

Checker of 3D Form Accuracy of Hypoid & Bevel Gear Teeth for the New Generation of Quality Control

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TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

The geometrical accuracy of the 3 dimensional tooth form is one of the most important items to insure the performance of gears. For cylindrical involute gears, tooth form checkers are available and are widely used to fulfil this industrial and technological demand. For bevel and hypoid gears though, the development in this field is still not well done. This report explains the special items to be solved to realize the curve measurement of the tooth flank of bevel and hypoid gears and introduce the tooth form checker that has solved these problems. The example of utilization of this checker for quality control of hypoid gears in mass-production in Japanese automotive industries to realize a quiet, final hypoid gear drive is introduced.

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1. Introduction

The geometrical accuracy of 3 dimensional tooth flank form is one of the most important items to insure the performance of gears. For cylindrical involute gears, tooth form checker is widely used to fulfill this techno-industrial demands. For bevel and hypoid gears although, the development of tooth form checker is still not well done. The conventional measurement was carried out usually at 9 x 5 matrix points on a tooth flank, and it is not easy to estimate the gear performance from that measured results. The lack of the number of measuring points makes it difficult to get necessary information, for instance, about heat-treatment distortion and about the state of lapping removal. The measuring technology of the curved figure of tooth flank, accurately in position and in absolute value of measurement, is therefore strongly demanded for the quality control of those gears.

The first attempt of the development of hypoid gear checker to fulfil the industrial demand mentioned above began in the later years of 1970's. This report explains how the curve measurement of the tooth flank of bevel and hypoid gears is realized through the continuous work of the development based on the original work^[1] and the accuracy of the measurement is discussed. The example of

utilization of this checker for quality control of hypoid gears in mass-production in Japanese automotive industry to realize quiet final hypoid gear drive is introduced.

2. Measurement of tooth flank form deviation

The form accuracy of machine parts is described on the design drawing and tooth flank form accuracy of gears is defined on the coordinate system fixed to the gear. When we measure the form deviation of gear tooth flank by using 3D coordinate machine or by gear checker, the displacement of the center of the contacting ball at the tip of probe stylus is obtained as the corrective value of the soll-position that is controlled by the scales of the checker, that is, the measured values are obtained on the coordinate system of the checker.

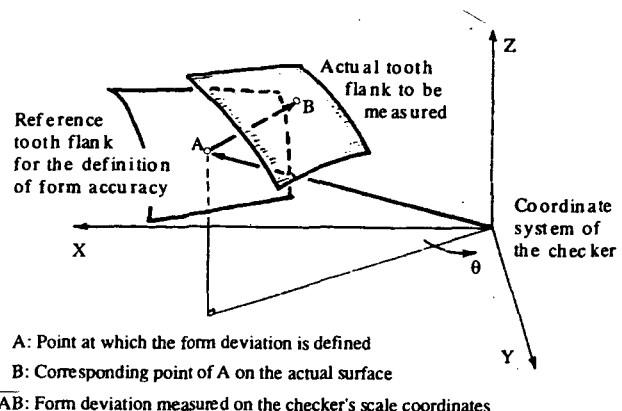


Fig.1 What is form accuracy of gear tooth flank?

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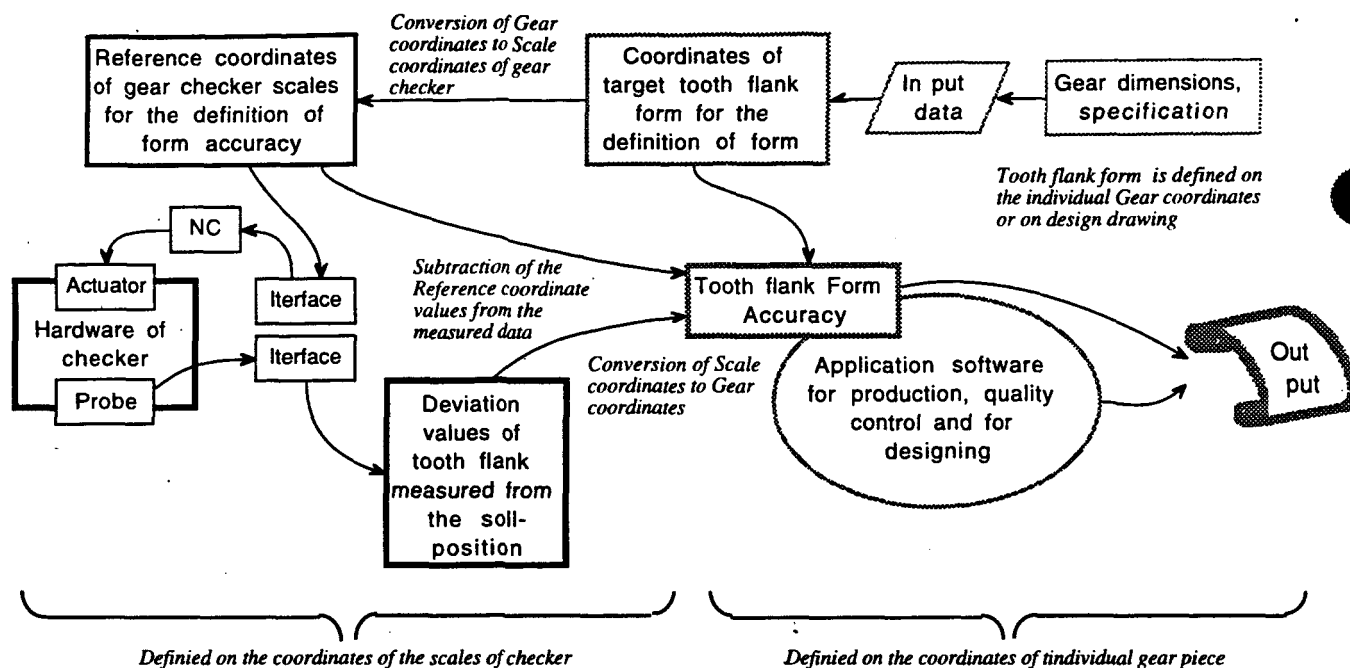


