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STUDY OF THE EFFECT OF LASER MARKING FOR STANDARD WEIGHTS

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Abstract: Most class E weights are made of austenitic stainless steel and they do not have any marking to be distinguished. In this study two special types of laser marking have been used to provide a proper marking so that the marking effect is negligible for the mass value and the corresponding drift. The drift has been studied by means of several calibrations during more than 10 years.

Keywords: weights, drift, laser marking.

1. INTRODUCTION

The use of class E weights without marking at metrological laboratories requires the operator to be very careful to avoid any confusion between laboratory and customer weights. Therefore weight marking is good practice to clearly identify individual weights as it helps to link a weight to its calibration certificate.

The OIML R111 recommendation [1] contains technical and metrological requirements for weights and establishes that the surface qualities shall be such that any alteration of the mass of the weights is negligible with respect to certain maximum permissible errors, also established in this recommendation.

The problem of marking weights arises in the metrological laboratories having old sets of weights standards with a long and well known drift behavior. In principle the marking process could cause a change not only in mass value, but also in drift behavior.

In order to evaluate the long term changes in mass, we have checked the mass values of a set of weights have been calibrated for a period of 10 years. This period includes calibrations before and after marking.

2. MARKING PROCESS

There are many systems to mark stainless steel: die stamping, spark erosion, acid etching or laser marking. For his study two special kinds of laser marking have been chosen so that they fulfill the requirements of [1] and they are not aggressive the weights metallic surface.

The weights marked in this study are an E_1.class set from 1 g to 20 kg, so according to table 7 in [1] the maximum marking height should be 2 mm and the maximum width should be 4.8 mm (3 figures × 1.6 mm figure width in CAD for 2 mm height).

Figure 1. Four weights of 10 kg without any mark to distinguish between them.

On the other hand, [1] establishes requirements about the weights surface roughness. These limits for E_1 weights are R_z = 0.5 µm and R_a = 0.1 µm, which are clearly fulfilled by these techniques.

The laser making technique used for the weights between 1 g up to 1 kg is based in irradiation with coherent ultraviolet light emitted by a solid state Nd:YVO_4 laser beam pumped by diodes that work in the third harmonic (λ =355 nm) and pulse time width of nanoseconds. A picture of the device is shown in figure 2.

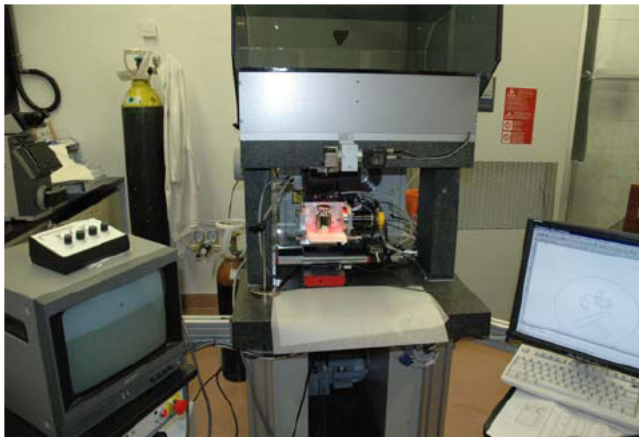

Figure 2. Micromarking system with Laser Optec ML-100

The marking procedure is called "direct writing". In this procedure the laser beam and the optics systems are fixed so that the weight surface remains in the focal plane and the marking is performed in the optical system focus in order to ensure a minimum line width marking. The visibility of the resultant marking is excellent as the interaction between UV laser and metal is poorly thermally affected because the energy absorption for UV is highly efficient. The resulting marking lines have 10 μm maximum width and a controlled depth between 100 nm and 300 nm.

