Uncertainty Evaluation for Martens Hardness. Analysis of the Velocity effect.

G. Barbato[1], G. Brondino[1], M. Galetto[1], A. Germak[2]

[1] DSPEA, Politecnico di Torino, Torino, Italy, mgaletto@athena.polito.it

[2] CNR-IMGC, Torino, Italy, a.germak@imgc.to.cnr.it

Abstract

The effect of indentation velocity is well known as one of the most significant parameters in hardness measurement. Tests accurately done using a primary hardness machine have shown effects larger than expected, however compatible with the differences evidenced with international comparisons, therefore acceptable in principle. This paper presents the measurement procedure adopted and the results obtained, with the invitation to other researchers to test velocity effect with different apparatus, to evidence, with independent measurement, the confirmation or rejection of obtained results and to help in finding an explication for this strong effect.

Introduction

Uncertainty evaluation for Martens Hardness is a complex task. As usual for hardness measurements, it requires the evaluation of different effects, due to the many parameters defining the hardness scale. Experience on Rockwell and Vickers scales has shown that one of the most significant parameters is the effect of indentation velocity [1,2,3]. Inherent correlation between time and velocity was, in the past, a strong reason of misunderstanding, therefore it was decided to start from the analysis of this factor.

The results obtained are significantly larger than expected, therefore it was necessary to deeply analyse each step of the measurement procedure adopted to understand the reason of such a large effect. On the one hand apparently every measurement was carried out correctly, on the second hand, looking at results of international comparisons [4], one can note that differences between participants are even larger. Should the velocity effect be one of the main components of the uncertainty, the authors decided to present e description of the work performed, to help in understanding the reasons of differences evidenced during the said comparison, and in defining proper tolerances in reference documents, to allow compatible results in Martens Hardness measurements.

This work represent a first approach to that problem, and the obtained results demonstrate the need of a more extensive investigation for a complete uncertainty budget analysis.

Experimental phase

Design of the experiment

The aim is to analyse the effect of velocity in the Instrumented Indentation Test [5] at three different hardness level, HM_S = (5500, 1700, 760) N/mm^2. The analysed parameter is only the Martens Hardness value.

Proc. of 2nd eu**spen** International Conference – Turin, Italy – May 27th – 31st, 2001

Due to the physical characteristics of the test machine, in this phase it is not possible to separate the time and the velocity effects.
The experiment has been designed in order to separate the possible effect coming from the non uniformity of the hardness blocks used for the investigation. The surface of each hardness block has been divided in 16 zones in order to follow a Latin Squares scheme as shown in fig. 1; the capital letters represent the four velocity levels at which the experiment has been conducted.

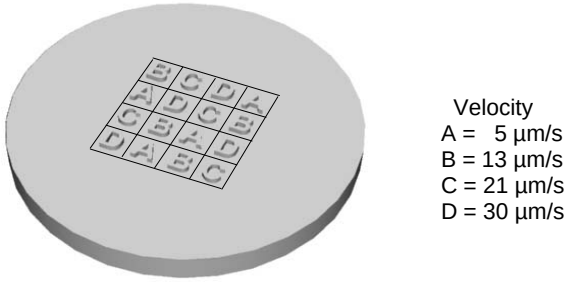

Fig. 1: scheme of the Latin Square used for arranging the indentations on the surface of each hardness block. The capital letters represent the four velocity levels at which the experiment has been conducted.

Test execution

Tests have been performed using the IMGC Primary Hardness Standard Machine following the relevant ISO standard specifications [5]. Forces are generated by dead weights and measured by a load cell with a resolution of 10 mN. Displacements are measured using a laser interferometer system with resolution of 0,01 µm.
The capacity of the IMGC machine is about 2 000 N: for these experiments the maximum applied force has been 300 N.

Data analysis

Data analysis is based on force versus depth curve. From data has been calculated Martens Hardness value (HM_S) for each of the 48 tests performed.
The first analysis with the Latin Squares had the aim to highlight possible non uniformity effects of the surface block's hardness. From the analysis of variance the null hypothesis that position factor has not influence can not be rejected (p-value is bigger than 5%).

