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Measures for correct design, manufacturing and exploitation of gear transmissions to increase the reliability

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Abstract. Knowing the causes of product defects is very important in order to take the necessary measures in the design, manufacturing and service stages of the product. This paper presents the main solutions to be adopted to increase the reliability of gears. Gear mechanisms have many uses in machine building for their advantages. It is absolutely necessary to know the causes of damage to the toothed wheels and the measures to be taken to eliminate the defects. Technical literature present in many papers aspects of gear defects, causes of defects and measures to eliminate defects. This paper presents a modern method of quality management, called the tree diagram, applied to the issue of increasing the reliability of gear transmissions. The tree diagram made outlines the relationship between the overall goal pursued and the actions taken to achieve them. The tree diagram provides a picture of the potential solutions that can be adopted to avoid the two forms of gear failure: teeth breaking and damage to the active surface of the teeth flanks. This tool can be used in planning and solving quality assurance problems in the case of gear transmissions. The grouping of measures on the main objectives offers the possibility to focus specialists by focusing on the specific problems of each stage in the design, manufacturing and service of gear transmissions.

1.Introduction

Gear wheel gears have a great use in the industrial field due to their advantages, such as the ability to achieve a constant transmission ratio, the ability to obtain a very wide range of transmission ratios with different speeds and powers (from 0.0001 kW to 10000 kW), safety in service, high efficiency, relatively low gauge and long service life.

Gear wheels are machine parts with complex loads and as a result their modes of deterioration will be multiple. International standards, such as ISO 10825, ANSI/AGMA 1010-F14, as well as the technical literature in the field, make a detailed classification of the main forms of gearing deterioration. Of these, the most common forms of damage are: Bending due to tooth bending, Pitting wear, Abrasive wear, Tooth grip, Forearm destruction. In practice, there are two main forms of disposing of gears: tearing of the tooth and deterioration of the active surface of the teeth flanks.

An examination and an analysis of all defects on a spare/subassembly/product may lead to the correct identification of all the causes and actions to be taken to eliminate the causes of the malfunctions. Correct and detailed analysis of a malfunction is a very important step in the process of repairing a piece or product and help in choosing the appropriate actions.

In many situations, numerical data is rarer, and then quality issues cannot be solved by analytic methods. Quality Management offers many classic and modern tools (which uses numerical data and non-numeric al data) to help find solutions that ensure quality improvement.

Thus, using non-numerical methods (the tools of quality management) is identified: the problem, the causes determining a non-quality problem, solutions for solving the analysed problem. Non-numeric data can be transformed into different types of graphs that provide the possibility of a comparative analysis, highlighting some trends of the phenomenon studied or establishing relationships between different elements of the research problem.

This article presents a modern method of quality management, the tree diagram, applied to the issue of increasing the reliability of gear transmissions.

The tree chart was used to analyse defects and establish measures to eliminate nonconformities in many areas of activity (industrial and service activities). In the technical literature, there are many articles that present quality problems using the tree diagram. The paper [1] illustrates how event tree diagrams used in safety engineering can be applied to test the design of a healthcare service. A water quality study was conducted on the basis of the decision tree and is presented in the paper [2]. Islam presents [3] a methodology based on the tree diagram that determines the dimensional requirements of a product according to the needs of the clients. In papers [4, 5, 6, 7] there are presented non-quality issues and case studies from different domains where quality management tools are applied.

2. Measures for correct design, manufacturing and exploitation of gear transmissions to increase the reliability

In this paper we propose a study on the application of the tree diagram for a problem in the field of machine building. The problem is "increasing the reliability of gear transmissions".

For the tree diagram we used the specific methodology according to the SR ISO 9004-4:1996 standard and we considered the recommendations in the paper [8].

Thus, the following six steps have been taken:

-determination of the problem: increasing the reliability of gears,

-study more specialized papers in the proposed theme,

- -organizing a Brainstorming meeting with problem specialists,
- recording the proposed measures to solve the problem,
- the grouping of measures on several specific objectives,
- drawing up the chart with the identified objectives and the proposed measures.

The tree diagram will highlight the relationships between the objectives pursued and the measures or actions proposed to solve the problem. Tree diagrams will provide a table of solutions to the problem of increasing the reliability of gears. Aspects of the problem are detailed from general to particular, starting from a general goal set and then developing specific (or primary) measures and secondary measures.

