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Study on Screw-Ball Differential Gear Operating Process

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Abstract

This article includes an analysis of structure, operating principle, main mathematical relation of the self-blocking screw-ball differential gear operation in different modes of the vehicle motion. Relations of the half-axles rotation speed, as well, as of the blocking factor to time are presented for each mode of motion. These relations were generated during testing on a dynamic operating test bench.

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Keywords: screw-ball differential gear, self-blocking differential gear, differential gear testing, differential gear blocking factor, torques distribution in wheeled running gear

1. Intorduction

At the present time we can see the tendency on using the screw-ball differential gear (SBDG) in automobiles transmission systems. SBDG is implemented in order to rationally use the automobile weight on driving axles and draft on adherence for improving dynamic parameters.

2. Design of SBDG

SBDG is one of the promising designs of the self-blocking differential gears. This differential gear design was patented in the middle of the XX century [3], but due to more strict requirements to materials and manufacturing accuracy the SBDG was not mass-produced until recent time. Upgraded design was patented by Russian engineer V.N. Krasikov, its production was already mastered [2].

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This differential gear has simple design and consists of the few components. The SBDG design is illustrated on Fig. 1.

The SBDG consists of a body 2 with two cylindrical half-axle elements (screws), located in central part and touching each other on butt ends. Half-axle elements surfaces have screw grooves of right-hand rotation on one screw, and of left-hand rotation on another screw. Pairs of parallel located close to each other holes 5 are penetrated in body 2. Holes diameter is equal to the used ball diameter. These holes ends join each other, forming closed channel, filled with balls 6.

In case half-axle elements are removed, closed chain of balls 6 can move freely in channel 5 without obstacles. Balls chain in the channel forms an oval pinion - satellite, balls being its teeth. One branch of the channel 5 (located closer to the half-axle elements rotating line) is opened in order to place balls into half-axle elements grooves. Closed balls chain connects both half-axle elements into united kinematic chain.

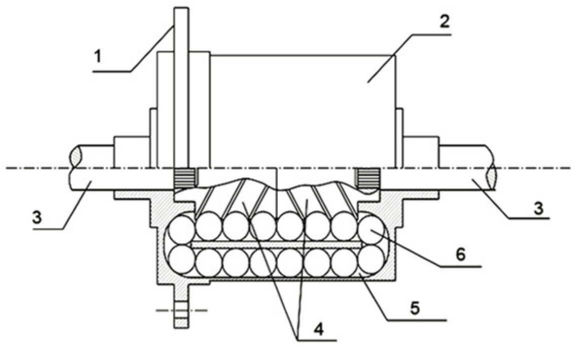

Fig. 1 - the SBDG design: 1) Final drive pinion flange, 2) Differential gear body, 3) Vehicle half-axles, 4) Half-axle elements, 5) Channel for balls passing , 6) Rolling bodies – balls.

Rotating of the body 2 through balls chain transfers power to screw grooves of the half-axle elements 4, which transfer power to the vehicle wheels through the half-axles 3. When the half-axle elements 4 are rotated in reverse direction through the half-axles, than balls 6 chain starts moving, allow-ing half-axle elements free and easy rotation. In this case the SBDG operates as a conventional differential gear [4].

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Screw-ball differential gear operates as follows. Under uni-form moving, when the SBDG is characterized by the relative forces balance, balls chain freely moves over the channels and equally distributes power between wheels. The vehicle is maneuvering as if it was equipped with a conventional differential gear. Opposite to the limited-slip differential gear, in this mode the SBDG does not resist the turn. When forces balance is broken (different resistance coefficients on wheels, sharp speeding up or engine braking), the balls chain is loaded, and forces action balance in turning channel leads to locking the chain. The differential gear blocks. The higher is the driving wheels loads difference, the higher is the blocking factor. The SBDG reacts not on the wheels rotation speed difference, but on the difference between the driving wheels loads and engine power [2].

3. Screw-ball differential gears operating feature and mathematical relations.

Moment on the wheel with higher friction coefficient depends on the differential gear blocking factor (Eq. 1), which is determined by the ball transmission components effectiveness (Eq. 2).

$$M_{\max} = M_{\min} \cdot K_b \tag{1}$$