Fig.2 Measurement of form accuracy of gear tooth flank by CNC gear checker and conversion of data inside

For the quality control of the geometrical form accuracy of gear teeth, it is necessary to convert these positional values of tooth flank in 3D space of gear checker's scales into the form accuracy or form deviation of the tooth flank, that is to convert these values into the values on the coordinate system of the objective gear. For this purpose, the zero point adjustment of checker scales is first done by measuring the datum surface of the objective gear by the same probe of the checker.

Form deviation is the deviation of the position of the actual tooth flank to be measured from the reference tooth flank for the definition of form accuracy, i.e. $\overline{AB}$ in Fig.1. In case of CNC gear checker, this reference tooth flank is given by the numerical data. For example, at the measurement of cylindrical involute gear teeth, the 3D coordinate values of involute helicoid are converted to the gear checker's scale values to drive the probe along the reference surface for the definition of the form accuracy of gear tooth flank. Fig.2 illustrates the relation between hardware and software to measure form accuracy of tooth flanks by CNC gear checker.

3. Nature of hypoid or bevel gear tooth measurement

It is interesting that so much percentage of gear engineers and gear researchers knows only cylindrical involute gears

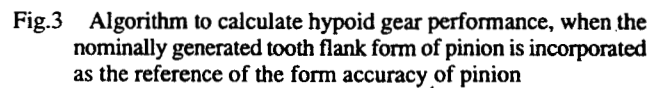
and hardly knows the fundamental about hypoid or bevel gears. They usually extrapolate their thought about cylindrical involute gears to the hypoid or bevel gears and sometimes that extrapolation is not correct.

To measure the tooth flank form accuracy of hypoid or bevel gears, the first difficulty is that the reference tooth flank for the definition of form accuracy is not uniquely approved: This is the main difference from the case of cylindrical involute gears and the reason why the tooth form accuracy of hypoid or bevel gears is not defined in any national or international Standards.

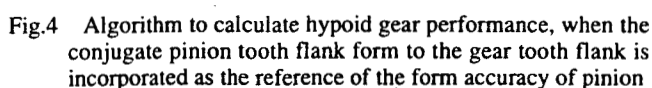
The Gleason and Klingelnberg companies propose to use the trajectory surface of cutter blade to the work piece at gear cutting for the reference of the definition of form accuracy. The main trouble is that the reference surface becomes the function of setting parameters or summary data of each type of gear cutting machine and it is not expressed by explicit mathematical formulae. Compare this fact with the case of cylindrical involute gears whose reference for the definition of tooth flank form deviation is involute helicoid that is a well known mathematical function.

The quality control of hypoid or bevel gears is usually carried out by observation of contact pattern of tooth flank and this brings another difficulty. The operator of gear cutting machine or lapping machine changes machine settings according to the experience to obtain the specified

Hypoid or bevel gears are usually heat treated after tooth cutting and lapped. Distortion or deformation of the gear through heat treatment process is considerably large, and the datum surface of the work piece at the gear cutting loses its position. After the heat treatment, the datum surface of the work piece is regenerated by holding the distorted tooth flank. Gear lapping is then carried out on this new datum surface that is different datum from that of the gear cutting. The reference surface for the definition of tooth flank form accuracy is obtained on the old datum and the conversion of the measured data of objective tooth flank stored as the gear checker's scale data to the data defined on the coordinate system fixed to the objective gear to evaluate the form accuracy becomes therefore less accurate. For the case of cylindrical involute gears, such problem also exists, but for hypoid or bevel gears this problem becomes serious because of its complexity in three dimensional figure.



To measure the tooth flank of bevel/hypoid gears, the contacting position on the surface of ball at the tip of probe stylus is not a fixed point: it moves over the surface of the ball. This brings difficult problem to compensate the influence of the radius of the ball from the measured data for the form accuracy of gear tooth. The maintenance of probe stylus of the checker is very important.



Hypoid or bevel gear wheel and pinion is cut with quite different machine. The conventional measurement of