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About the Forces Resulted in the Cogged Gear

Niculae Grigore, Ion Nae

Universitatea Petrol-Gaze din Ploiești, Bd. București 39, Ploiești
e-mail: ngrigore@upg-ploiesti.ro

Abstract

The paper presents the calculation of the forces resulted in the cogged gear for different ways of inclination of the teeth, but also for the different ways of rotation of the wheels. It is illustrated for case of a speed gear of 2 levels cogged-cylindrical.

Key words: *cogged gear, cogged wheel, force, inclination*

General Considerations

When it transfers the nominal mechanical power P_1 (or the moment of the driving forces M_{t1} corresponding to this one) and the rotation movement, having the angled speed ω_1 on the lateral sides of the engaged teeth it results the ordinary linear contact loading, having an uniform distribution along the teeth.

For the calculation of the strength of the teeth these loadings are replaced with a nominal concise force resulted in the ordinary plan (*n-n*), after the direction of the engaged line, called normal, nominal, engaging the teeth force, F_n (see fig. 1).

By breaking the engagement force F_n by the radial and tangential direction in the rolling curves of *n-n* normal plane are obtained the resultant tangential and radial component:

$$F_{tn} = F_n \times \cos\alpha_n \qquad (1)$$

$$F_{r1} = F_n \times \sin\alpha_n \qquad (2)$$

In the tangential plane worm-worm wheel it is represented the resultant component F_{tn} and the friction μF_n force and decompose on the axial and the transverse direction of the worm. Are obtained F'_{t1} and F''_{t1} components and the axial F'_{a1} and F''_{a1}.

Resultant forces of these components are:

$$F_{t1} = F'_{t1} + F''_{t1} = F_{tn} \times \sin\gamma + \mu \cdot F_n \times \cos\gamma = F_n \times (\cos\alpha_n \times \sin\gamma + \mu \times \cos\gamma) \qquad (3)$$

$$F_{a1} = F'_{a1} - F''_{a1} = F_n \times (\cos\alpha_n \times \cos\gamma - \mu \times \sin\gamma) \qquad (4)$$

where they took into account the relations (1) and (2).

Determination of the worm tangential force F_{t1} (equal and opposite axial force F_{a2} worm wheel) is based on the torque transmitted:

$$F_{t1} = \frac{2 \cdot M_{t1}}{d_1} = F_{a2} \qquad (5)$$

where d_1 is the division diameter of the worm.

From the relations (3) and (4), it results:

$$\frac{F_{t_1}}{F_{a1}} = \frac{tg\gamma + \frac{\mu}{\cos\alpha_n}}{1 - \frac{\mu}{\cos\alpha_n}\cdot tg\gamma} \qquad (6)$$

