

## INCREASING UNIFORMITY OF POWER DISTRIBUTION IN DUAL-PATH GEAR TRANSMISSION

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### Summary

One of the phases of existence of machinery according to [5], is among others, constructing. The aim of constructional diagnostics used in this case is to identify sources of potential risks.

In a dual-path gear transmission power is transferred by two parallel paths. Due to backlash and precision of making the whole gearing, the power is not transferred evenly along both paths. It creates potential risk which makes it necessary to create such gearing with higher module. This in turn causes an increase in dimensions and weight of the gearing. The paper presents a technical solution that allows to delete backlash on teeth on all stages of the gear transmission and thus increase the uniformity of power distribution into two paths. The solution consists in applying an intermediary split shaft whose parts can be exactly positioned angularly in relation to each other in the process of assembling the gear transmission.

Keywords: identifying sources of potential risk, constructional diagnostics, dual-path gear transmission

### ZWIĘKSZENIE RÓWNOMIERNOŚCI ROZDZIAŁU MOCY W PRZEKŁADNI DWUDROŻNEJ

#### Streszczenie

Jedną z faz istnienia maszyny wg [5] jest m. in. konstruowanie. Celem stosowanej w tym przypadku diagnostyki konstrukcyjnej jest identyfikacja źródeł potencjalnych zagrożeń.

W przekładni dwudrożnej moc przekazywana jest dwiema równoległymi drogami. Z uwagi na luzy i dokładność wykonania całej przekładni moc nie jest przekazywana równomiernie. Stanowi to potencjalne zagrożenie, które pociąga za sobą konieczność wykonywania takich przekładni o zwiększonym module, co z kolei jest przyczyną zwiększenia gabarytów i masy przekładni. W artykule przedstawiono rozwiązanie techniczne pozwalające na skasowanie luzu między zębami na wszystkich stopniach przekładni a tym samym zwiększające równomierność rozdziału mocy na dwie drogi. Rozwiązanie polega na zastosowaniu dzielonego wału pośredniego, którego części mogą być dokładnie pozycjonowane kątowno względem siebie w procesie montażu przekładni.

Słowa kluczowe: identyfikacja źródeł potencjalnego zagrożenia, diagnostyka konstrukcyjna, przekładnia dwudrożna

## 1 INTRODUCTION

The strength of gear transmissions is determined by the strength of a pinion [1, 2, 3]. The pinion works under heavier load than the gear and its teeth are more strenuous and they work more often than the teeth of the gear. One way to reduce the size of the pinion is having power take-off in two places on its circumference. Thus the power is divided into two parallel paths (Figure 1). The power is transferred to two gears fixed on two shafts, on which two pinions are fixed and they in turn transfer the power to the output gear. On the first stage of transmission the pinion is less loaded and on the second stage there are two pinions. Thanks to such configuration, it is possible to reduce weight and dimensions of the gear transmissions. That is why they are applicable in aeronautical construction.

The divided power on the second stage of the gearing is taken by one output shaft. Obtaining an even distribution of power into two paths in such transmission is not a simple matter because the power is transferred in a kind of discrete (discontinuous) way by gear transmission, especially the one with straight teeth. There are fluctuations of power transferred by both paths connected with the actual contact ratio changing during rotation of wheels. This fact is taken into account in classic calculation where a coefficient of uneven power transmission is assumed. In addition to uneven power transmission connected with discontinuous nature of work of toothing, a large influence on division of power has the precision of making gears - the accuracy of angular pitch and of tooth profile and flank line. A total of errors of making the transmission gears and other its components, including the angular accuracy of fixing the wheel

on the shaft and accuracy of assembly affect inter-tooth backlash occurring in the transmission. Backlash is of crucial importance to distribution of power into two paths. In case when inter-tooth backlash occurs on one of two paths due to incorrect settings of the wheel in relation to the shaft, the worst scenario is when the power is transferred by only one path.

