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17284

DP/ID/SER.A/1132
2 February 1989
ORIGINAL: ENGLISH

CHINA NATIONAL TECHNICAL DEVELOPMENT CENTRE OF GEARS

DP/CPR/85/015/11-05

THE PEOPLE'S REPUBLIC OF CHINA

Technical report : Gear testing*

Prepared for the Government of the People's Republic of China
by the United Nations Industrial Development Organization,
acting as executing Agency for the United Nations Development Programme

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* This document has not been edited.

V.89-50973

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ABSTRACT

Title, project number: Gear testing, DP/CPR/85/015/11-05/J 133 16
Duration of the mission: from 30 October to 6 December 1988.
Duty station: Zhengzhou Research Institute of Mechanical Engineering (further ZRIME).
Objective of the activities:

1. Giving lectures on:
   a.) Involute and worm gear testing: the technique of gear pair and gear box testing, tests for worm gears, developments of test technique, data logging and processing.
   b.) Design, strength, lubrication, and some manufacturing problems of involute and worm gears.
2. Gear testings:
   a.) Determination of the pitting resistance of spur gears.
   b.) Testing of a new type of double enveloping worm gear drive, developed in ZRIME.
   c.) Testing of high speed gears.
3. Installation of four computer programs to the computer of ZRIME. The programs calculate the strength, load distribution, optimal tooth modifications, and elastohydrodynamic load capacity of involute and worm gears, and the design and manufacturing parameters for high precision hobs. The programs had been developed by the author of this report.

INTRODUCTION

The mission was completed in the period from 30 October to 6 December 1988, at the Zhengzhou Research Institute of Mechanical Engineering.

The original objectives of the mission were gear testing related, but to the request of the host institution the lectures were extended to some other topics, as the strength, load distribution, optimal tooth modifications, elastohydrodynamic lubrication, and manufacturing of gears. The ZRIME was also interested in some gear related computer programs, developed by the author of this report. The request of the host institution was fulfilled, and the original objectives of the mission were extended by the above mentioned activities.

During my stay in Zhengzhou I attended the International Conference on Gearing, organized by ZRIME in the period from 5 to 8 November, and presented the paper "Double Enveloping Worm Gear Drive with Smooth Gear Tooth Surface".

RECOMMENDATIONS

To improve the gear testing and to broaden the experimental gear research in ZRIME, I am suggesting the following equipment to be provided to ZRIME:

1. A high speed slip-ring collector with rating speed 40000 rpm, model 6144-40, made by Eaton Corporation, Electronic Instrumentation Division, Troy, Michigan 48099, USA. It is needed in the testing of high speed gears, for a research project which is in progress.

2. Four hydraulic loaders for loading torque up to 2000 N.m and with rated rotational speed 3000 rpm. The hydraulic loaders which are used in ZRIME, because of oil leak they can not perfectly work and the requested load can not be applied.

3. Surface roughness measuring instrument with the capability to measure surface roughness in three directions. Such an instrument is the Talysorf 10, made by Rank Taylor Hobson Limited in the United Kingdom. It would be used in the research on elastohydrodynamic lubrication of gears.

4. Ferrograph DR III with the corresponding software program for the determination of the wear particle concentration, needed in the research on the pitting resistance of gears.

REPORT ON THE ACTIVITIES

A. Main duties of the job description

1. Introducing the developing information and trend about international testing technology of gear devices and worm devices.

2. Introducing the methods, data logging and processing, used instructions on testing gears and gear devices.

3.Introducing some testing procedures of load capacity and criteria on gear products.

4. Giving lectures for a week on the above mentioned fields.

5. Suggesting suprvisory opinions in the aspect of establishment of a testing centre about gears and gear devices.

The later request of ZRIME was to extend the lectures to some other topics, as the strength, load distribution, elastohydrodynamic lubrication and some manufacturing problems of involute and worm gears. Also, the ZRIME was very interested in some gear related computer programs, developed by the author of this report.

B. The activities carried out

During the mission the following activities have been accomplished:

Lectures for a week

1. Involute and worm gear testing:
   a.) The technique of gear pair testing, determining the
      - contact fatique,
      - bending fatique,
      - scoring fatique.