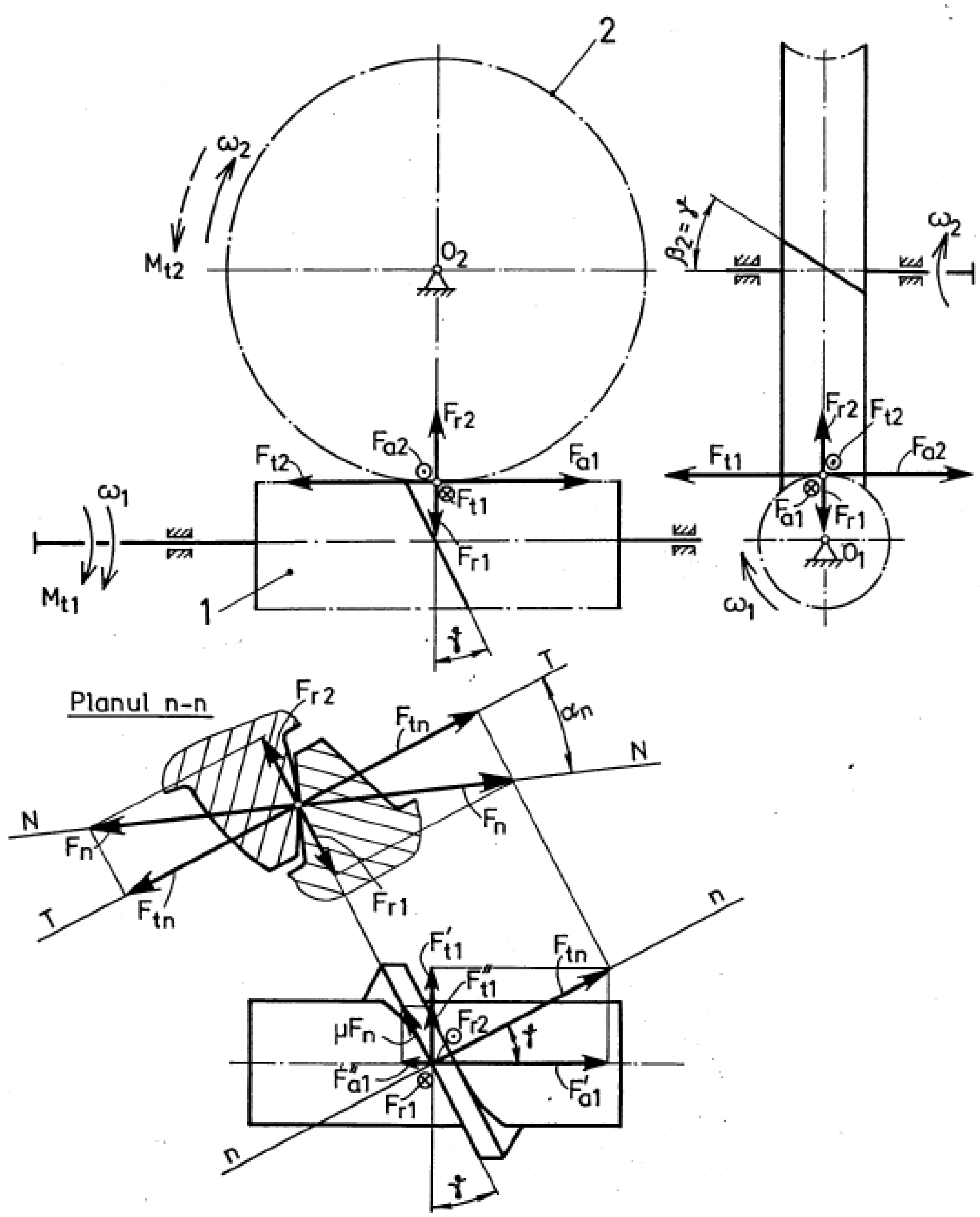

Fig. 1. The forces resulted in the cogged cylindrical gear
(the rotation direction of the snail 1 is to the right):
1 – spiral axle; 2 – spiral wheel.

It notes: $$\frac{\mu}{\cos\alpha_n} = \mu' = tg\varphi' \qquad (7)$$

where φ' is the angle of friction bear and get:

$$F_{a1} = \frac{F_{t1}}{tg(\gamma + \varphi')} = F_{t2} \qquad (8)$$

From equation (4) is obtained:

$$F_n = \frac{F_{a1}}{\cos\alpha_n \cdot \cos\gamma - \mu \cdot \sin\gamma} \cdot \sin\alpha_n \qquad (9)$$

If neglecting friction (μ=0) is obtained:

$$F_{r1} = F_{r2} = \frac{F_{a1}}{\cos\alpha_n \cdot \cos\gamma} \cdot \sin\alpha_n = \frac{F_{a1}}{\cos\gamma} \cdot tg\alpha_n \qquad (10)$$

Taking into account the relation (8) is obtained:

$$F_{r1} = F_{r2} = \frac{F_{t2}}{\cos\gamma} \cdot tg\alpha_n \qquad (11)$$

The forces which appeared as a result of the cogged cylindrical gear are shown in the Figures 2, 3 and 4 and they depend on the way of inclination of the teeth and on the direction of rotation of the snail.

For the cogged cylindrical gears are established the direction of the tangential radial and axial forces, corresponding to the different ways of rotation of the snail and of the cogged wheel and also corresponding to the different ways of inclination of the teeth of the two wheels.