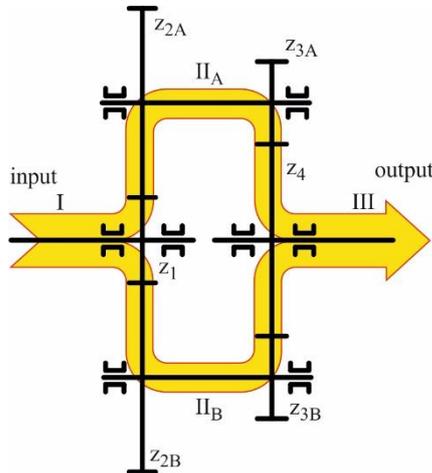


Fig. 1. A diagram of dual-path gear transmission (developed view), I – input shaft, II<sub>A</sub>, II<sub>B</sub> – intermediary shafts, III – output shaft,  $z_1$  – teeth number of pinion,  $z_{2A}$ ,  $z_{2B}$  – teeth number of wheels on shafts II,  $z_{3A}$ ,  $z_{3B}$  – teeth number of pinions on shafts II,  $z_4$  – teeth number of wheel on output shaft

Nowadays increasing even distribution of power is achieved mainly by increasing the precision of making a gear transmission. Authors suggest applying a mechanism allowing backlash correction while assembling the transmission which considerably enhances equal distribution of power [4].

## 2 BACKLASH DELETION MECHANISM

Figure 2 shows a diagram of front view of the dual-path gear transmission with axle distances of shafts and angles of their settings tagged on it. Figure 2 also shows tagged areas of meshing that occur in the discussed transmission.

With a given direction of rotation of pinion assumed at assembling, it is necessary to set the gears on the first stage as shown in Figure 3, deleting circumferential backlash  $\varepsilon$  at both points of meshing in area A. In a similar way, it is necessary to delete backlash in the meshing area B (Figure 4).

Deleting circumferential backlash in areas A and B is not problematic because it can be done by rotating shafts I, II<sub>A</sub>, III. However rotating wheel  $z_{3B}$  in order to delete backlash is impossible (Figure 5). It is caused by determined earlier angular setting of

shaft II<sub>B</sub> and by deleting backlash in gear pair  $Z_1/Z_{2B}$ .

For example, it is possible to fix wheel  $z_{3B}$  on an external spline and also to make the junction which will ensure backlash deletion. However, it is only a hypothetical possibility because, due to the precision of making, either assembling will be impossible or inter-tooth backlash will appear.

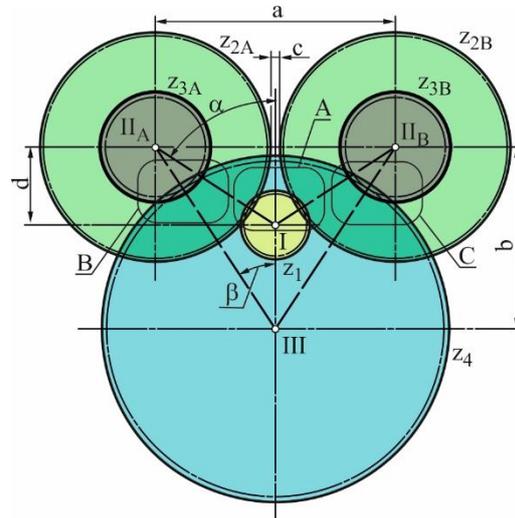


Fig. 2. A diagram of dual-path gear transmission (front view), A, B, C – details shown in figures below

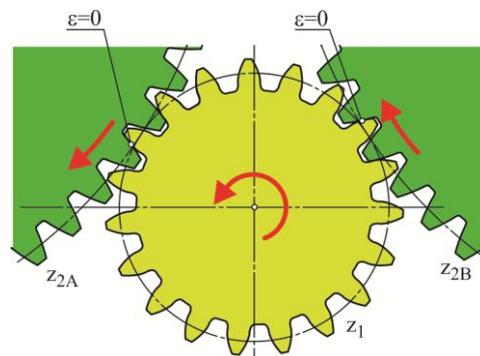


Fig. 3. The area of meshing A from Figure 2;  $\varepsilon$  – circumferential backlash

