ENG56 DriveTrain

Good practice guide

on thermalisation times of large gear and large ring measurement standards

Introduction

The standard reference temperature for dimensional measurements, as written in ISO 1 [1], is 20.0°C. Accredited laboratories and other laboratories with the demand of high accuracy are respect this specification. Due to requirements of accurate measurements and small measurement uncertainties, not only the environmental temperature is important, but also the temperature of the measurement standard. Therefore, the demand of a homogeneous temperature inside the measurement standard exists.

Small workpieces like well-established gear measurement standards for the automotive industry (diameter < 0.4 m) have small volumes. The measurement standard needs a required time-period to adjust the workpiece temperature to the environmental temperature of the measurement laboratory, which is short. Due to its handy size the measurement standard can be placed inside the laboratory before it is placed inside the measurement volume. Therefore, the required time-period for thermalisation issues is a negligible circumstance.

In contrast to this simple solution, a large workpiece is not easily stored inside the laboratory without huge afford due its weight etc. and disadvantages as storage space. The adjustment of temperatures is a time-consuming factor. Therefore, the required time-period is extremely interesting to know, so that the occupancy of the measurement volume is as short as possible.

Example measurement standards

The gear measurements standard has the shape of a cylinder segment. It is a 60° segment, with a diameter of 1 m and a height of 0.4 m.

Figure 1 – gear measurement standard

The second workpiece is a ring measurement standard with an outer diameter of 0.8 m and an inner diameter of 0.6 m. The height is about 0.2 m.

Figure 2 – ring measurement standard

Temperature monitoring

In this case both measurement standards are equipped with boreholes for temperature sensors, so that it is possible to monitor the inner temperature and estimate the temperature distribution.
The gear measurement standard has 21 boreholes. 17 temperature sensors are equally distributed on the vertical sides (seven sensors each time) and the front (four sensors) of the segment. The cylinder in the back (one sensor) and the top level (two sensors) have further sensors.
The ring measurement standard has 12 equally distributed boreholes on its circumference. They are distributed in two different heights.

All sensors are calibrated and a monitoring is manageable due to the corresponding system who logs temperature data from each sensor frequently.

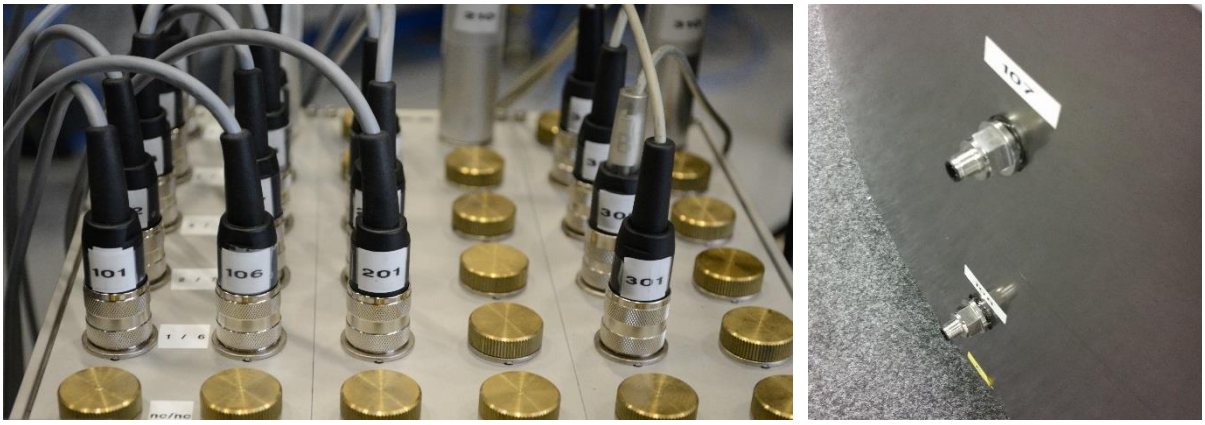

Figure 3 – temperature monitoring system

Additionally, the usage of temperature sensors for the control of the workpiece surface is useful. In the case of the test measurements seven sensors were distributed on the top and bottom of the workpiece as well as on the sides respectively the circumference. Further temperature data is collected by the coordinate measuring machines (CMM) itself, which sensors log data of the environment inside the measurement volume.

Conclusion

For the measurements of large workpieces, a homogenous temperature distribution is important. The thermalisation process is more time-consuming than the process of small workpieces due to its material volume.

A pre-thermalisation-period within controlled climate conditions (close to the conditions of the laboratory environment, if possible) is recommendable. A temperature monitoring of the measurements volume and the workpiece surface are mandatory. Further control of the inner workpiece temperature is preferable, if possible. The sensors have to be calibrated and their position must be equally distributed. For the monitoring of the laboratory and measurement volume environment at least eight sensors should be positioned. The workpiece should be equipped with at least eight inner and four outer sensors.

In the described test measurements, the time-period for the simultaneous adjustment of environment and workpiece temperatures is necessary for at least 30 hours inside the measurement volume, if the temperature difference of the workpiece temperature and the environmental temperature is up to 10 K (see Appendix A).

In contrast to the test measurements a pre-thermalised workpiece has a slightly (smaller than 10 K) different temperature than the environment of the laboratory. Therefore, a comparison to the test measurements is difficult. Experiences due to a national intercomparison of a large ring gear measurement standard (2 m in diameter and 0.2 m thickness of material) show a storage of 24 hours inside the measurement volume is acceptable to reach a homogenous temperature distribution. Further this value is close to theoretical considerations in D3.1.1/REG(RWTH) D2.

Appendix A

Test measurements and its results

Test measurements in a controlled climate chamber were conducted at RWTH Aachen. Therefore, each workpiece was located successively inside the measurement volume of the machine, which is placed inside the climate chamber as well.