      Method and items of testing, and criteria of failures.
   b.) The technique of gear box testing, including the
      - criteria for the evaluation of the composite quality of gear boxes,
      - the critical value for each test item.
   c.) Testing of worm gears.
   d.) The development of test technique, as
      - quick methods for fatiuqe tests,
      - realistic simulation of gear testing.
   e.) Data logging and processing.
2. Design, lubrication, strength, and manufacturing of involute and worm gears:
   a.) Thermoelastohydrodynamic analysis of lubrication of involute, hypoid, and worm gears.
   b.) Stress analysis in spur, helical, and worm gears.
   c.) Tooth contact analysis for spur and helical gears and optimal tooth modifications.
   d.) Worm gear meshing according to gear manufacturing. High precision hobs for gear manufacturing.
   e.) Worm gear developments, the comparision of cylindrical and double enveloping worm gear drives.

Gear testings

1. The pitting resistance for the following spur gear pair was determined:
   - module = 6 mm,
   - center distance = 150 mm,
   - pinion tooth number = 20, gear tooth number = 30.

The testing was carried out on a back - to - back testing machine.

The applied testing speed of the pinion was 1640 rpm, and the applied torques were 700, 750, 800, and 850 N.m. The gears were made of 4 different materials and for each kind of material 10 gear pairs were tested. By using only half face width of the gears, in total 20 test results were obtained for each material. The obtained data were of big scattering and a statistical method (Weibull distribution) was applied to determine the pitting fatique.

2. Testing of a new type of double enveloping worm gear, developed in ZRIME by Mr. Hu Songchun and his colleagues. The data of the worm gear drive were as follows

- module = 6 mm,
- center distance =150 mm,
- number of worm threads = 6,
- number of gear teeth = 48.

The aim of the testing was to determine the performance characteristics of a new alloy of cooper, used for the rim of the worm gear.

Different torques were applied : 500, 1000, and 1600 N.m, and a constant worm speed of 476 rpm. The test was running for 15 hours. By measuring the input and output torque and speed (rpm) the power loss was calculated. Also, the oil temperature was measured. An efficiency of 86% and the oil temperature varrying between 70 and 80 deg.C was obtained. Also, the wear of the gear tooth surface was registered.

3. Testing of a high speed gear pair to determine the power loss and the temperature distribution in the gear teeth and gear body. The data of the tested gear pair were as follows

- normal module = 3.5 mm,
- center distance 250 mm,
- pinion tooth number = 46, gear tooth number =93,
- helix angle = $13^{o}20'$,
- face width = 120 mm.

The temperature distribution was measured by 46 senzors located in 3 gear teeth and in the adjacent hub portions.

The influence of three different materials and the effects of the carburization were investigated.

Computer programs

The following programs were installed to the computer of ZRIME:

1. WORFEM, calculates the stresses in the worm thread and in the gear tooth by finite element method. Four different types of cylindrical worm gears are included: Archimedian, convolute, involute, and with ground worm.

2. GEARMO, calculates the load distribution and the optimal tooth modifications for spur and helical gears.

3. EHWORM, makes the thermal elastohydrodynamic analysis of lubrication for the above mentioned four types of cylindrical worm gears. Calculates the pressure and temperature distributions in the oil film, the temperature distribution in the gear teeth, the load capacity of the oil film, and the power loss.

4. ODVGLO, performs the design and the calculation of the manufacturing parameters of high precision hobs for the processing of involute gears and the same four types of worm gears. The installation of this program was not completed.

CONCLUSIONS

From the experience gained during the mission the following conclusions can be made:

1. The Zhengzhou Research Institute of Mechanical Engineering is a relatively well equiped research institution. In the part of the report RECOMMENDATIONS, the completion of the facilities is suggested. The completed laboratories and the high level of knowledge of the researchers would qualify the ZRIME to become one of the leading research institutes in the world for gear, and especially for worm gear developments.

2. The interest for the lectures was very enthusiastic, the presentations were followed by long discussions.

I think that the mission was successfully accomplished, and has fulfilled its aim.