On the other hand, the laser marking technique used for weights from 2 kg up to 20 kg is based in irradiation with coherent infrared light emitted by a solid state Nd:YAG laser beam pumped by diodes that work in the fundamental harmonic (λ = 1064 nm) and pulse time width in the range of thenths of nanoseconds. A picture of the device is shown in figure 3

Figure 3. Micromarking system with Laser Trumpf VectorMark VWS 800

The marking procedure is based on a lighting technique by means of a scanner. The IR irradiation with controlled pulse width allows marking by means of an allotropic transformation of the material with slight generation of molten phase.

In both cases the material interacts with the metallic surface of the weight being mainly absorbed by the free charge from the metal. However, in the IR irradiation case the photonic mean free path in the material is lower than in the IR case, which allows establishing a controlled ablation process with minimum mass ablation compared to the achieved visibility and contrast.

On the other hand, in the IR case the energy absorbed by the surface electrons in the photonic field is thermally conducted up to a limited depth, allowing an allotropic transformation of the material and a possible surface fusion with depth around tenths of nanometers.

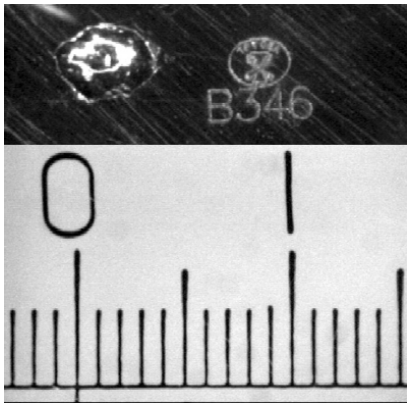

Figure 4. Photograph of one example for the marking of one weight with indication of their dimensions in mm.

In figure 4 there is an example of the marking. The big marking on the left corresponds to the initial marking made by the manufacturer in order to distinguish duplicated weights. At he bottom of the photograph there is an indication of the horizontal dimensions in mm.

Prior to the analysis of the possible mass variation induced by the marking process and its evolution along time, a parallel analysis of the variability of the marked features was performed for the case of the specimens of lower nominal value (i.e. 1 g to 50 g) in order to check for the stability of the induced modifications along time.

In figure 5, the respective confocal microscope views corresponding to three different observation moments (June 2007, November 2007 and July 2008) made on the mass of 1 g can be observed with the results corresponding to four typical regions defined around the performed mark. For each of these regions, the surface roughness parameter S_a defined as:

$$S_a = \frac{1}{A}\iint_A |Z(x,y) - Z_{av}|\, dA$$

was evaluated. Their results are displayed in Table 1.

Region	S_a (nm) June '07	S_a (nm) Nov. '07	S_a (nm) July '08
1	136,12	110,44	118,72
2	152,48	113,76	123,41
3	26,76	21,43	26,97
4	43,51	45,98	38,03

Table 1. Comparison of surface roughness parameter, S_a, determined by confocal microscopy in four characteristic regions around the mark of the mass of 1 g nominal value in three different moments after the production of the mark.

