Precision Engineering xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Precision Engineering

journal homepage: www.elsevier.com/locate/precision

A review of tangential composite and radial composite gear inspection

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ARTICLE INFO

Article history:
Received 16 November 2016
Received in revised form 4 May 2017
Accepted 5 May 2017
Available online xxx

Keywords:
Gear metrology
Transmission error
Tangential composite inspection
Radial composite inspection
Single-flank rolling test
Double-flank rolling test

ABSTRACT

This paper presents an overview of the literature on tangential composite and radial composite gear inspection. It demonstrates – by dealing with their origins and key milestones in their history and development – the important role that inspections play in terms of the functional nature of the gears concerned. This comprehensive consideration of the subject also attempts to demonstrate how the lack of clear guidelines and standards designed to unify the criteria applied to testing, the interpretation of results and calibration of equipment, along with the number of simultaneous variables involved in trials of this type, leads to doubts (including with respect to the actual standards concerned) as to whether these tests are valid, or instead accepted only has partial validations. Even so, the repeatability of the experimental data demonstrates not only their metrological potential, with respect to functionality, but also the fact that they are both effective and original

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1. Introduction

Mechanisms containing gears have existed for several thousand years. Despite their development from the Industrial Revolution onwards, and after the appearance of the machine tool, it was not until the first decade of the 20th century, with its need for higher transmission speeds, that the emergence of the gear-cutting machine made it possible to improve considerably the quality of the tooth surfaces. As with the other production processes involved, this improvement in precision was associated with the evolution of control and monitoring systems. From the 1920s onwards, with the invention of a gear inspection machine based on the method of examining the involute tooth profile relative to the base circle, the inspection of gears began to be more reliable, thanks to the simplicity of the procedure. This can be considered as the starting point of current gear metrology. Various items of equipment have been developed since then, adapted to new designs and the needs of high-speed transmissions [1,2].

The inspection of gears is a wide-ranging and complicated affair, due to the large variety of types, sizes, configurations and different parameters [3] involved. There is for this reason a virtually infi-

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http://dx.doi.org/10.1016/j.precisioneng.2017.05.007
0141-6359/

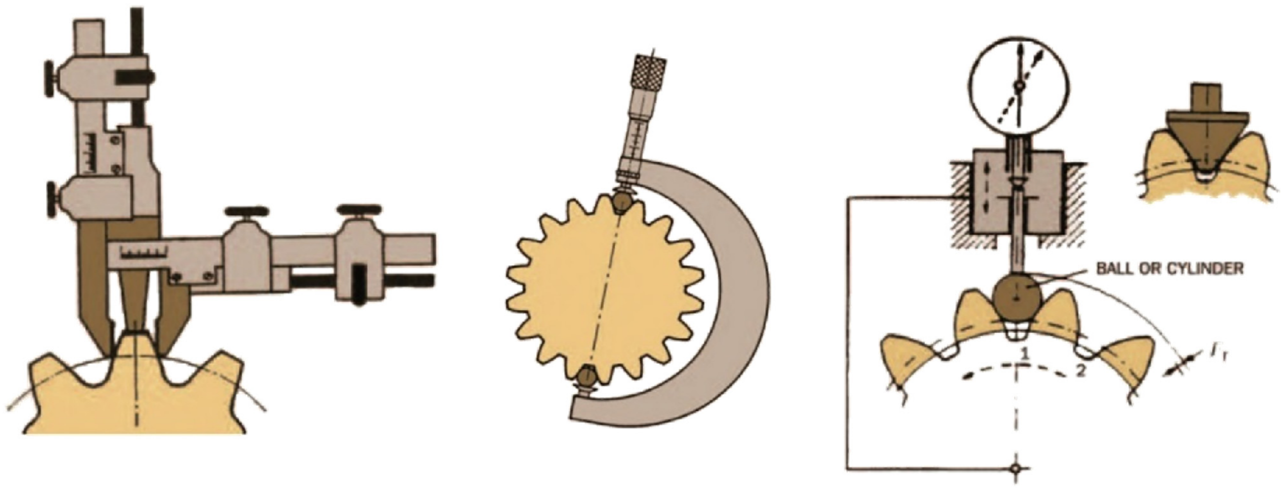

Fig. 1. Examples of manual inspection tools (source: [4]).

