PAPER • **OPEN ACCESS**

Experimental study of phase correction determination in steel by stacking method experiment

Experimental study of phase correction determination in steel by stacking method experiment

E Beer, L Álvarez, K Bastida, G Giarmana and L Di Lillo

INTI, Instituto Nacional de Tecnología Industrial, Av. Gral. Paz 5445 CP 1650
San Martin, Buenos Aires, Argentina

E-mail: ethelb@inti.gob.ar

Abstract. The phase correction determination by stacking method experimentation is carried out by comparing the interferometric length of a set of gauge blocks wrung to each other, with the individual interferometric lengths of each gauge block. In this work the repeatability of the phase correction in steel and the uncertainties associated with this correction by using the stacking method are analyzed. Some variables considered in the analysis are the number of gauge blocks that form the stack, the nominal length of the set and the difference of the interferometric lengths obtained for both sides of each gauge block.

1. Introduction

Metre materialization is achieved by using interferometric techniques by means of gauge blocks of different nominal length. The length of the gauge blocks is traceable to standard laser frequencies. These are recommended by the Bureau International des Poids et Mesures, BIPM for the realization of the metre.

In agreement with the definition of the length of a gauge block, and in order to measure its central length, it is necessary to wring the block to an auxiliary platen which has the same surface characteristics and quality. This is not always possible to accomplish in practice. To compensate for differences in reflection properties, a phase correction is added to the measurement result of interferometric calibration of gauge blocks. Reference literature [1,2] has proven that this correction is influenced by material, surface finish and optical properties of gauge blocks and platen. The aim of this work is to study the phase correction obtained by means of the stack method which depends on a variety of parameters.

Our purpose is to establish adequate criteria in the determination of the correction. This has high impact on length measurement quality related to industrial processes, which require tight values of mechanical tolerance, like automotive industry and nuclear technology.

2. Phase correction by stack method

Because of optical properties and superficial quality of materials, the localization of the plane where incident laser radiation is reflected, does not match the real mechanical surface. Such is the origin in the need for the phase correction. The surface quality is also a critical factor in wringing film quality between gauge block and platen.

There are different methods to determine the phase correction from reflectivity or superficial roughness measurements [3,4]. In this work, the stack method is used. The phase correction is experimentally determined for a set of gauge blocks. This method consists in selecting n short gauge blocks from the set, which have been previously measured interferometrically, and the length result for both faces of each block are in good agreement. The blocks are wrung to each other to form a larger one, the stack, (Figure 1).

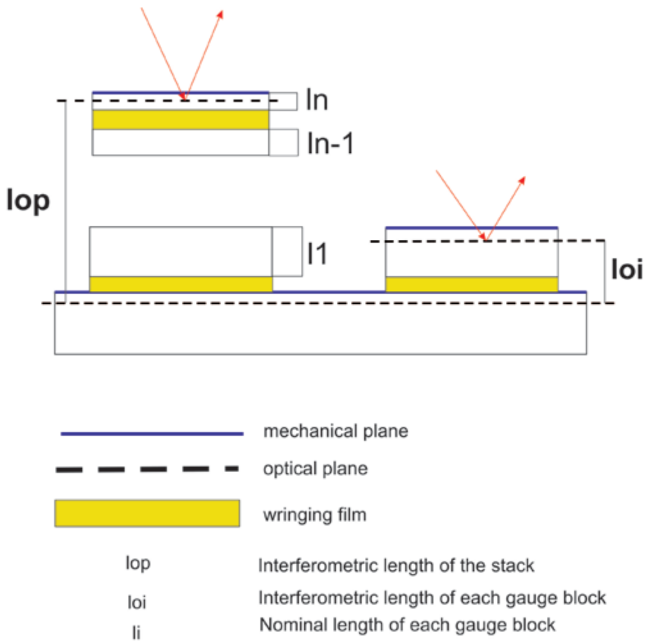

Figure 1. Stack method: localization of mechanical and optical planes.

The length of the pack, $l_{o,p}$,is measured interferometrically, and is compared with the sum of the individual lengths of the blocks $l_{o,i}$ .The difference yields the phase correction ,φ, equation 1

$$\varphi = \frac{1}{n-1}\left[l_{o,p} - \sum_{i=1}^{n} l_{o,i}\right] \tag{1}$$

If the nominal lengths of the gauge blocks that form the stack are short (< 30 mm), the phase correction combined measurement uncertainty is [4]:

$$u_c^2(\varphi) \cong \frac{(n+1)}{(n-1)^2}\left[u_c^2(F_i) + u^2(l_w) + u^2(l_A) + u^2(l_G)\right] \tag{2}$$

The contributions to this uncertainty, equation (2) are due to the fringe fraction F_i , wringing film l_w, wavefront errors l_A and form defects l_G.

3. Experimental method

The phase correction is determined for steel gauge blocks, taking into account the following influence parameters: number of blocks in the stack, total nominal length, difference between interferometric calibration lengths for each of the faces of each block in the stack, Table 1

Interferometric calibration is made in a Twyman Green-TESA system, which uses two stabilized lasers in 633 nm and 543 nm wavelength. Interference pattern are analyzed using the fringe fraction method. Table 2 shows the contributions to the phase correction measurement uncertainty.

