

REPRODUCIBILITY OF MEASUREMENT RESULTS OF GAUGE BLOCKS OVER A PERIOD OF 15 YEARS

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Abstract: The paper gives a presentation of monitoring the results of measuring the gauge blocks length over a time period of fifteen years. The analysis has been performed on five gauge blocks of the highest accuracy class, of nominal lengths of up to 100 mm. Five different laboratories carried out the measurements, using three times interferometric and three times comparative methods. The measurement results analysis indicates constant need for checking the measuring procedure at the metrology laboratories.

Keywords: gauge blocks, traceability, uncertainty, reproducibility

1 INTRODUCTION

The Laboratory for precise length measurement of the Faculty of Mechanical Engineering and Naval Architecture (Cro.abbr. LFSB) has long experience in the field of length measurements. The first data regarding calibration of a set of gauge blocks using interferometric method date back to 1969. During its 40 years of existence, LFSB has carried out a number of researches in the field of measuring length standards. The first comparative measurements of gauge blocks using interferometric method were performed at LFSB in 1979 jointly with the IMGCI institute from Torino. Since then, comparative measurements of length, angle and roughness standards have become a standard practice at LFSB. This paper presents the measurement results of five gauge blocks of the accuracy class 00 (DIN 861, 1980) produced by the distinguished world manufacturer, obtained over a period of 15 years. The measurements have been carried out at LFSB (interferometric and comparative method), as well as in four more metrology laboratories in other countries (1 in Sweden, 1 in Italy and 2 in Slovenia). The measurement results have been analysed with the aim of indicating the need to carry out comparative measurements as the basis for insuring traceability.

