



TOGETHER
for a sustainable future

OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.



TOGETHER
for a sustainable future

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

17566

CHINA NATIONAL TECHNICAL DEVELOPMENT CENTRE OF GEARS

DP/CPR/85/015/11-02

THE PEOPLE'S REPUBLIC OF CHINA

Technical report : Inspection and quality control of gears and gear reducers *

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

Based on the work of Mr. Munro
UNIDO Expert

Backstopping officer : H. Seidel, Engineering Industries Branch

United Nations Industrial Development Organization
Vienna

* This document has not been edited.

1 / 34

TABLE OF CONTENTS

	Page
1. Objectives	1
2. Timetable	1
3. Lecture Programme	1
4. Observations in the gear measuring laboratory	2
5. Other gearing activities at Zrime	4
6. Functions of a National Laboratory	4
7. Some possible research topics	6
8. Future collaboration	6
9. Contacts with international organisations	7
10. Summary of recommendations	7
11. Acknowledgements	8

INSPECTION AND QUALITY CONTROL

OF GEARS AND GEAR REDUCERS

1. OBJECTIVES

The objectives of the visit (summarising the UNIDO job description) were :

- a) To introduce the latest western developments in gear measuring techniques.
- b) To describe current western organisational methods for gear quality control.
- c) To give lectures on the above two topics.
- d) To make suggestions regarding the establishment of the China National Centre for Inspection and Quality Control of Gears.
- e) To suggest ways in which ZRIME can become more involved with international organisations in this field.

2. TIMETABLE

Sunday 26 February : arrive in Zengzhou.

Monday 27 February : brief tour of the Institute and introductory lecture.

Tuesday 28 February - Friday 3 March : in the gear measuring laboratory.

Saturday 4 March : tour of noise and vibration laboratory, testing laboratory and discussion.

Monday 6 March - Saturday 10 March : lecture programme.

Monday 13 March - Tuesday 14 March : final discussions.

Tuesday 14 March : depart from Zengzhou

3. LECTURE PROGRAMME

Objectives 1, 2 and 3 were covered by lectures on the following topics :

- Introduction
- A review of gear quality control in Europe and USA
- Management of quality (total quality control)
- Statistical process control
- Causes of gear errors

- Trends in gear measuring equipment
- Gear measuring accuracy, calibration and traceability
- Gear kinematics
- Profile and lead correction of gears
- Quality and the gear designer
- Gear transmission error and vibration
- Gear noise

Papers on most of these topics had been sent to Zhengzhou in advance, while others plus overhead projector films of lecture material were all photocopied at the time of presentation.

4. OBSERVATIONS IN THE GEAR MEASURING LABORATORY

a) Main items of equipment

Involute, and involute and lead testers :
Klingelberg PFSU 1200 involute and lead tester
Zeiss involute tester
Goulder Mikron portable involute tester

Pitch tester :
Attachment to Klingelberg PFSU 1200

Single flank tester :
Klingelberg PSKE 900

Hob tester :
Klingelberg hob testing machine PWP 250

Miscellaneous :
Dual flank measuring machine
Moore indexing table
Master gears and artefacts
IBM-compatible personal computer

b) Klingelberg PFSU 1200 involute and lead tester

Although this machine is about 12 years old it appears to be in good condition, and its design is fundamentally sound.

Its chief drawback is that the presentation of the measured errors is done on a strip recorder, and the curves have to be analysed by hand. By comparison, modern CNC machines and co-ordinate measuring machines present the errors of a number of teeth, both involute and lead errors, on a convenient sheet of A4 or A3 size paper. Moreover, they analyse the error parameters and give print-outs of their numerical values.

It may be possible to update this machine to provide a modern form of output, but in the longer term the objective should be to obtain a modern CNC or co-ordinate measuring machine.

c) Zeiss involute tester

This is also a sound machine, but suffers from the same output limitations as the Klingelberg machine.

d) Goulder Mikron portable involute instrument

This instrument is based upon a very old mechanical principle of generating an approximate involute curve. This method is very approximate and compares unfavourably with modern portable involute measuring instruments such as the Maag ES 401, which is effectively a small co-ordinate measuring machine. The mechanical method is also very susceptible to set-up errors, is inconvenient to use, and its further use is not recommended.

e) Pitch testing attachment to Klingelberg PFSU 1200

The pitch testing attachment for the Klingelberg machine appears to be satisfactory, but the automatic electronic analysis equipment is inoperative. This means that all data has to be observed and calculated manually, with risk of error and a less satisfactory form of presentation (it was necessary to show the operators how to do this in a satisfactory manner).