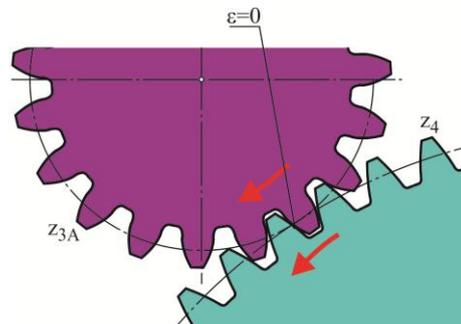


Fig. 4. The area of meshing B from Figure 2;  $\varepsilon$  – circumferential backlash

It is therefore necessary to apply another solution that will allow to delete backlash in meshing C ( $z_{3B}/z_4$ ) through small correction of angular position of gear  $z_{3B}$  in relation to shaft II<sub>B</sub> (Figure 6).

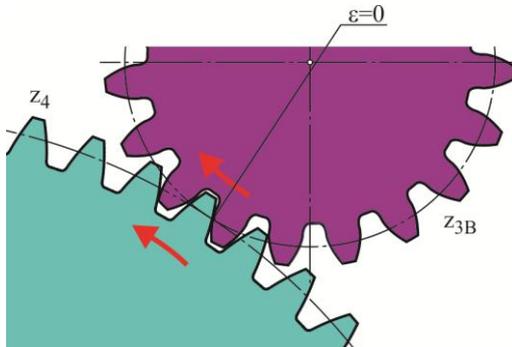


Fig. 5. The area of mashing C from Figure 2;  $\epsilon$  – circumferential backlash

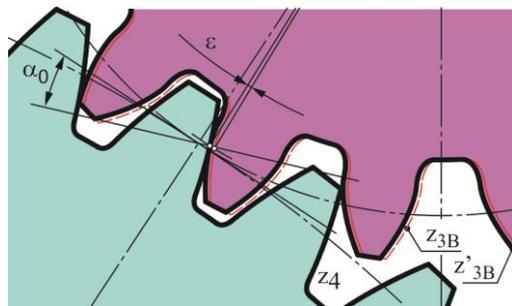


Fig. 6. Correction of angular position of gear  $z_{3B}$  to position  $z'_{3B}$ ,  $\alpha_0$  – pressure angle,  $\epsilon$  – deleted circumferential backlash

Such correction will be possible when shaft II<sub>B</sub> is made as separable shaft (Figure 7). If the shaft is separated and gears  $z_{2B}$  and  $z_{3B}$  could be placed freely while mounting, it would be possible to remove backlash in the meshing pair  $z_{3B}/z_4$ . The problem arising here is making a separable shaft, which could be united in order to transfer torque. In such a case authors suggest using a screw-nut mechanism.

Such a mechanism is made on one of intermediary shafts II<sub>A</sub> or II<sub>B</sub>, and in the discussed example it is made on shaft II<sub>B</sub>.

Two parts of shaft are united by an external muff by means of parallel keys or splines. On one part of shaft the spline is parallel to the shaft's axis and on the other it is helical. Moving the muff along the shaft forces change of positions of one part of the shaft in relation to the other. To correct position of gear  $z_{3B}$  by angle  $\epsilon$  it is necessary to move the muff by  $f$  (the direction depends on the direction of the helix, Figure 8):

$$f = \frac{\epsilon \cdot h}{360^\circ} \quad (1)$$

where  $h$  is the lead of spline.

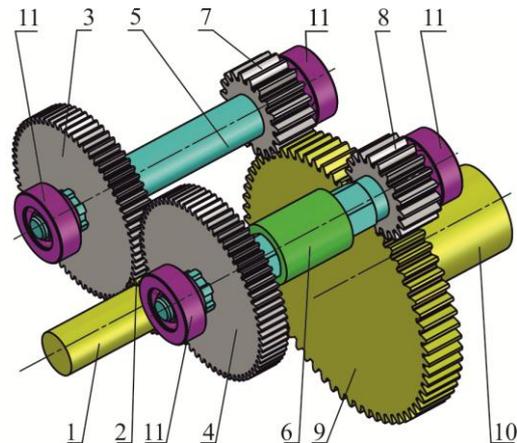


Fig. 7. A 3D view of the gear transmission; 1 – input shaft, 2 – pinion  $z_1$ , 3 – gear  $z_{2A}$ , 4 – gear  $z_{2B}$ , 5 – shaft II<sub>A</sub>, 6 – shaft II<sub>B</sub>, 7 – pinion  $z_{3A}$ , 8 – pinion  $z_{3B}$ , 9 – gear  $z_4$ , 10 – shaft III, 11 – bearings