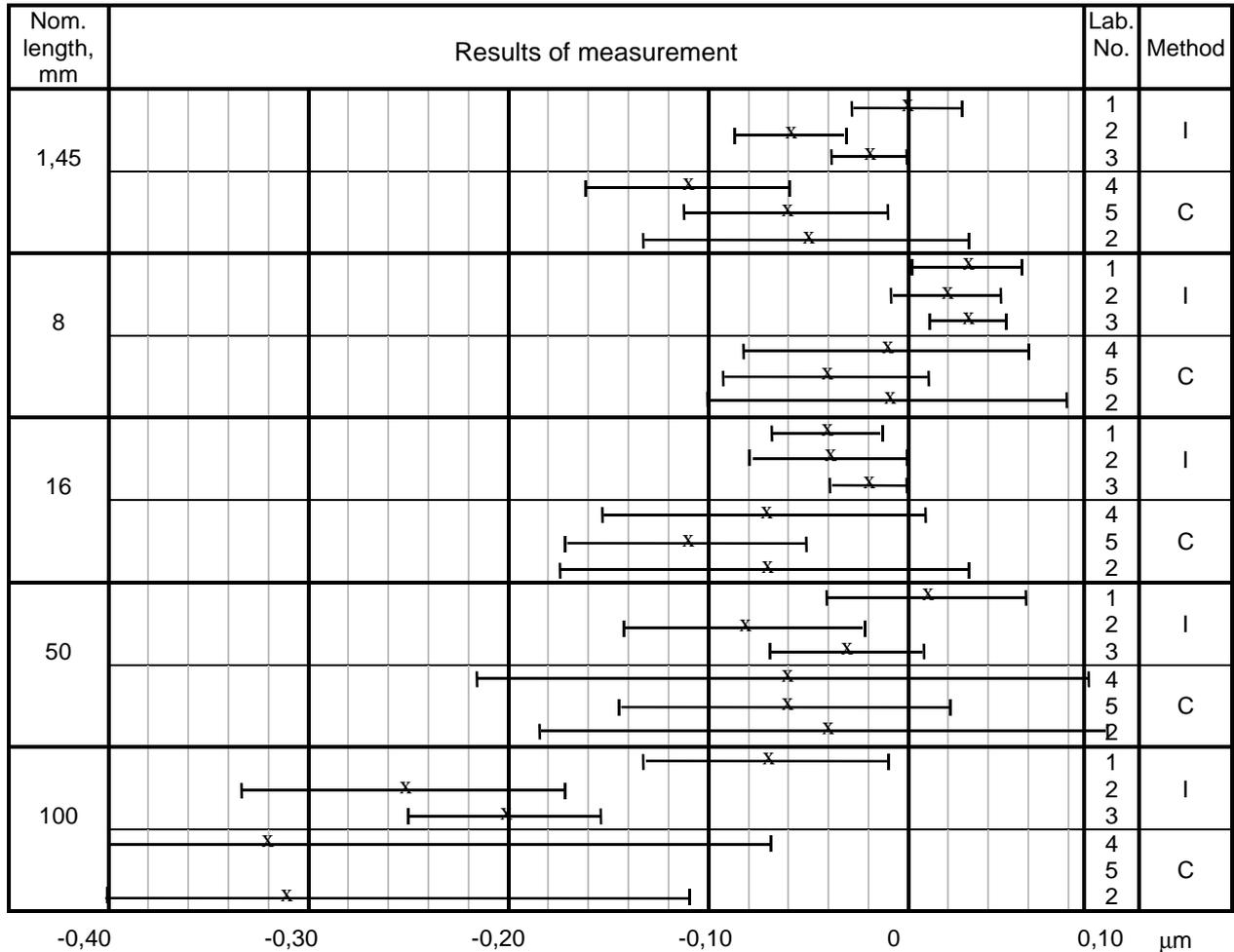
2 MEASUREMENT RESULTS

In the period from 1989 to 1998, the results of measurements obtained for gauge blocks of nominal length values 1,45 mm, 8 mm, 16 mm, 50 mm and 100 mm are presented in Table 1, along with the graphical presentation in Figure 1.

Table 1. Results of measurement

Nominal length mm	Laboratory No.											
	1		2		3		4		5		2	
	Interferometric						Comparative					
	1984		1989		1995		1998		1998		1998	
Deviation from nominal length ΔL and measuring uncertainty U ($k=2$), μm												
	ΔL	U	ΔL	U	ΔL	U	ΔL	U	ΔL	U	ΔL	U
1,45	0	0,03	-0,06	0,03	-0,02	0,02	-0,11	0,05	-0,06	0,05	-0,05	0,08
8	0,03	0,03	0,02	0,03	0,03	0,02	-0,01	0,07	-0,04	0,05	-0,01	0,09
16	-0,04	0,03	-0,04	0,04	-0,02	0,02	-0,07	0,08	-0,11	0,06	-0,07	0,10
50	0,01	0,05	-0,08	0,06	-0,03	0,04	-0,06	0,15	-0,06	0,08	-0,04	0,14
100	-0,07	0,06	-0,25	0,08	-0,20	0,05	-0,32	0,25	*	*	-0,31	0,20

*Gauge block of nominal length 100 mm was not calibrated in laboratory number 5.



I - interferometric method C - comparative method

Figure 1. Graphic presentation of the measurement results

The presented results show with all the gauge blocks a moderate trend towards lower values. Here it can be mentioned that in the archives of the Laboratory there are data according to which it may be obviously seen, i.e. which indicate a significant increase in length (expansion) over a shorter period of time. In any case and according to the statements in literature, both positive and negative trends to change the length (drift) are possible. In the concrete case, we are interested in the reproducibility i.e. compatibility of the presented measurement results. With the aim of indicating compatibility or matching of the results, E_n value was calculated according to the following expression (1):

$$E_n = \frac{|\bar{x}_{lab} - \bar{x}_{ref}|}{\sqrt{U_{lab}^2 + U_{ref}^2}} \tag{1}$$

Value E_n should be less than 1 so that the results could be regarded as compatible.

Compatibility is especially determined for the interferometric method (Table 2.1) and for the comparative method (Table 2.2).