The Forces Resulted in Cogged Cylindrical Speed Gear

For a cogged cylindrical speed gear (fig. 5) it is shown the way of determination of the forces resulted in the two gears in Figure 6.

For cylindrical gear (2'-3) nominal force F_n gear on the wing breaks in normal plane into two components: F_r radial and F_{tn} tangential resultant:

$$\overline{F_n} = \overline{F_{tn}} + \overline{F_r} \qquad (12)$$

In turn, the $\overline{F_{tn}}$ resultant component decompose after two directions: tangential and resultant, resulting in:

$$\overline{F_{tn}} = \overline{F_a} + \overline{F_t} \qquad (13)$$

where $\overline{F_t}$ is the tangential component (tangential force) to the pitch circle and $\overline{F_a}$ the axial component (axial force).

Normal force F_n gear components are specified in Figure 6.

- for the leading wheel 2':

$$F_{t2'} = \frac{2 \cdot M_{t2'}}{d_{2'}} \qquad (14)$$

where $d_{2'}$ is the dividing diameter of the wheel spin 2';

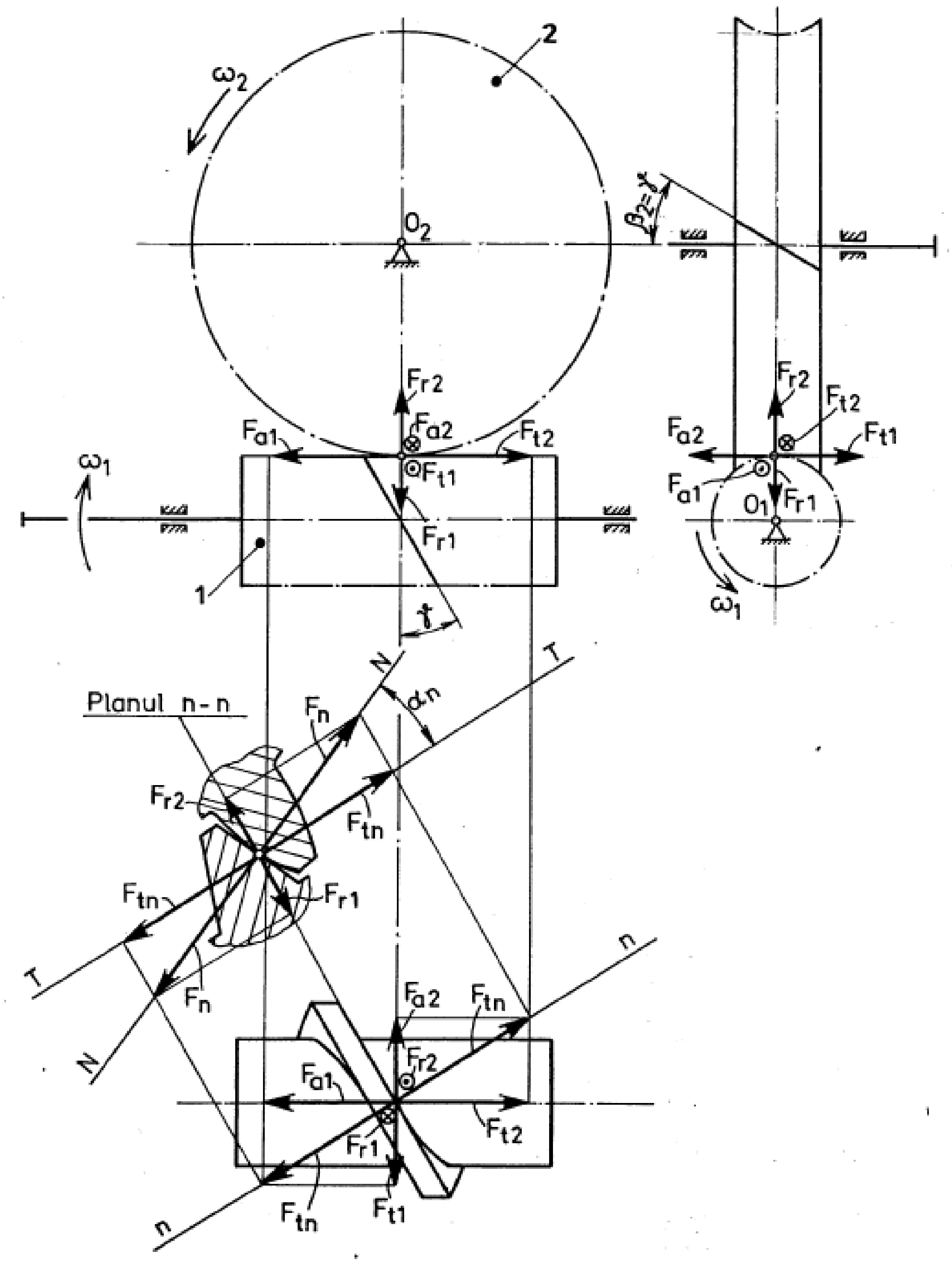

Fig. 2. The forces resulted in the cogged cylindrical gear (the direction of the rotation of the snail is left): 1 – spiral axle; 2 – spiral wheel.

$$F_{a2'} = F_{t2} \times \text{tg}\beta \tag{15}$$

where β is the angle of the teeth;

