GAUGE BLOCKS DIMENSIONAL STABILITY IN TIME: PROPOSAL FOR INITIAL MATERIAL CHARACTERIZATION

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Abstract. *As it is know, the gauge blocks sizes should remain within a desired dimensional constancy in time. Many users have reported a change of the dimension of the hardened and aged gauge steel blocks. This dimensional instability has been report as shrinkage, growth or as change from one to the other at different times of measurement. Dimensional stability is a prime requirement for gage blocks, and stability could be affect by the structure and stresses within materials. The used steels have a metastable structure, which has a tendency to martensite transformation with an expected reduction in volume effect. After tempering operations, the phases are also metastable and can transform into bainite upon ageing at room temperature with an increasing effect.*

Residual stresses can induce in the gauge blocks at room temperature, a growth or shrinkage depending on the sign and orientation of the stress. Several other characteristics and properties are necessary in addition to dimensional stability: a high degree of surface finishing; flatness of surfaces; a parallelism of opposite faces for precise measurements, characteristics that are related to the surface hardness and structure. The coefficient of thermal expansion should be equal to those of high carbon steel. The materials with zero or very low coefficients are the best. Accuracy temperature control is essential and both gauge block and the measured piece must to come to the same temperature.

Keywords: *gauge block, thermal expansion, microhardness, shrinkage*

1. INTRODUCTION

As it is know, the gauge blocks sizes should remain within a desired dimensional constancy in time. Many users have reported a change of the dimension of the hardened and aged gauge steel blocks. This dimensional instability has been report as shrinkage, growth or as change from one to the other at different times of measurement.

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Dimensional stability is the main characteristic for the gauges, which is dependent of thermal microstructure stability and internal stresses, in final state.

2. PROPOSED METHODOLOGY

The eight gauges blocks were selected, to be characterized. The specimens for metallography, microhardness and expansion tests were sampling from the gauges like it shown in Figure 1.

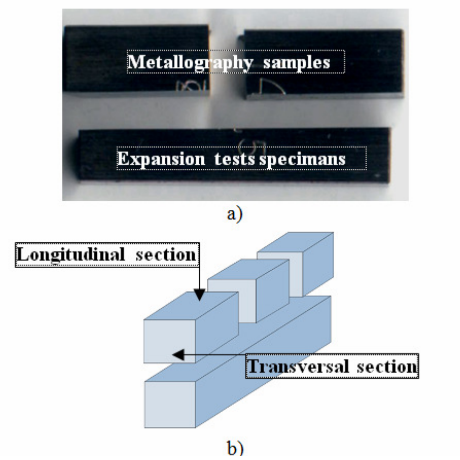


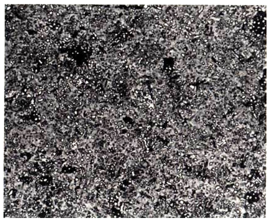
Figure 1. a) - Gauge block section for metallography and expansion test; b) – drawing for metallography samples in longitudinal and transversal section
Table 1. Margins and columns to be used in this paper

In order to characterize the gauge blocks, the proposed methodology consist of the next steps;

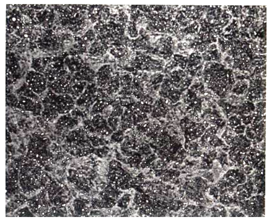
- Microstructure characterization (structure identification);
- Microhardness characterization;
- Thermal stability (expansion test in order to measure the coefficient of thermal expansion (CTE).

2.1 Microstructure characterization

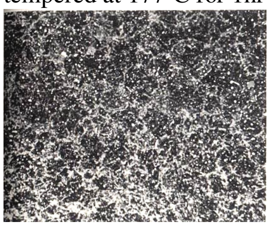
The microstructure for the eight gauges studied is typically for a ball bearing steels.
For exemplification and for identifying the microstructure, see Figure 2 is show the microstructures of these steels from Metal Handbook [2].



a) 52100 steel, austenitized at 788^{0}C for 1/2hr, oil quenched, tempered at 177^{0}C for 1hr



b) 52100 steel, austenitized at 843^{0}C for ½ hr, oil quenched, tempered at 202^{0}C

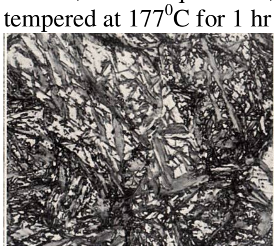


c) 52100 steel, austenitized at 857^{0}C for ½ hr, oil quenched, tempered at 260^{0}C for 1 hr

d) 52100 steel, austenitized at 843^{0}C for ½ hr, oil quenched, tempered at 399^{0}C for 1 hr

e) 52100 steel, austenitized at 843^{0}C for ½ hr, oil quenched, tempered at 177^{0}C for 1 hr

f) same specimen as used for d), tempered martensite



g) 52100 steel, austenitized at 982^{0}C for ½ hr, oil quenched, tempered at 177^{0}C for 1 hr