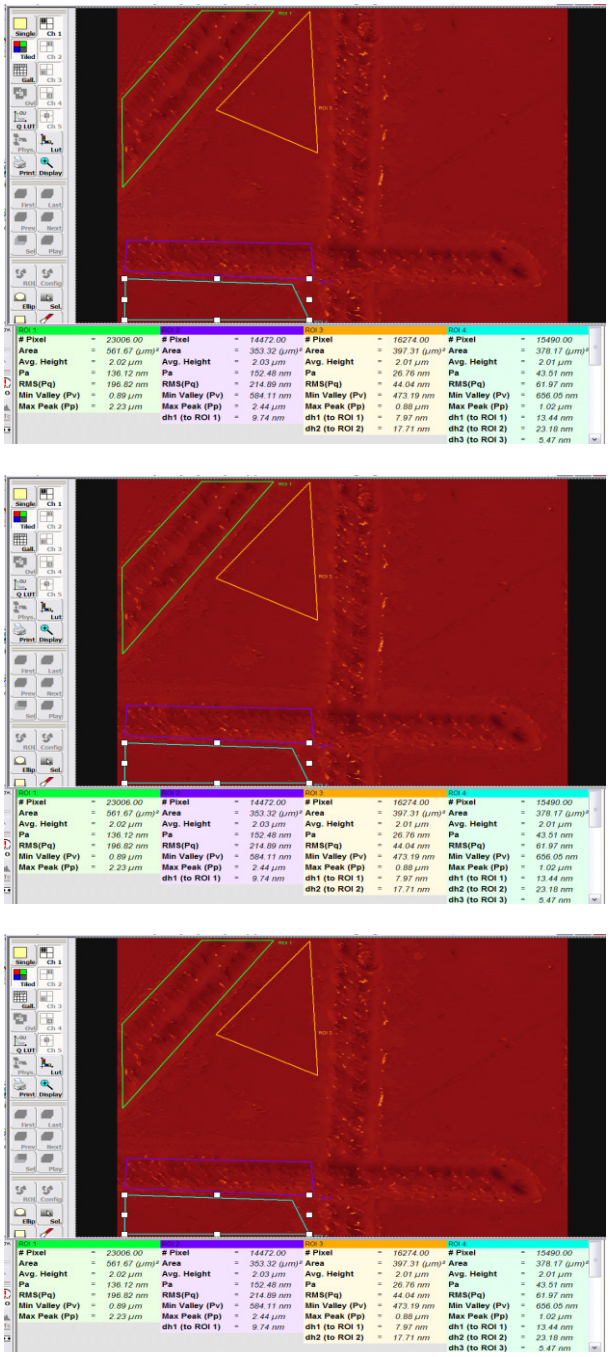

Figure 6. Comparison of microscopic observations and confocal microscope topographic analysis for different characteristic regions around one of the marked features in the 1 g weight obtained respectively in June 2007, November 2007 and July 2008.

According to the numerical data obtained for the surface roughness and the microscopic observations, which were performed over the different standard masses, a clear conclusion can be extracted. The topographical alterations and roughness states induced in them as a consequence of the considered laser marking processes have a remarkable time stability implying a full conservation of the marking visibility along the time with no appreciable alteration of the surface properties. In fact the small numerical differences observed can be attributed to the difference among sampling surfaces at each measurement time and their corresponding measurement uncertainties. These results effectively support the practical conservation of the mass values described in the next section.

3. MASS MEASUREMENT

Nominal value	Maximum permissible error (mg)	Maximum expanded uncertainty (mg)
20 kg	10	3,0
10 kg	5,0	1,6
5 kg	2,5	0,8
2 kg	1,0	0,3
1 kg	0,5	0,16
500 g	0,25	0,08
200 g	0,10	0,03
100 g	0,05	0,016
50 g	0,03	0,01
20 g	0,025	0,008
10 g	0,020	0,006
5 g	0,016	0,005
2 g	0,012	0,004
1 g	0,010	0,003

Table 1. Maximum permissible errors and the maximum expanded uncertainty allowed in the mass measurements for each nominal value according to [1]

The weights marked in this study are an E_1 set from 1 g to 20 kg. Table 1 shows the maximum permissible errors and the maximum expanded uncertainty allowed in the mass measurements for each nominal value according to [1].

The mass values were measured every 3 or 5 years from 1995 to 2016. The weights were marked in 2006. Another set of identical weights from the same manufactured were used as a contrast. This set was always stored at the same place and also calibrated like the marked set. Before calibration each weight was cleaned with alcohol and thermally stabilised following the recommendations included in [1], section B.4.

The following figures show the mass change for every weight under study in every plot it is shown the mass change for a marked weight and the no marked weight of the same nominal value over time. The vertical line corresponds to the moment when the marking was performed. The horizontal lines show the maximum expanded uncertainty limits.