It is suggested that the automatic analysis equipment should be repaired by Klingelberg. Alternatively, it should be possible to program a personal computer to do this.

Again in the longer term, a modern CNC or co-ordinate measuring machine would solve this problem.

f) Klingelberg single flank tester PSKE 900

This machine was only installed last year, it is excellent in design and performance. Some training was given in the interpretation of the output curves, and on methods of assessing the accuracy of the machine.

g) Klingelberg hob tester PWP 250

This machine has become the standard method of testing hobs, almost universally. The design has not changed for many years, but it is still satisfactory, and modern CNC machines do not offer any significant advantages.

This particular machine was not examined in detail, but it appeared to be in good condition.

h) Miscellaneous

The Moore indexing table is a highly accurate and valuable piece of equipment.

Not all the master gears and reference artefacts are satisfactory, since they do not have reference diameters or faces. Without these, they cannot be used with confidence. Many

new master gears will be needed, with the advent of the single flank tester.

i) Measuring uncertainty and traceability

Satisfactory methods are used to establish measuring uncertainty and traceability of involute and lead measurement, via the national laboratory in Beijing. However, the analysis should be done in more detail in terms of parameters measured and statement of uncertainty. As work progresses it may be possible to identify and eliminate some systematic errors.

No work has been done on accuracy of pitch measurement, and a method was suggested which utilises the Moore indexing table.

A method of assessing the accuracy of the single flank tester was demonstrated, and the machine appears to be satisfactory. It is a criticism of Klingelnberg that they have not provided any means or suggestions to do this.

j) Personnel

The laboratory personnel appeared to be skilled in handling the equipment, but needed some training in interpretation of the results. It is suggested that some more senior engineers be involved in this laboratory to help with measuring uncertainty, which is a continuous and painstaking process, and in maximising the potential of the single flank tester.

5. OTHER GEARING ACTIVITIES AT ZRIME

The research work on gear vibration and noise, and on tooth corrections, appears to be of a very high quality, by international standards. Equipment for gear noise and vibration measurement, and rig testing, is also excellent.

By comparison, activity in the field of gear metrology appears not to have had the same priority in terms of personnel and management. A truly national centre for gear measurement must address this problem.

The fact that so much good work is being done in other areas of gearing should be a great asset in developing a national gear measuring centre. There should be more cross-fertilisation of ideas and movement of personnel to take advantage of this situation. For example, the relationship between single flank errors and gear performance should be studied. ..

6. FUNCTIONS OF A NATIONAL LABORATORY

It might be helpful to list the main functions of a national gear measuring laboratory, and to comment on the current position at ZRIME in performing these functions. The list is not necessarily in

strict order of priority.

a) Measuring facilities

To provide comprehensive and precise measuring facilities for industry, with known uncertainty of measurement, traceable to national standards. Some work needs to be done on uncertainty and traceability, particularly for pitch measurement.

b) Advice

To give advice to industry on gear measuring problems. I understand that this is being done.

c) Arbitration

To arbitrate in cases of measurement disagreement between industrial organisations. I understand that this is being done.

d) Awareness

To maintain awareness of current developments in gear measurement, and to disseminate this knowledge to industry through literature, training courses, consultancy and personal contacts. This is a continuous process.

e) Demonstration

To be able to demonstrate to industry the best techniques and equipment for gear measurement. In this respect the laboratory needs some new equipment and some updating of existing equipment.

Also, although the standard of 'housekeeping' in the laboratory is satisfactory, the approach routes to the laboratory are not in keeping with the image of precision.

f) Quality management

To offer advice to industry on quality management, not just of gears, but of total quality management. Total quality management is a subject which might be considered in more detail at ZRIME, but this is beyond the scope of this project. However, it should be pointed out that it is difficult for an organisation to offer advice on this subject if it is not fully practised by that organisation. Detailed study of the recommendations of the ISO standard 9001 is suggested.

g) Research

To carry out research into gear measurement, with particular emphasis on the practical needs of industry rather than 'academically interesting' subjects. A list of possible topics is given in the next section.