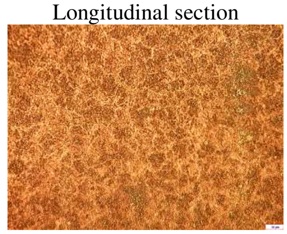
h) 52100 steel, austenitized at 857^{0}C for ½ hr, oil quenched in a salt bath at 260^{0}C for 1 hr, held for ½ hr, air cooled to room temperature

Figure 2. Microstructures of 52100 steels from Metal Handbook [2]

Structure identification

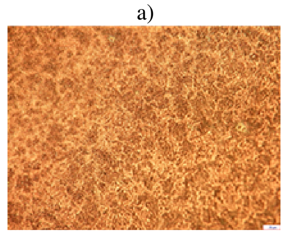
The same structure can be seen in Figure. 3.

Longitudinal section | Transversal section



a)

b)



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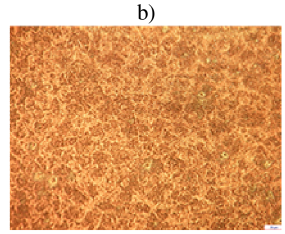

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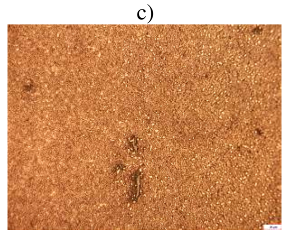

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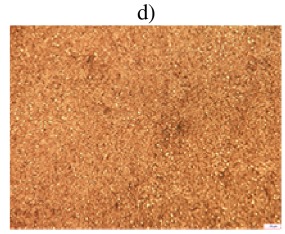

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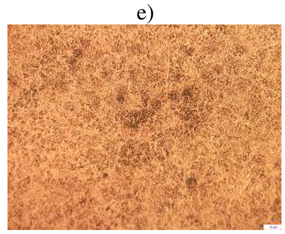

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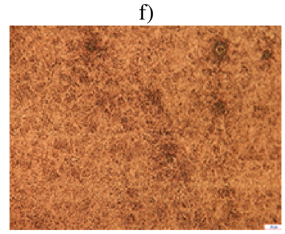

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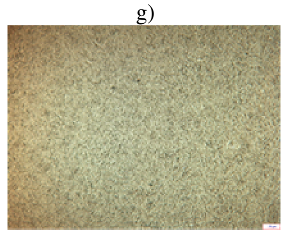

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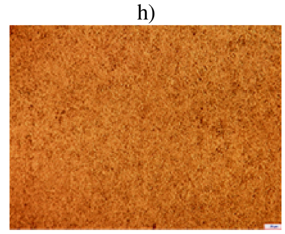

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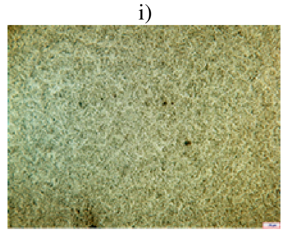
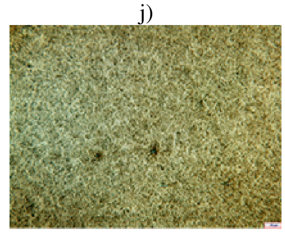


k)



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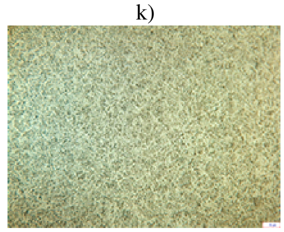

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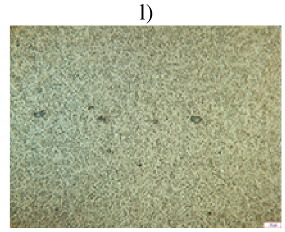
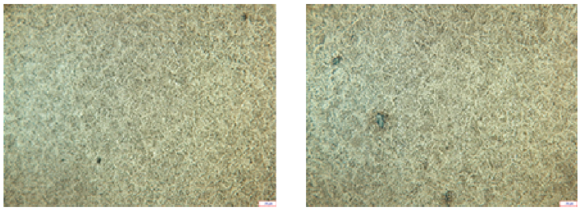


n)



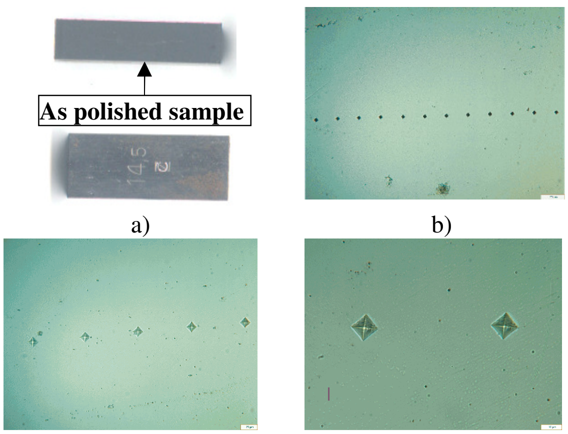
o) p)

Figure 3. Metallography of gauges: a, b) - 1; c, b) – 2; e, f) – 3; g, h) – 4; i, j) - 4; k, l) – 5; m, n) – 6; o, p) – 7.