Identifying forms of damage to gears and determining the causes that cause them helps to avoid or limit their effects and thus to meet the conditions of safe operation within a set period of time.

It is known from industrial practice that a series of defects may occur during the operation of gear transmissions systems. Identifying and eliminating the causes of defects is important because it increases the reliability of gear transmissions.

The problem of destruction and defects of gears with gears is addressed in many papers in the technical literature. In the paper [9], a copula-based reliability method is proposed in order to evaluate the reliability of the bevel gear transmission system with established performance functions for different failure modes. The paper [10] reviews various aspects of recent research in decoupling diagnosis of hybrid faults in gear transmission systems, and discusses the techniques used for gearbox hybrid faults decoupling.

Pitting and tooth root breakage are typical fatigue failure modes of case hardened gears. The [11] paper presents this problem. This paper describes main characteristics of a failure mode characterized by tooth breakages which start in the area of the active flank from cracks that are typically initiated at a considerable depth beneath the loaded flank surface.

Another interesting study focused on the causes of tooth damage in gears. Teeth of actual gears though contact not only on tooth flank to tooth flank, but also at edges of tooth tip and of tooth sides. Such edge contact is usually out of the conjugate meshing theory of gearing. [12]

Based on the data from the technical literature, from the papers [13, 14, 15,16] and with the help of the solutions obtained during the Brainstorming session we identified the following elements for realizing the tree diagram:

a. Specific objective 1. Proper design based on reliability

Measures:

- Designing correct gear geometry,
- Prescription of thermal hardness treatments of tooth surfaces,
- Choosing the materials in correlation with the tasks requiring toothed gear teeth,
- Properly prescribing the roughness and hardness of the flanks,
- Choice of gearing materials in conjunction with service life and temperature resistant,
- Selecting appropriate profile shifts,
- Correcting the prescribed hardness for the flanges with gear ratios,
- Choice of materials by correlation with lubrication conditions,
- Using calculation models to assess the risk of malfunctions,
- Elaboration of the gear test procedures,
- Designing the lubrication system correctly,
- Choosing the right lubricants.

b. Specific objective 2. Proper gearing manufacturing Measures:

- Precision manufacturing technologies,
- Machine tools and precision tools for manufacturing gears,
- Modern manufacturing processes with additional post-processing processes,
- Thermal treatments according to prescriptions,
- Appropriate and high-precision control technologies,
- Measurers and high precision control,
- Technological discipline, compliance with the execution documentation,
- Application of gears tests.
 - c. Specific objective 3. Proper gearing exploitation Measures:
- Use of high quality lubricants,
- Avoiding unstable loads,
- Optimal load of gears,
- Ensuring sufficient lubrication,
- Proper lubrication of heavy loads,
- Compliance with prescribed temperature conditions,
- Avoiding high overloads or shocks,
- Vibration within the maximum permissible limits,
- Avoiding highly contaminated work environments.

3. The original tree diagram to increase the reliability of gear transmissions

A original tree diagram for the proposed problem has been made - Increasing the reliability of gear transmissions. The proposed problem is also the general objective. For the general objective, we have proposed three specific objectives defined as: proper design based on reliability, proper gearing manufacturing and proper gearing exploitation. The proposed measures for each of the three specific objectives are Level 3 of the Diagram. The three-level tree diagram is shown in Figure 1.



Figure 1. The original tree diagram

4.Conclusions

The tree diagram can be used in planning and in solving quality assurance issues in many areas of activity. The tree diagram outlines the relationships between the objectives pursued and the actions taken to achieve them. The advantage of using this diagram is that it offers the possibility of examining logically and chronologically the objectives and actions that solve a quality or non-quality problem.

The case study presented in this paper demonstrates that this tool can be used to identify the measures needed to increase the reliability of gear transmissions. The specific objectives and actions identified are suitable for a graphical representation of the tree diagram type. The grouping of measures on the three specific objectives offers the possibility of the specialists by focusing on the specific problems of the three main stages: design of gears, gearing manufacturing and gearing exploitation. In this paper, the author presents an original diagram.

The use of this diagram in the case study proposed in this paper allows to get rid of the problem of increasing the reliability of gears and then investigates possible solutions to solve the problem. Subsequently the study can continue, the proposed solutions can be evaluated using efficiency, feasibility criteria, etc. Reliability analysis is of great importance in engineering practices.

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