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EXAMINATION OF THE CONTACT PATTERN OF ROLLING SURFACES

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Abstract: This article provides a brief summary of the potential applications of contact pattern examinations. The examination of contact pattern is a frequently used test for gear drives, rolling bearings and checking support rollers. It is used on gear drives and support rollers to test operating conditions, whereas in the case of rolling bearings the cause of the failure has already been identified. The chapters mention the types of contact patterns, the shape and size of contact patterns. This article is an introduction to a multi-part article series that presents the computerbased capabilities of contact pattern examination.

Keywords: *gear, gear drive, rolling bearing, support rollers, tooth contact pattern, contact pattern*

1. INTRODUCTION

A commonly used method for examining the connection of rolling or sliding roller components is the contact pattern test. Most often we are looking at the resulting contact pattern for gears. In addition to gears, we can also see the problem of the contact patterns on roller bearings and support rollers. Traces of wear on the treads of automotive tires can also be interpreted as a contact pattern that indicates the correct alignment of the chassis or the correct tire pressure applied *(Figure 1)*.

a) b)

Figure 1. Contact pattern (wear) on the tire, (a) as a result of incorrect chassis alignment, (b) excessive tire pressure [9]

Contact print illustrates contact zones between contact elements. The shape, size and position of the zones can be inferred from a structure-specific property. In the following chapters, the article provides a brief literature review on how to make a contact pattern scan, its conditions and how to use the result.

2. About contact pattern examinations in generally

The load-bearing tests can be divided into two distinct groups according to the applied load. One group where the test should be conducted under operational conditions and the other group when the test is performed with minimal load. In the case of a contact pattern making, one of the contacting pairs of surfaces should be coated with paint (painted element) and the other left clean (clean element). By touching the elements, the ink is pressed onto the clean element and creates a pattern there. The resulting pattern is called a contact pattern. In order to keep the paint on the surfaces from the contact elements, the lubricant must be removed and degreased. The material of the paint will not adhere to dirty surfaces, thus preventing the wear image from forming on the clean element. Alternatively, the entire tooth is painted, and the paint is removed from the contact points to create a wear pattern *(Figure 2)*. From what has been described so far, it seems simple to carry out the test, but in many cases, it is not or only difficult to carry out under operational conditions.

Figure 2. The formed contact pattern on the tooth surface (the worn area) [10]

2.1. Minimum load test

The contact pattern test shall be carried out with a minimum load where it is possible. The load must reach the value at which the associated surfaces remain in contact during the connection process, without separation and re-contact. For gear drives this is achieved by turning the gear unit at low torque (often manual force) and applying slight braking on the driven wheel. Most often the load from the inertia of the rotating parts of the gear unit is enough to carry out the test. The contact pattern formed in this case may vary greatly (and often deviate) from the load condition. Special testing equipment is often used for testing unloaded carriers (e.g. cone wheels). Low load tests can be organized into two further groups. These are called snapshots and totals. In the case of a snapshot, the large gear of the assembled gear rotates only one, while in the case of a total, the gear is rotated for a longer period.

2.2. Workload test

In the case of tests under operational load, it shall be expected that depending on the degree of loading, the contact surfaces will suffer elastic deformation. Deformation may cause the paint applied between the two surfaces to be pushed out of the surfaces at higher surface pressures. In terms of the consistency (density, viscosity) of the paint used, it is a paste rather than a conventional ink.

3. SUPPORT ROLLER BEARINGS AND ITS INSPECTION

A useful method of adjusting the support rollers is to examine the contact pattern image. For example, when testing castor furnace support rollers (or otherwise running rollers), a no-load test is practically impossible. *Figure 3* shows the support roller of a drum furnace.

Figure 3. Support/running roller for drum furnace

The load on the support/running rollers of the drum furnaces is primarily not the material fed to the furnace, but the furnace body (shield, masonry), which means that the own weight of the structure can place a very heavy load on the rollers. Often the material fed into the furnace is not counted when the rollers are loaded. Since it is only possible (and meaningful) to test the contact pattern of the drum furnace rollers under operating conditions, the test instrument should also be chosen accordingly. In general, operating conditions are often characterized by high temperatures and slow rotation speeds. Most paint materials are no longer usable at high temperatures, their flash point may be below the process temperature, which can lead to serious accidents. In such cases, lead wire testing is usually used. Lead is a very soft metal that easily deforms between the rolls. The lead wire is guided between the support rollers parallel to the axis of the rollers. The wire undergoes a large amount of permanent deformation due to the forces. The degree of papulose depends on the force applied to the lead wire. In the part of the rollers where greater force is transmitted, the degree of papulose will be greater. If the lead wire has suffered approximately the same amount of deformation along its length, the roller alignment can be said to be good, i.e. the axes of the contact rollers are nearly parallel to each other.

