving tooth "a" comes in contact with the non working flank of the driven tooth "b". Then, the tip of tooth "a" is bent by two opposite forces as it is shown in figure 3. One force is the normal load W_n acting along the line of action; the second, W_n' , is applied on its back by tooth "b". It is argued here that this bending moment induces, at a section above the pitch circle, stresses high enough to break the tooth at that section. In the following, this contact on the back of the tooth will be called back interference.