The temperature change was conducted in three separated steps for the gear measurement standard. The first one from 15 °C to 25 °C, the second one from 20 °C to 30 °C and the last one from 30 °C to 15 °C. Each time the data of the environmental temperature sensors and the inner workpiece sensors were logged.

Table 1 – time-period of temperature adjustment for gear measurement standard

Temperature	Thermalisation time of environment	Thermalisation time of material
15°C to 25°C	26 hrs	21.5 hrs
20°C to 30°C	16 hrs	13 hrs
30°C to 15°C	8 hrs	11.5 hrs

Next to contradictory values out of those test measurements, which are existing according to the characteristics of the climate chamber heating and cooling process and as well the usage of a fan and a radiant heater, the conservative conclusion is considering the maximal amount of time. Therefore, the time-period to adjust the environmental temperature and the material temperature in a controlled changing environment is up to 26 hours according to a heating process of 10 °C.

The temperature change for the ring measurement standard was conducted transition-free, but different changes can be highlighted. The first one from 15 °C to 20 °C, the second one from 15 °C to 30 °C and the last one from 25 °C to 10 °C. Each time the data of the environmental temperature sensors and the inner workpiece sensors were logged.

Table 2 - time-period of temperature adjustment for ring measurement standard

Temperature	Thermalisation time of environment	Thermalisation time of material
15°C to 25°C	19 hrs	30 hrs
20°C to 30°C	29 hrs	29 hrs
30°C to 15°C	188 hrs	188 hrs

The conservative conclusion is considering the maximal amount of time. Therefore, the time-period to adjust the environmental temperature and the material temperature in a controlled changing environment is up to 30 hours according to a heating process of 10 °C.

Appendix B

Experience from a national intercomparison

The estimated value is also confirmed through experience knowledge regarding a intercomparison with a large ring gear measurement standard. It is 2 m in diameter and has a height of 0.4 m.

Figure 4 – ring gear measurement standard

It was mandatory to have a pre-thermalisation-period within a climate close to the measurement environment. After locating the measurement standard inside the measurement volume an adjustment-time-period of 24 hours was set. In all eleven cases of measurements including the temperature monitoring, a temperature homogeneity was given at the beginning of the measurements. This homogeneity shows a stable value during the measurements as in Figure 5. An influence of the environmental temperature change on the inner workpiece temperature sensors is obvious. It seems to be temporally delayed, but all over not too much. The influence is about 10 to 20 % of the temperature changes of the environment.

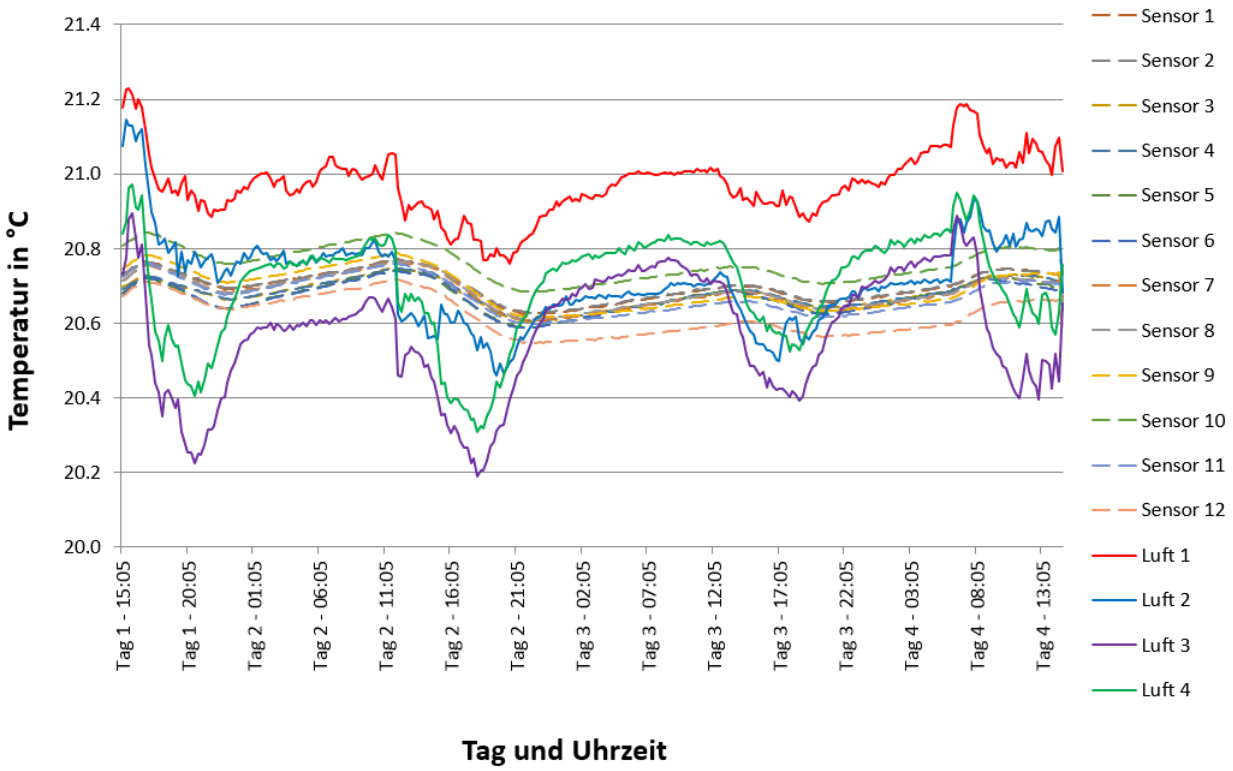

Figure 5 – monitoring example of temperature sensors during measurement