Bevel gears monitoring methods development in the total contact patch terms

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Abstract. The article describes the main provisions of the method, which allows to perform the control of the gear rims of bevel gears according to the shape and relative position of the total contact patch. In comparison with the standard, the developed method allows to evaluate the conformity of the teeth of the ring gear with its considerable displacements relative to the calculated point of the gear transmission.

1. Introduction.
Conical spur gears in the construction of heavy vehicles are used in the differential mechanism, allowing to redistribute the torque from the wheels, when cornering and in the conditions of wheel slip when the vehicle is moving on dirt roads.

To ensure the durability of the differential operation, it is important to ensure the required level of contact patch over all teeth of bevel gears included. Irregularity of the area and location of contact spots on the teeth of the rims of the conical wheels can lead to uneven loading of individual teeth and their intense local wear. In some most unfavorable operating conditions of the car, their breakdown is possible.

The difficulty of ensuring a given spot size of the contact bevel gear in the differential mechanism lies in the fact that it is unregulated. Many factors influence the contact patch size, beginning with the design stage, for example, cutting tool profile provision [1,2], and at the stage of cutting tools wear [3], processed layer state of the blank [4] and other factors. As a result of the above factors, the teeth of the ring gear receive different geometrical deviations, leading to deviations of the location and area of the gear contact patch. Received deviations of the location and area of contact spots can’t be compensated or redistributed by means of adjusting the position of gears in the process of assembling the differential. Consequently, the operations of bevel gears are imposed special requirements of ensuring the total contact patch on (picture1).

Under workshop conditions, the main method for assessing the size of the contact patch is a visual method of comparing the resulting contact patch with the allowed forms. Measurements and recording of its parameters are not provided. A visual comparison of the acceptable forms and contact spots location by experienced and qualified personnel ensures the availability of product, but it does not allow to register the quantitative values of this indicator, to monitor the trends of its changes, and therefore effectively manage the process of manufacturing wheels.
2. Theoretical part

The contact spot requirements for bevel gears are established by a number of regulatory documents [5, 6]. Regulatory requirements are formulated in tolerance form (Figure 2 a). Standard requirements [1] are applied to the total contact patch dimensions. Its size is determined as a percentage of the length of the tooth “the ratio of the distance between the extreme points of traces of fit to the length of the tooth” \( \frac{a}{b} \times 100 \), the height of the tooth "the ratio of the average height of the traces of fit to the average height of the tooth of the corresponding active lateral surface" \( \frac{h}{h_a} \times 100 \) (Figure 2 b).

Determining the size of the total contact patch implies its initial location in the coordinates of finding the calculated point (at the intersection of the average height of the tooth and forming the separating cone), i.e. in the conditions of already adjusted process of a crownwork of a cogwheel crown.

In practice, even in a well-established process of teeth processing, the total contact patch can significantly shift relative to the calculated gearing point (Figure 2c), and in some cases, may go beyond the boundaries of the teeth. Under these conditions, direct adherence to the method of calculating and rationing the dimensions of the total contact patch by the standard method is the risk of declaring unfit products suitable. Thus, there is a need to develop a more universal method for estimating the total contact patch.

The developed method is given additional modern requirements concerning its incorporation into the quality system of the enterprise [7], providing a collection of quantitative data on controlled characteristics, the identification of diagnostic components of the process of tooth processing [8], suitable for evaluating the result of processing as a result of mathematical modeling of the process [9]. As a result,
to ensure the above requirements, in the developed method, the form of the total contact patch and its relative positioning are separately normalized. To establish the requirements of the contact patch shape, similar to the standard method, the minimum and maximum limits of its boundary are set (Figure 3 b). In contrast with it, the nominal or ideal position of the total contact patch is given as an ellipse. For the considered bevel gear, according to the test results, its optimal position was found, shifted from the calculated transfer point towards the flat end (Figure 3 a). The minimum and maximum dimensions of the ellipse are set depending on the length of the tooth along the pitch circle and the average height of the tooth.

Figure 3. Normalization of the shape and relative position of the total contact patch a) nominal location, b) the allowable dimensions of the total contact patch, c) the maximum allowable boundaries of the location, d) the minimum allowable boundaries. Its relative location is normalized by establishing the minimum and maximum allowable areas for finding contact spots. The minimum allowable area is an area that limits the minimum allowable shape of the contact patch (Figure 3 g). The boundaries of the maximum allowable zone are set to prevent the total contact patch from escaping to the tooth boundaries under the maximum operating load (Figure 3c). The lines limiting the minimum and maximum areas of the total contact patch are equidistant to the corresponding opposite tooth profile. The position of the lines is normalized in the form of linear dimensions from the corresponding boundary of the zone of finding the total contact patch up to the borders of the gear tooth. They take values from 1 to 3 mm.

Thus, the assessment of compliance of the total contact patch is simultaneously performed on a group of indicators: % L, % H - normalizing the shape of the total contact patch along the tooth and its height, as well as indicators L1, L2, L3, L4 - setting restrictions on the relative location of the contact spot. For each of these indicators, the upper and lower deviations are calculated.

Finding the actual values of these indicators is carried out according to the graphical processing of photographic images of contact patches formed as a result of erasing ferric acid pigment on the lateral surfaces of the ring gear teeth (ls) as a result of rolling the processed gear and the reference gear (Figure 2c).
Figure 4 Histograms of the distribution of indicators a) $\% L$ and b) $\% N$ of the bevel wheel in the process of setting up a gear rolling machine.

Correctly performed adjustment should ensure that all six indicators ($\% L, \% H, L1, L2, L3, L4$) hit all the side surfaces of the ring gear in the tolerance field when the bevel gear is run-in on a gear-cutting machine. The technique has shown its high efficiency in terms of maintaining the statistical office [10].

Thus, the developed method of controlling bevel gears is more versatile and allows not only to perform the control of the ring gear for any deviations in the position of the total contact patch, but also to control the setup of the machine.

References

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