Structure consists of a mixture of tempered martensite, lower bainite, spheroid carbides and retained austenite.

2.2 Microhardness Testing

Tests were performing on an Epitip microscope and the results are the average of ten indentations per section and sample (see Figure 4).



a) b) c) d)

Figure 4. a) – Sample for microhardness indentation; b, c, d) – Indented sample

The microhardness tests results are show in Table 1.

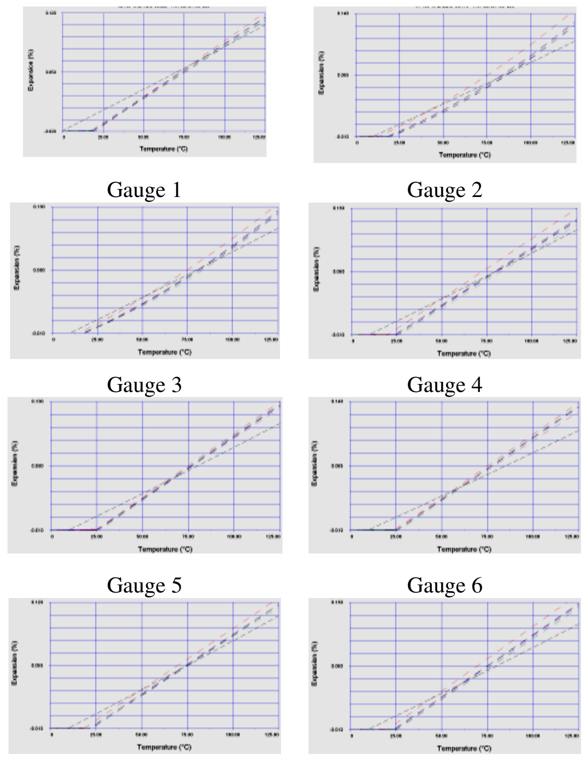
Table 1. Microhardness tests results

MICROHARDNESS		
Gauge	Longitudinal, $[HV_{100}]$	Transversal, $[HV_{100}]$
1	1158.30	1193.97
2	1123.81	1166.99
3	1076.44	980.33
4	1167.44	1022.49
5	1067.44	1022.49
6	903.47	940.72
7	940.71	940.72
8	940.71	1067.44

The microhardness is the main characteristic of this steel class; reflects the precision of heat treatments.
Gauge block dimensional stability at the temperature range bellow 150^0C, associated with hardness, are the main characteristics, in this case. For example, the relative deformation after tempering at 150^0C is about 10^{-5}mm.

2.3. Expansion Tests

As a result, after a simulation in the expansion tests, after 5 cycles of heating and cooling, at the same range, the final retained expansion length for the eight gauges block specimens are: 0,009µm, 0,002µm, 0,007µm, 0,004µm, 0,002µm, 0,004µm, 0,005µm, 0,006µm.
Expansion tests graphs are show in Figure 5.
A reference curve (the cut short line) is figure on the same graph in order to be easy to compare (reference curve – 316L steel).



Gauge 1, Gauge 2, Gauge 3, Gauge 4, Gauge 5, Gauge 6, Gauge 7, Gauge 8

Figure 6. Gauges expansion test

The coefficient of thermal expansion (CTE), decreasing with the number of repeated increasing tests.
In the same time, the residual stresses pitch decrease and gauge block dimensional stability increase in time.
Here it is some clue already known technological solutions which can increase the gauge blocks dimensional stability, without substitute the gauge material**.**

3. CONCLUSIONS AND DISCUSSIONS

According to the proposed methodology steps, we can affirm that:

- The gauge block has the required hardness (minimum 65HRC according to ISO 3650) [3]
- The hardened surface (active one) presents uniform values (between 1343.6 and 1140.6

Hv100) for 85 measurements.

- Uniform structure (bainite) with formed secondary carbides and a hardened surface can be observed from the metallographic analysis. This type of structure could induce a dimensional instability in time.
- from the thermal linear expansion tests we can observe that the material have a variation of expansion from the first cycle (0,014 mm residual expansion) to the others (0,011mm) that means that the residual stresses accumulated at room temperature in time are released.

4. REFERENCES

[1] West Port Corporation, ISO 9001, 6506, 6508 & ISO/IEC 17025 & ANSI/NCSL Z540 Accredited, http://www.westportcorp.com/gages/Gage%20Blocks.asp?gclid=CIS80JmS8rcCFYSV3god0jYAVA

[2] Metals Handbook, Metallography, Structures and Phase Diagrams, Vol. 8Vol.8, ASM International,

[3] SR EN 3650:1999, Geometric Product Specifications (GPS). Length standards. Gauge.