Table 2.1. E_n values for interferometric method

Nominal length mm	$E_{n1,2}$	$E_{n1,3}$	$E_{n2,3}$
1,45	1,41	0,55	1,11
8	0,24	0	0,28
16	0	0,55	0,45
50	1,15	0,62	0,69
100	1,80	1,66	0,53

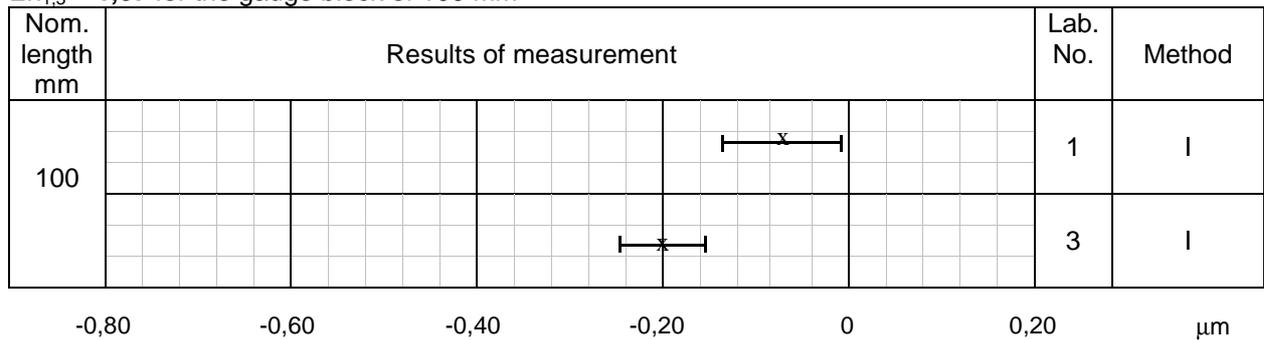
Table 2.2. E_n values for comparative method

Nominal length mm	$E_{n,4,5}$	$E_{n,4,2}$	$E_{n,5,2}$
1,45	0,71	0,64	0,11
8	0,35	0	0,29
16	0,40	0	0,34
50	0	0,09	0,12
100	*	0,03	*

Shaded values in Table 2.1 represent values of factor E_n greater than 1, i.e. cases where the condition of compatibility has not been satisfied. It may be noticed that in four out of five cases where the criteria of compatibility have not been achieved the work included participation of Laboratory 1. Knowing that Laboratory 1 is the laboratory of the gauge block manufacturer, this might have significance since metrology practice has proven many times that the manufacturer's results should be taken with a qualified acceptance. Table 2.2 shows no shaded cells, which means that all the results are jointly reproducible. The reason for this certainly lies, among other things, in greater uncertainties of measurement, i.e. lower level of accuracy compared to interferometric method.

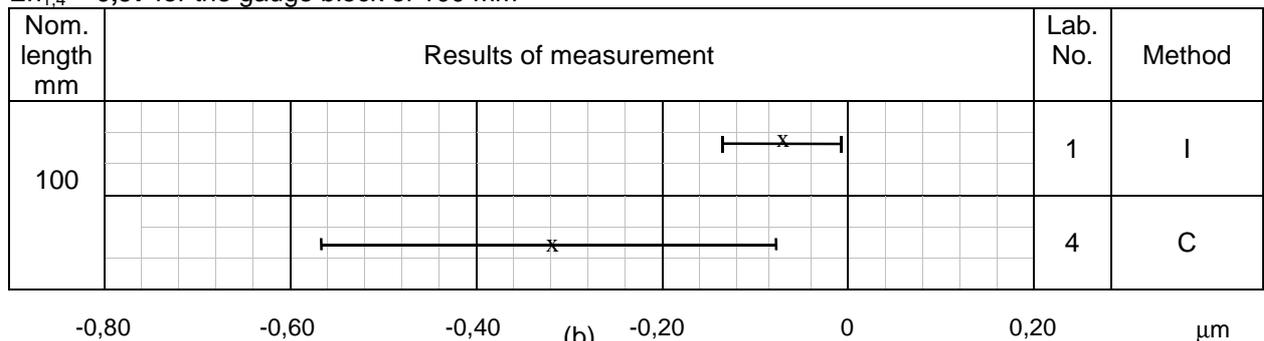
Compatibility analysis has been performed separately for the applied measurement methods. However, in practice, and also in analysing the comparative measurements, comparison is often done with measurement results of different accuracy levels, i.e. of significantly different uncertainties of measurement. This e.g. would be the case when a certain result obtained by comparative method would be compared with a result obtained by interferometric method. What may be concluded in such a case is presented in Figures 3a and 3b.