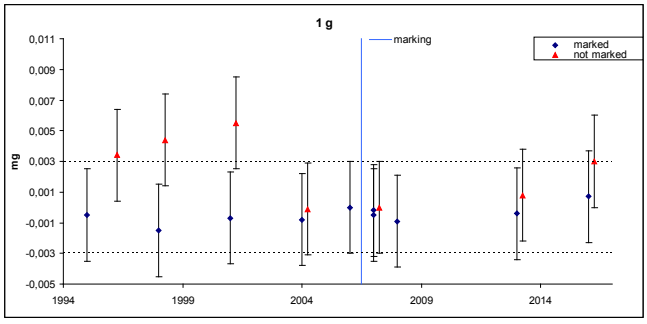

Figure 5. Mass change for 1 g weights

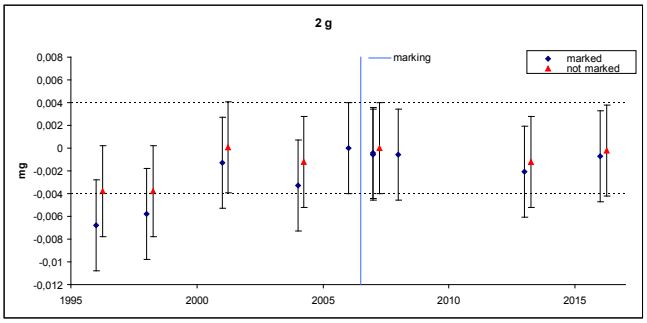

Figure 6. Mass change for 2 g weights

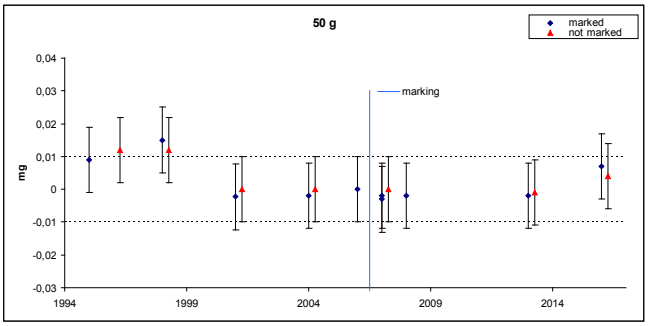

Figure 10. Mass change for 50 g weights

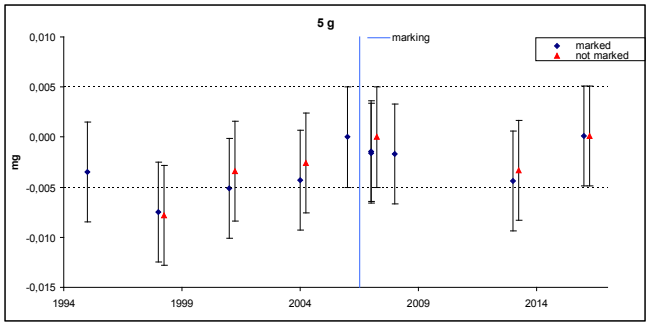

Figure 7. Mass change for 5 g weights

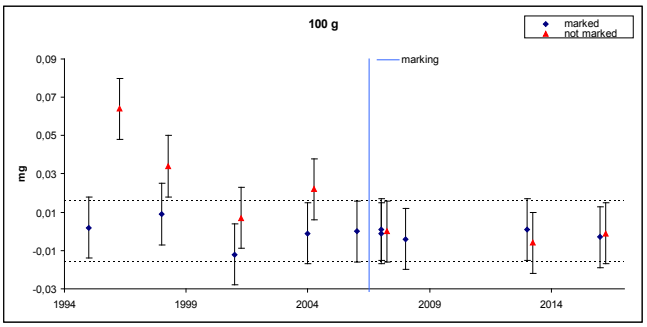

Figure 11. Mass change for 100 g weights

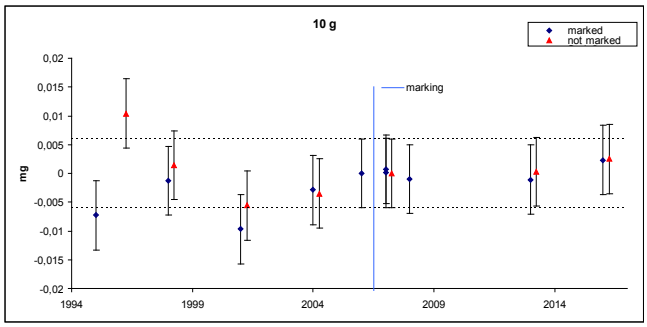

Figure 8. Mass change for 10 g weights

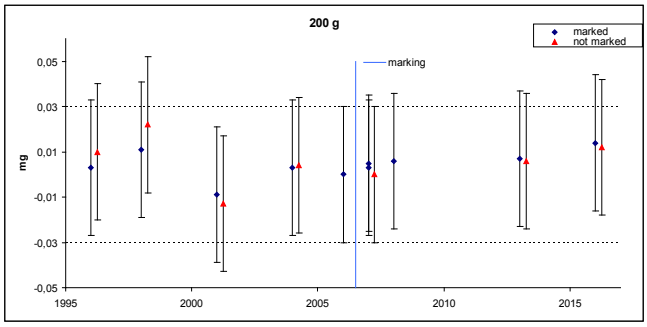

Figure 12. Mass change for 200 g weights

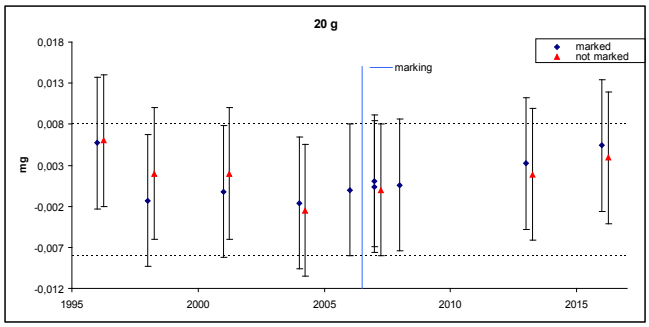

Figure 9. Mass change for 20 g weights

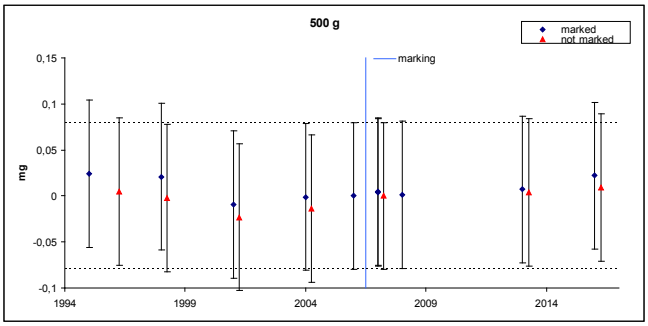