4. CONTAC PATTERN OF ROLLING BEARINGS

In the case of rolling bearings, as with all rolling pairs, we can speak of contact pattern. Because of the very limited insight into the running surfaces of rolling bearings, the contact pattern of the bearings can be examined in disassembled condition. Most of the tests are done because of some kind of failure. For many types of bearings, the roller bearings can only be disassembled with destruction, thus rebuilding the bearing is no longer possible. The correct bearing pattern of the bearings cannot be directly investigated; it is the installation, operation and design of the used structure, which can influence the wear image and thus the life expectancy based on the calculations. The rolling bearings manufacturer's catalogs state what technical parameters (size tolerance, position tolerance, shape tolerance, surface roughness, hardness, stiffness) the bearing elements (seat, bushing) must have. This way the bearings will work with the desired bearing pattern. By inspecting the rolling surfaces of the removed bearings, it is possible to determine whether the load pattern was optimal and based on the differences to determine the cause of the error. Refer to [7] and [8] for a detailed discussion of each rolling surfaces lesion and its causes.

5. TOOTH CONTACT PATTERNS OF GEARS

Tooth contact pattern testing is the most widespread and commonly used in gear drives. There are two types of gear contact patterns. One is the full contact pattern and the other is the localized contact pattern. The contact pattern of a gear drive depends on many factors (e.g. load size, load change, rotation direction, shaft stiffness, bearing stiffness, manufacturing and mounting accuracy, etc.). The size of the contact pattern is expressed as a percentage of the size of the tooth surface, the *Equations (1)* and *(2)* being represented by the notations in *Figure 4*.

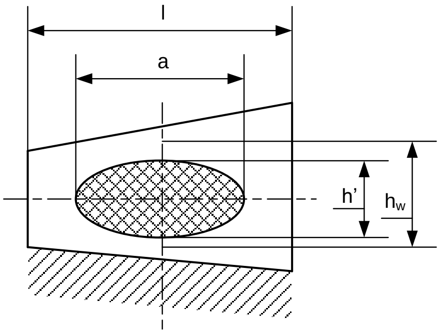

Figure 4. Interpretation of the size of the contact pattern on the tooth surface [2]

Toward the length of the tooth:

$$s_l = \frac{a}{l} \cdot 100\% \tag{1}$$

Toward the height of the tooth:

$$s_h = \frac{h'}{h_w} \cdot 100\% \tag{2}$$

where:

- a: the length of the tooth contact pattern,
- l: tooth width,
- h': the height of the tooth contact pattern,
- h_w: working tooth height.

The full load profile is used for gear units in subordinate positions, or for very precise manufacturing and rigid bearings, or for kinematic drives. Localized portraits are expensive to produce and are therefore only used in demanding applications (e.g. automotive). Due to tooth misalignment, due to manufacturing and assembly errors, wheelbase error or axle angle error, the localized tooth contact pattern determined during design may be shifted from the ideal position on the tooth surface. If part of the contact zone is removed from the tooth surface, the remaining contact area is less than necessary. The disadvantage of reducing the surface area is that the stress will increase because the same load has to be transmitted on a smaller surface. In the most severe cases, increased tension causes tooth fracture.

6. SUMMARY

Based on the previous chapters, it can be stated that contact pattern testing is a testing tool that carries a lot of information, whether we are thinking of gear drives, roller bearings or support rollers. The location of the contact pattern is greatly influenced by the accuracy of alignment of the axes of the associated elements. There are several standards that deal with the shape of the resulting portrayal and the types of axis defects that are created [3], [4]. Knowing these, the necessary action can be taken on the drives. The extent of the intervention is more difficult to determine and here the experiment is the solution to achieve the desired contact pattern image. In order to reduce the cost of the experiments, one possible method is the finite element method, which can determine the resulting contact pattern image taking into account the deformation of each element. The next part of this article will analyze the finite element testing capabilities for contact pattern with several different drive types.

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