$$F_{r2'} = F_{t2'} \times \frac{tg\alpha_n}{\cos\beta} \tag{16}$$

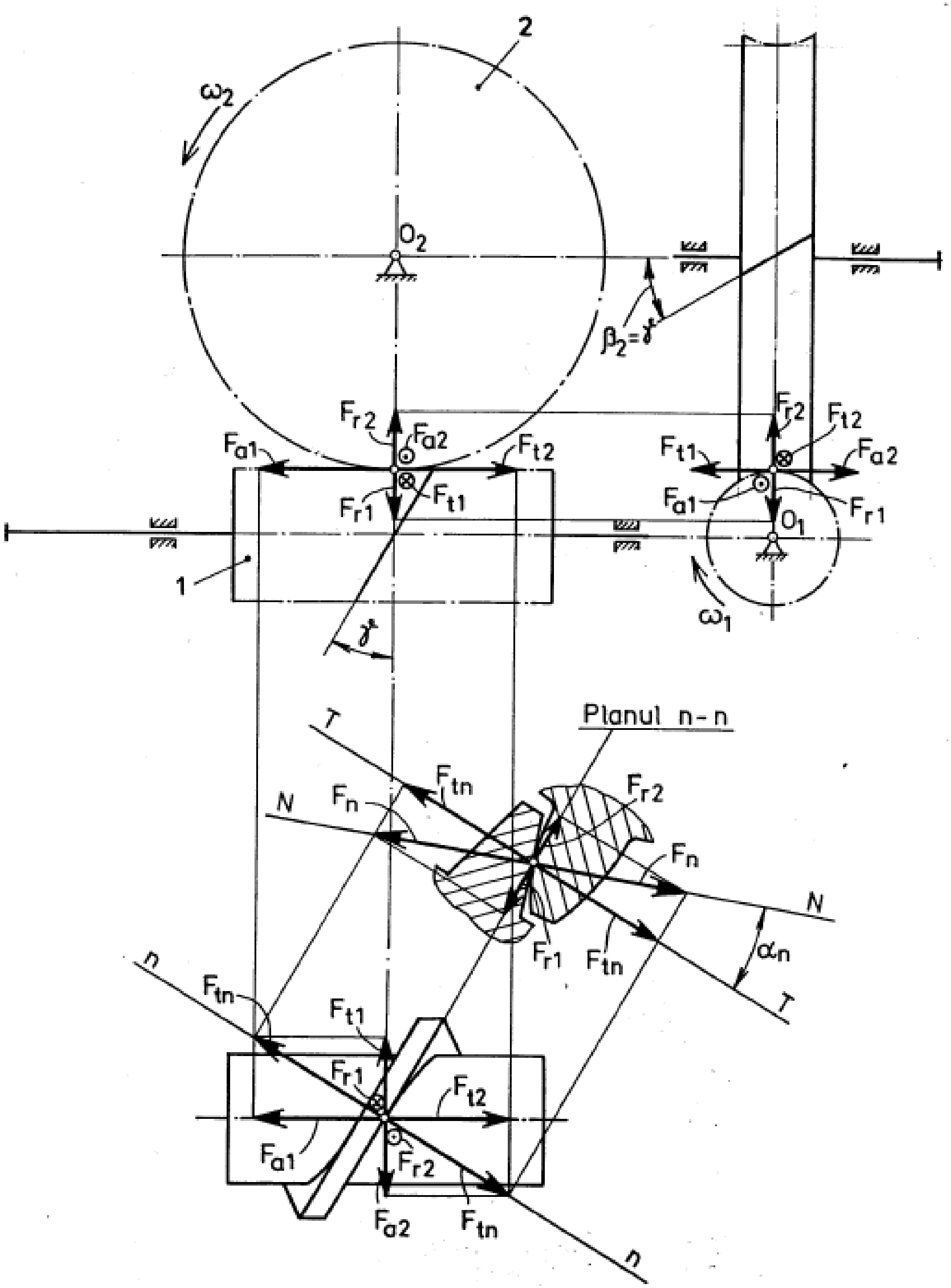

Fig. 3. The forces resulted in the cogged cylindrical gear; the direction of the rotation of the snail is right, the inclination of the teeth of the left cogged wheel: 1 – spiral axle; 2 – spiral wheel.

- for wheel 3 (led), based on the principle of action and reaction:

$$F_{t3} = F_{t2};$$
$$F_{a3} = F_{a2'}$$
$$F_{r3} = F_{r2'}$$

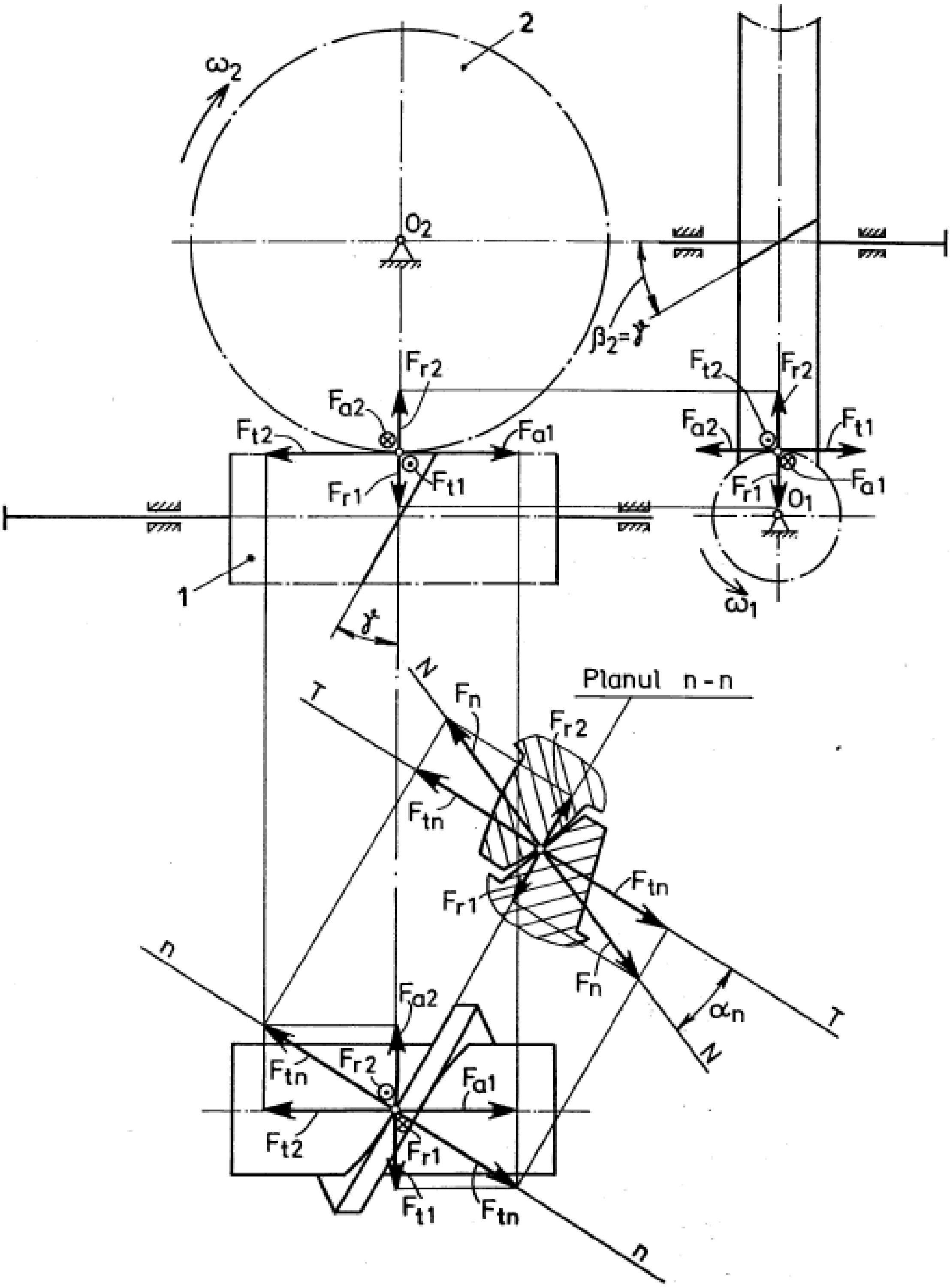

Fig. 4. The forces resulted in the cogged cylindrical gear- version:
1 – spiral axle; 2 – spiral wheel.

Shows the following:

- direction of radial forces is always oriented from gearing pole toward the wheel center;
- direction of tangential forces depends on the direction of rotation; for leading wheel tangential force F_{t2} has reverse rotation of the leading gear and the led wheel F_{t3} has the same direction as the rotation of the led wheel;