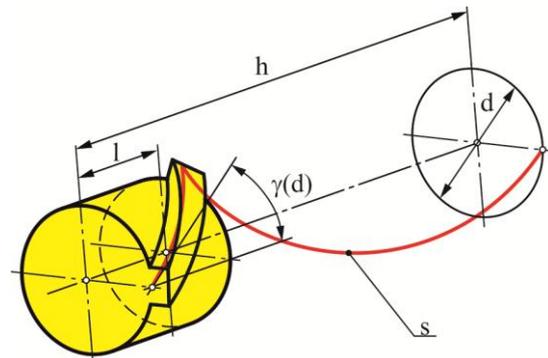


Fig. 8. Helix  $s$ ;  $h$  – the lead (left direction),  $l$  – the width of journal with spline,  $d$  – the diameter of helix,  $\gamma(d)$  – the lead angle on diameter  $d$

An exemplary technical solution is shown in Figure 9. An intermediary shaft consists of two parts: no 1 and no 2. Journal 3 of shaft no 2 goes into an axial hole in shaft no 1. Gear 4 is fixed on shaft 1 (e.g. on spline no 5). Pinion no 6 is made on shaft 2. Pinion no 6 can be an independent gear fixed on shaft no 2. Muff 7 is set on shafts 1 and 2. In a part of the muff set on shaft 2 there is a slot 8 for parallel key 9. Through key 9 slot 8 transfers torque from the muff to shaft 2. In a part of muff 7 set on shaft 1 there is a helical slot. On shaft 1 there is helical spline ( or splines) 10 corresponding to the helical slot in the muff. Torsional moment is transferred from shaft 1 to muff 7 through spline 10. Moving muff 7 along shafts in a given range one gets a change of angular position of shafts. It is necessary to block the muff in a required angular position with nuts 11 and 12, set adequately at screwed journals 13 and 14 together with star

washers 15 and 16. The shaft can be supported by cone bearings 17 and 18 which additionally influences tightening of shafts 1 and 2.

Changing angular position of gear 4 and pinion 6 makes it possible to regulate and delete inter-tooth backlash. In this way you can eliminate backlash resulting from inaccuracy of making a gear transmission.

The solution presented here can also be used in other mechanisms which require adjustment –

correction of mutual angular position of elements placed on shafts.

Constructional diagnostics, applied at the stage of designing the gearing, makes it possible to remove potential threats that may occur during operation. Preliminary diagnostics at the stage of analysis of correctness of adopted design allows to eliminate or significantly reduce these type of problems.

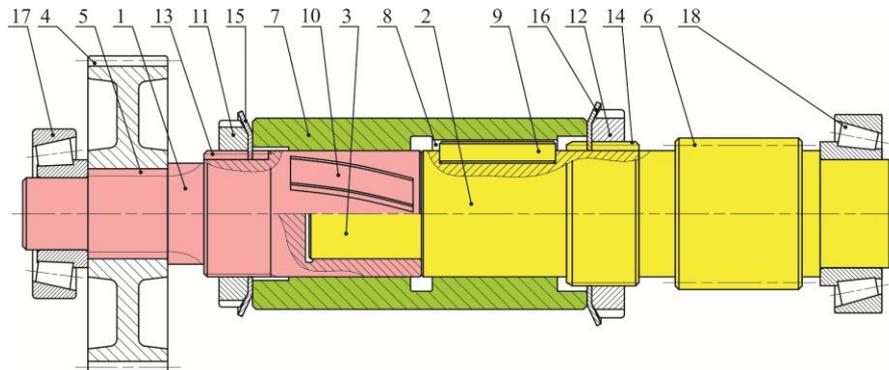


Fig. 9. An exemplary technical solution of backlash deletion mechanism (described in the text)

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