IOP Conf. Series: Journal of Physics: Conf. Series **975** (2018) 012030 doi:10.1088/1742-6596/975/1/012030

Table 1. Influence parameters taken into account in the determination of φ in steel.

Stack nominal length	Nº of stacks	Manufacture	Nº of blocks in the stack	Platen
< 5 mm	2	#1	4	106
5 mm < L ≤ 11 mm		#1 (3)	3, 4, 5	106
	5	#2 (2)	3, 4	84 and 83
≅ 15 mm	3	#1 (3)	2, 3	83 and 105
		#1 (4)	3, 4, 5	106
> 20 mm	6	#2 (1)	3	83
		#3 (1)	3	105

Table 2. Contributions to the measurement uncertainty of φ.

Component	u_i (nm)
Fringe fraction, $u(F_i)$	2,2
Wringing film, $u(l_w)$	5,2
Wavefront errors, $u(l_A)$	2,5
Form defects, $u(l_G)$	1,1

4. Results and discussion

Figures 2 to 5 show the results of the phase correction determination as a function of the parameters previously described: number of gauge blocks in the stack, the stack nominal length, the mean length differences between faces of each gauge block in the stack and platen used in the measurements.

It is verified that the uncertainty in φ is reduced by increasing the number of gauge blocks in the stack. Although, in practice, it is better to keep the number of blocks in less than four. This is because of the difficulty in the wringing process in the stack construction. A minor dispersion for the phase correction is observed for stack nominal lengths between 10 mm and 25 mm. The packs wrung on platen 105 and 106 show major dispersion than the rest. In relation to the length difference between faces of individual blocks, it is advisable to take differences between 2 nm and 15 nm.

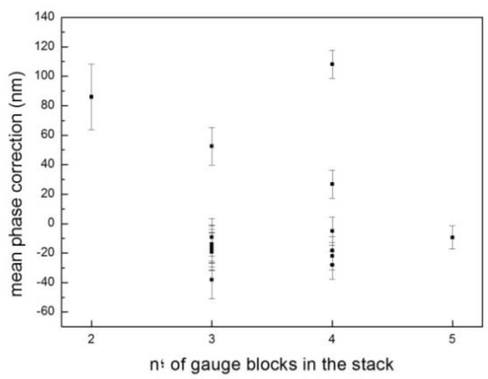

Figure 2. Phase shift as a function of the number of gauge blocks in the stack.

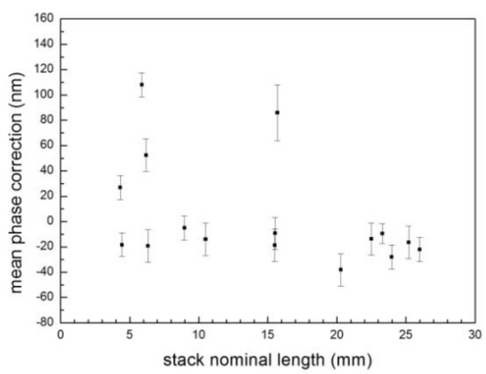

Figure 3. Phase correction as a function of nominal length.

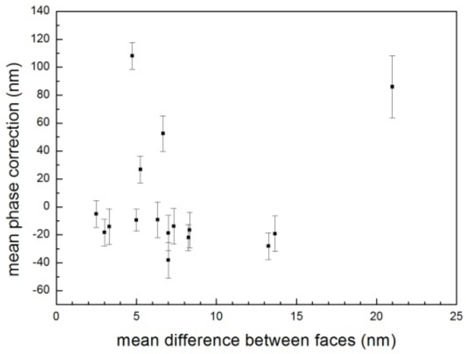

Figure 4. Phase correction as a function of length difference between faces.

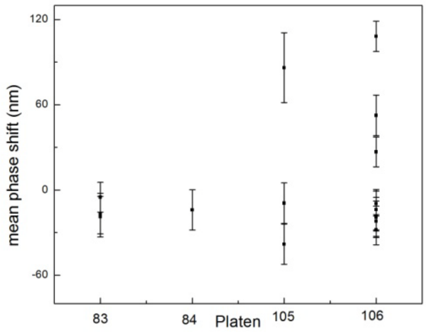

Figure 5. Phase correction as a function of number of platen.

5. Conclusions

The phase shift correction has been experimentally determined using the stack method experiment with different configurations to analyze influence parameters. This has allowed to establish adequate criteria in the determination of the phase shift correction in the interferometric calibration of gauge blocks. This is, in fact, a significative improvement in the materialization of the national length standard at INTI.

Furthermore, it is considered convenient to make a statistical analysis of stacks wrung to different platens. A similar analysis is necessary for the different manufactures; in order to count with an empirical reference that can be used in individual gauge block calibrations or when a particular set of gauge block does not include adequate blocks to build a stack.

6. References

[1] Ramotwski Z and Salbut L 2012 *Meas. Sci. Technol.* **23**

[2] Thwaite E 1978 *Metrologia* **14** pp 53-62

[3] Leach R, Jackson K and Hart A 1997 NPL Report MOT 11

[4] Decker J and Pekelsky J 1997 *Metrologia* **34** pp 479-493