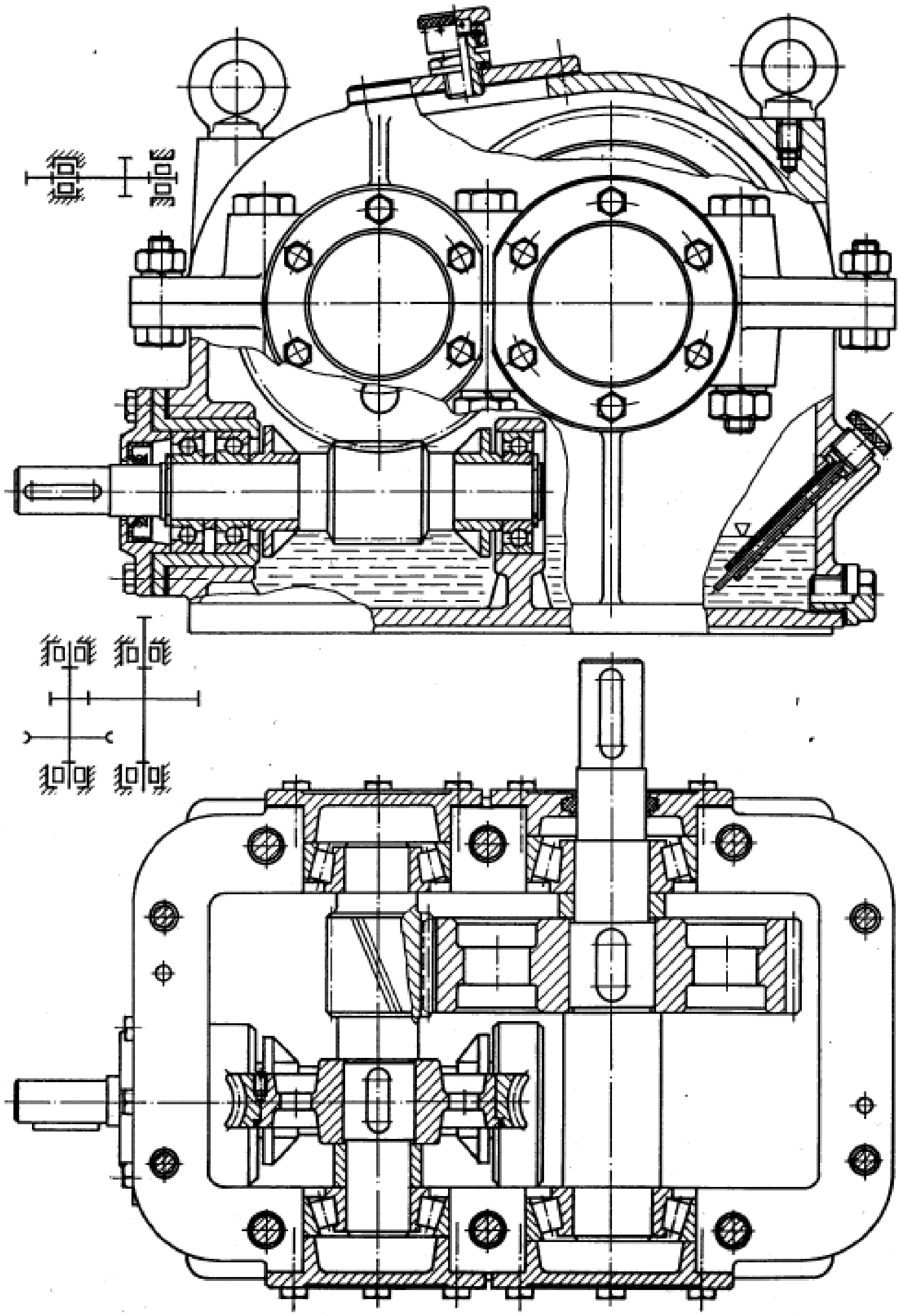

Fig. 5. The cogged cylindrical gear.