$E_{n,1,3} = 1,67$ for the gauge block of 100 mm



(a)

$E_{n,1,4} = 0,97$ for the gauge block of 100 mm



(b)

Figure 3. Analysis of factor E_n

In case when results of approximately similar level of accuracy are compared, such as e.g. measurement results of Laboratories 1 and 3, then the compatibility factor for, e.g. gauge block of 100 mm amounts to $E_{n1,3} = 1,67$. This means, then, incompatible. Graphically this can be shown as in Figure 3(a). If, however, compatibility $E_{n1,4}$, was calculated using the expression (1), where the results of interferometric and comparative method are compared, these two results would seem compatible. These results are presented graphically in Figure 3(b). We agree that regarding metrology, the incompatibility presented in Figure 3(a) is acceptable, rather than the grotesque compatibility in Figure

3(b). Therefore, it is to be recommended to define the limitations related to correct usage of this expression. There is sense in comparing the results if the ratio of uncertainty lies within the range of high gradient of change E_n depending on the change of ratio U_{lab}/U_{ref} (area left from the vertical line) as presented in Figure 4.

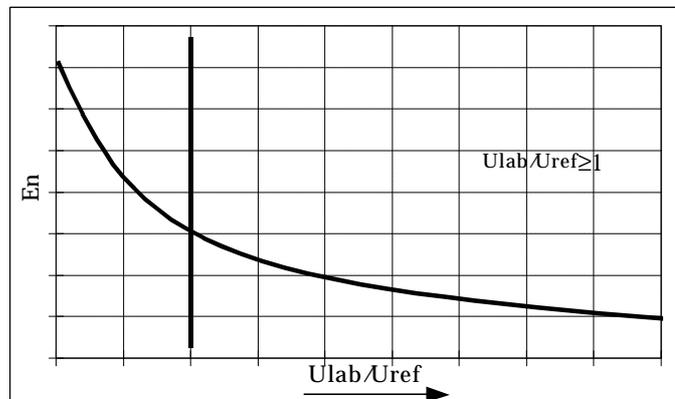


Figure 4. Value E_n depending on ratio U_{lab}/U_{ref}

3 CONCLUSION

Metrology practice, as well as the presented results show that it is necessary to check the gauge blocks in certain time intervals. The check can be carried out in two ways:

- by calibrating the standards in laboratories of higher level,
- by carrying out comparative measurements.

If this includes laboratories of such a level of accuracy that they need reference gauge blocks calibrated by interferometric method, then this may already today cause a big problem. The problem is mostly in the fact that it takes several months for the calibration to be done at one of the European institutes, and often more than half a year, not to mention the high price. Even this might not be such a great problem, hadn't it been stipulated by unwritten rules that this should be done every two years. It is questionable how much sense there is in such a short interval, having in mind that full confirmation of the claimed measuring uncertainties of the observed laboratory may be obtained by its participation in comparative measurements. It is the author's opinion that in the future the calibration intervals using interferometric method should be prolonged (3-5 years) due to technical and financial reasons, with obligatory participation in comparative measurements with the laboratories of similar level of accuracy.

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