nite number of both manual and automatic measuring techniques; ranging from workshop-bench procedures to complex, analytical evaluation carried out in metrological laboratories. Partial verifications must also be performed throughout the production process in order to guarantee the required precision. Inspections can help to identify not only the quality of the gears, but also the correctness of their machining and the condition of the cutting tools used [4]. When it comes to performing this task, rolling tests are a good alternative way of carrying out a fast but thorough inspection, thereby allowing us both to verify the production conditions of a set of transmission gears and predict its future behaviour.

This paper gives a general description of the rolling tests concerned, while explaining their functioning principles, the parameters that they verify and the interpretation of the results; before going on to give a summary of the origins and key milestones in the history of such rolling gear tests. Attention is also paid to current tendencies associated with various research groups, which have created great interest; along with the possibilities offered by new inspection techniques in the growing area of microfabrication. It also includes a summary of the corresponding standards, and their evolution up to the current way in which they are applied to single-flank or double-flank rolling tests.

2. The metrology of gears

Metrology, as applied to gears, can be divided into two classes; differentiated by the type of information that each one provides. Analytical measurement attempts, on one hand, to quantify readings obtained during production, and verify whether they conform to the geometric data of the original design. Functional checks, on the other hand, focus on guaranteeing that a gear will work correctly, regardless of its margins of tolerance, as these can sometimes be accumulated or compensated for by its conjugate gear. The former therefore generally tend to be more quantitative, while the latter are more qualitative [5,6].

2.1. Analytical measurements

A wide variety of possibilities exists within the available range of individual, direct, geometric methods of measurement. These run from traditional, manual methods that verify the main dimensions of the teeth, to powerful coordinate-measuring machines (CMMs) with adapted operating cycles, and dedicated, high-precision gear-measuring instruments (GMIs) [7].

Checks carried out with simple manual instruments such as micrometers, callipers and dial indicators, together with pins and balls, are both fast and cost-effective (Fig. 1). It is for these reasons that they are widely used for initial inspection purposes, and to ensure that the various production stages are not subject to any ongoing defects [4]. They can be employed to measure individual tooth thickness, the chordal thickness of a series of teeth, the gap between teeth (to determine the amount of backlash), the reference diameter and even the eccentricity of the teeth.

If quality control of the final manufacturing process is to be thorough, the use of automatic inspection techniques based on continuous detection is recommendable. These take multiple readings from along a given trajectory, and then compare them to the theoretical model established in the corresponding standards (Fig. 2). The monitoring of a gear's typical parameters, such as deviation of

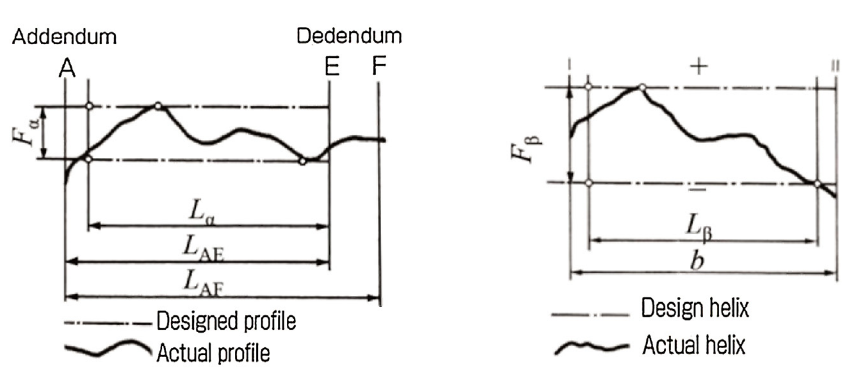

Fig. 2. Example of profile deviation and helix deviation (source: [4]).

Please cite this article in press as: Pueo M, et al. A review of tangential composite and radial composite gear inspection. Precis Eng (2017), http://dx.doi.org/10.1016/j.precisioneng.2017.05.007