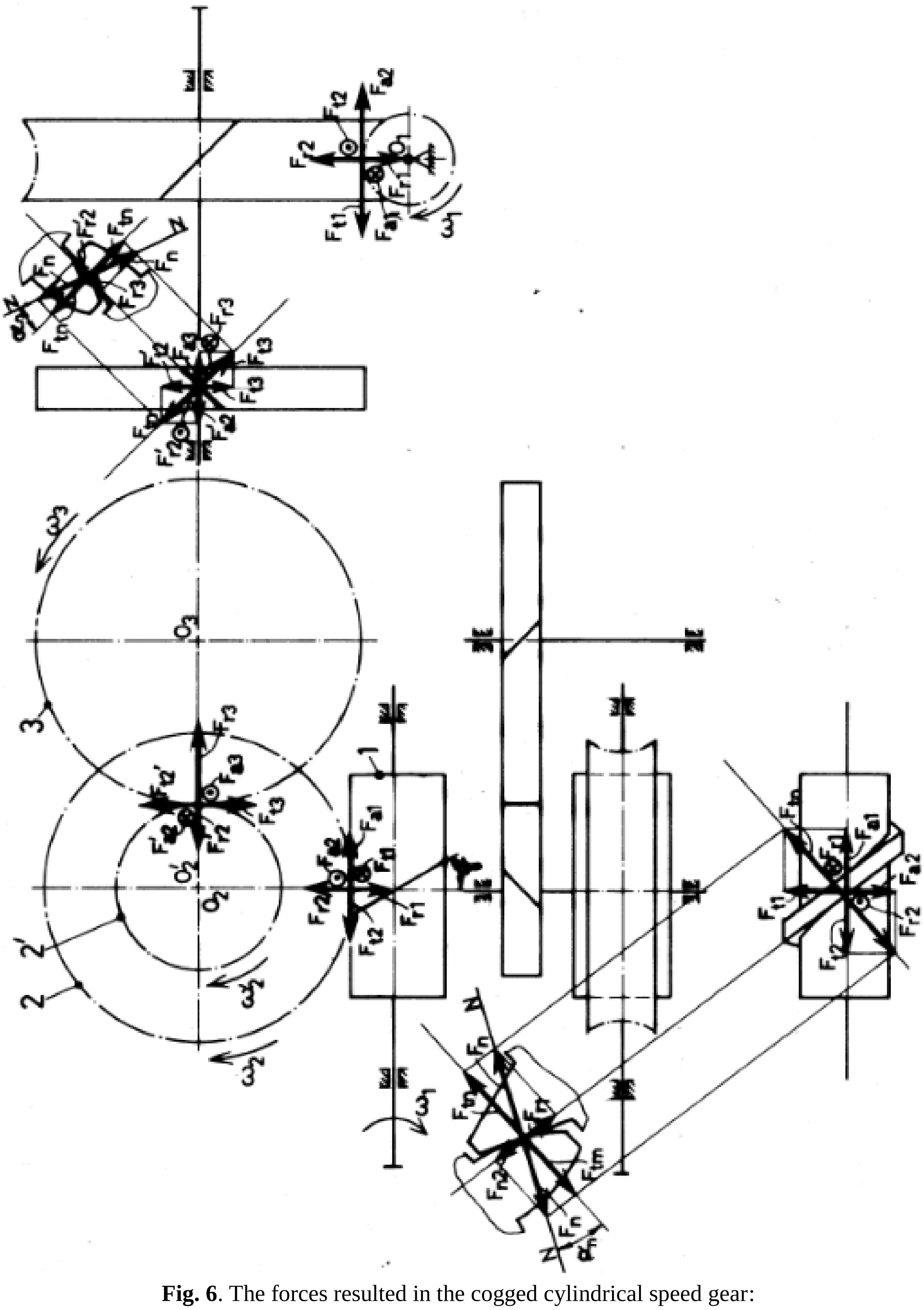

Fig. 6. The forces resulted in the cogged cylindrical speed gear:
1 – spiral axle; 2 – spiral wheel; 2' – conducting cylindrical cogwheel;
3 – guided cylindrical cogwheel.

- direction of axial forces depends on the direction and role of tooth inclination in the gear wheel (leading or led).

As shown in Figure 6 the tilt of the worm wheel has the teeth gear direction to the right and spur gear 2' has the direction of inclination of teeth also to the right.

In this context intermediate shaft bearing takes axial force (F_{a2}-$F_{a2'}$), (F_{a2} and $F_{a2'}$ have opposite directions), so in this case the intermediate shaft is subjected to a favorable load.

If is changed the sense of inclination of the teeth of the wheel cylinder 2' in kinematics of Figure 6 then, over the intermediate shaft bearing will act an axial force ($F_{a2} + F_{a2'}$), so we have a bad option.

Of course it will have negative repercussions on the durability of rolling bearings of the speed reducer.

This representation allows the determination of the forces developed in two gears, a global presentation, centralized, unitary, which allows viewing of the forces acting on the two gears on shafts (input, intermediate and output) and the rolling bearings.