Advantage should be taken of the fact that the gear measuring laboratory is part of a complete gear design, manufacturing and research organisation. This gives it a first class opportunity to work in a stimulating and highly relevant environment.

7. SOME POSSIBLE RESEARCH TOPICS

a) Sources of manufacturing error

A detailed study of measured manufacturing errors and how they are produced in the manufacturing processes. The ultimate objective would be to help pinpoint error sources and to suggest ways to avoid those errors. An expert system approach might be appropriate.

b) Cutter accuracy

A particular aspect of topic (a) would be to study the relationship between cutter accuracy and gear accuracy.

c) Machine accuracy

A further particular aspect is to study the relationship between machine tool accuracy and gear errors.

d) Industrial needs

An important and valuable research topic would be to survey industrial needs in gear measurement. In particular gear performance and manufacturing tolerances should be compared with industry's manufacturing and measuring abilities.

e) Transmission error

It would be useful to investigate ways in which the single flank tester can be used to improve gear performance. Particular aspects might be to study and measure transmission error under load and at running speeds, and to produce a low cost method of measuring transmission error for use in industry.

8. FUTURE COLLABORATION

Although this project was a single visit to ZRIME, it appears to have been helpful, but the maximum benefit would be obtained by a regular relationship. I have certainly found this to be the most fruitful form of help in consultancy arrangements which I have in the west. I would be pleased to do this if suitable financial support could be obtained, possibly through UNDP/UNIDO.

It is also possible that senior engineers from ZRIME could spend some time in the UK. I have checked with Huddersfield Polytechnic, where I do some part-time teaching and research. It would be

possible for an engineer to spend some time there. A good command of the English language would be essential, and funding would have to be found from ZRIME/UNDP/UNIDO for travel and living expenses. The Polytechnic would make no charge.

Future visits to ZRIME, either by myself or other people, would benefit from greater preparation by ZRIME in advising the visitor in more detail what information is needed, and what facilities and expertise already exist. For example, copies of publications would be helpful.

The process of obtaining a visa is slow and inconvenient. In my case it necessitated some 'last minute' visits to the Chinese Embassy in London. A multiple entry visa would be helpful for a regular visit arrangement.

9. CONTACTS WITH INTERNATIONAL ORGANISATIONS

It appears that some good contacts already exist, for example the international conference at ZRIME last November was a good opportunity. Also, some engineers at ZRIME are members of the American Gear Manufacturers' Association.

Attendance at international conferences is a valuable source of contacts, a personal contact is always the best.

Publication of research results, especially in the English language, would also enhance the reputation of Zrime. Research publications on gear measurement are not common, and the topics suggested above would be of wide interest.

10. SUMMARY OF RECOMMENDATIONS

- a) The Klingelnberg involute and lead tester should be updated if possible, to give a modern form of output.
- b) The pitch testing attachment for the Klingelnberg machine should be repaired so that the output can be recorded and analysed automatically. If this is not possible, then the possibility of using a personal computer for this purpose should be investigated.
- c) The longer term aim should be to acquire a modern CNC or co-ordinate measuring machine for involute, lead and pitch measurement.
- d) The Goulder Mikron portable involute tester should be abandoned, and replaced by a modern computer-controlled instrument.
- e) A portable pitch measuring instrument should be acquired, such as the Maag or Hofler.
- f) More master gears are needed, and it is essential that they

have reference bands.

- g) Efforts must be continued to determine measuring uncertainty, and to reduce it by identifying systematic errors which can be corrected out.
- h) Additional senior personnel are needed in the gear measuring area.
- i) Further training is needed in the use of the single flank tester and its applications.
- j) Total quality management techniques should be studied to establish which aspects are appropriate to ZRIME.
- k) More liaison is desirable between the gear measuring section and the gear research sections.
- l) A programme of research in gear measurement should be considered, as listed in section 7.
- m) Further international contacts should be established, as listed in section 10.
- n) Further regular visits would be more beneficial than just the single visit covered by this report.

11. ACKNOWLEDGEMENTS

I would like to express my sincere thanks to all the staff at Zrime for their hospitality and extreme kindness during my visit. It was a pleasure to work with them, and I wish them and the Institute success in the future.