Figure 13. Mass change for 500 g weights

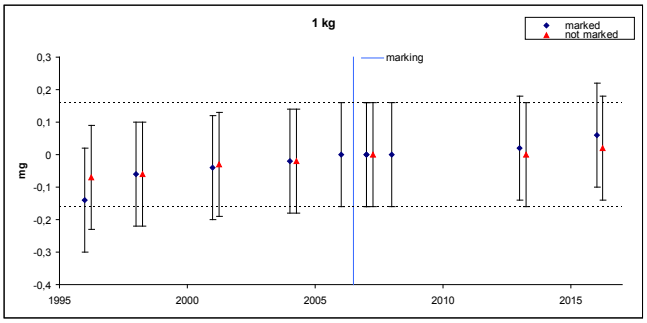

Figure 14. Mass change for 1 kg weights

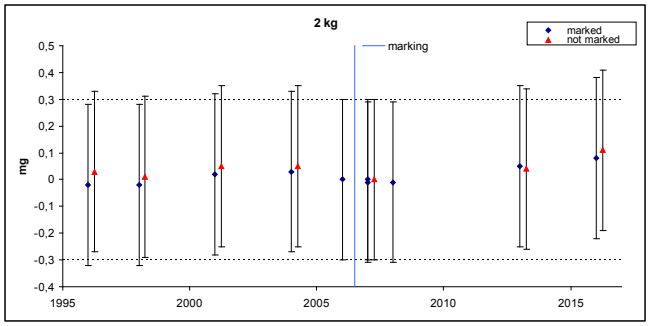

Figure 15. Mass change for 2 kg weights

The results clearly show that there are no significant changes in mass values over the time as they always remain between the uncertainty limits. On the other hand, it is also clear that the weights drift behaviour is not affected, as there is no difference in the behaviour of marked weights and no marked weights.

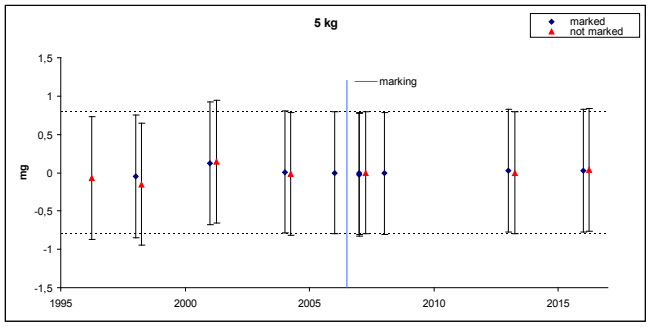

Figure 16. Mass change for 5 kg weights

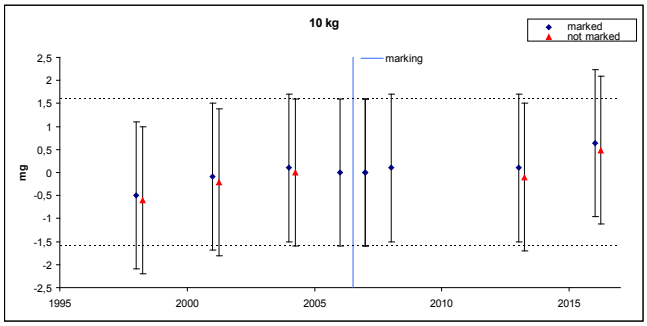

Figure 17. Mass change for 10 kg weights

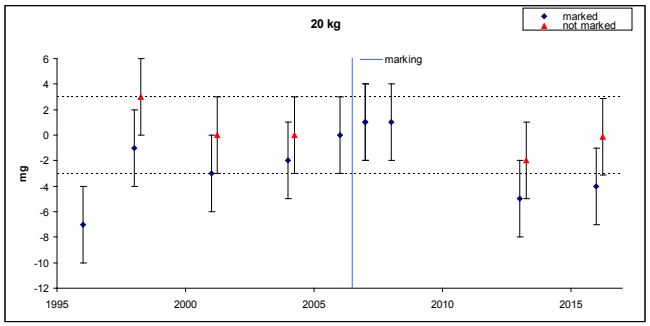

Figure 18. Mass change for 20 kg weights

4. CONCLUSIONS

The present study shows there is no effect in the mass values and the possible drift for the two kinds of laser marking used. These kinds of marking are a very good option for marking "old" high accuracy weights with any effect in their metrological characteristics. Of course, it is always recommended to calibrate the weight before and after the marking in order to ensure the marking has been properly performed and there is no significant change in the mass value.

References:

[1] OIML R 111-1. "Weights of classes E_1, E_2, F_1, F_2, M_1, M_{1-2}, M_2, M_{2-3} and M_3. Part 1: Metrological and technical requirements", 2004.