This representation also allows to determine and discuss the sense of the entire gear teeth tilt wheel for the two steps, choosing the convenient solution in terms of load bearing. It is found that very important is to identify angles of teeth tilt of the leading and led gear. This representation allows easy identification of the forces acting on trees indicating the charging scheme, forces diagrams etc.

Conclusions

The paper shows the rigorous way of establishing the forces resulted in 2 steps cogged cylindrical speed gear. It is shown the way of choosing the direction of the inclination of the teeth of the wheels for a favourable charge of the bearings of the intermediate axle.

This enables more accurate representation of forces developed in the two gears in a unified global perspective and emphasizing the forces acting on the shafts (input, intermediate and output) and the rolling bearings.

The work allows to establish full-tilt gear wheel teeth sense for the two-stage gear unit, establishing favourable solution in terms of load bearing.

It is also easy to identify forces acting on trees indicating charging scheme, forces diagrams etc.

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Asupra forțelor dezvoltate în angrenajele melcate

Rezumat

În lucrare se evidențiază modul de determinare a forțelor dezvoltate în angrenajele unui reductor de turație în două trepte melcat-cilindric. Corespunzător sensurilor de înclinare a danturii roților precum și sensurile de rotație ale roților se prezintă toate variantele posibile de precizare a forțelor dezvoltate în sistemul de transmisii mecanice.