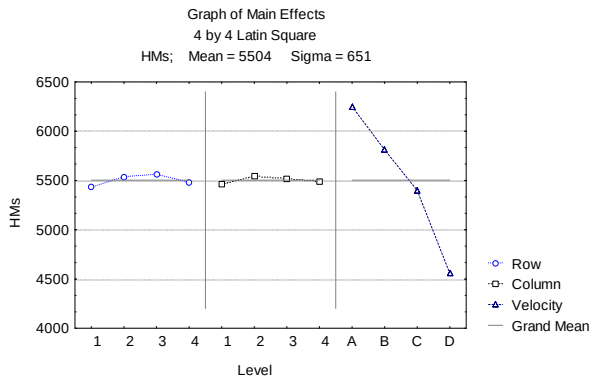

Fig. 2: Latin Square analysis of high hardness block (5 500 N/mm^2): Graphic of Main Effects.

This demonstrate that uniformity of surface block's hardness is adequate to carry on the investigation of other parameters.
The second analysis is concerned about the influence of indentation velocity at different hardness level.
The performance of HM_s at different velocity has been analysed by means of indentation final velocity. This choice drifts from experience in Rockwell's test.
For each hardness level the relationship between the mean values of HM_s and indentation final velocities has been calculated. The relative variation of each mean value of HM_s has been estimated in order to do a comparison at different hardness levels, see fig. 3.

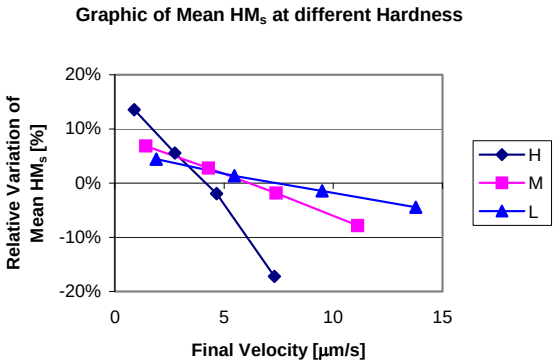

Fig. 3: relationships between relative variation of Mean HM_s and final velocity at different hardness levels (High, Medium, Low).

The hardness decreases when indentation final velocity increases. This trend is most visible for high levels of hardness, therefore the high hardness blocks have bigger sensitivity to indentation velocity.

In this analysis the time and the velocity effects cannot be separated. It's necessary a further processing, as there could be correlation between time and velocity. For this reason the data have been recalculated for different levels of applied force (200 N, 100 N). The values of HM_s and final velocity at different levels of force have been compared.
As shown in fig. 4 for high hardness level, the three levels of force do not alter the trend of HM_s versus final velocity. This is true for each hardness level.

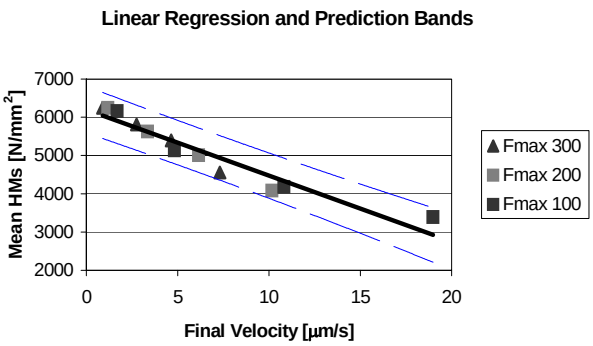

Fig. 4: relationships between Mean HM_s and final velocity at different force levels at high hardness level (5 500 N/mm^2).

Conclusions

The performed analysis has highlighted the strong influence of the velocity in Martens Hardness measurements. This fact confirm, on the one hand, the know effect on evidenced by Marriner [3] of NPL for Rockwell and Vickers scales, as produces variations with the same trend. On the other hand the amount of variation is strongly larger: to give a comparison, the effects evidenced for Vickers scales on hard blocks is in the range of 1%, result compatible with that found for the Rockwell scale, about 0,5 HRC [1]. For Martens hardness the difference obtained was in the range of 10%, that is ten times larger then the amount observed for other scales.
Every possible instrumental reason for that was examined, and eventual reason connected with the different condition of measurement, static for Vickers and Rockwell scales, dynamic for the Martens scale, were discussed. No reason connected with the measurement was found to envisage the presence of experimental errors. At the end of such comprehensive work of revision the authors decided to present the results obtained, at least to give a sign of warning to a factor that require the attention of researchers to a point that needs further investigations. In fact many questions are still open, apart of the principal one on the real amount of velocity effect. The main questions could be:

- the effect observed depends from the velocity with which the total load is reached, as observed for Rockwell and Vickers scales? But in the case of Martens scale the concept of total load is not completely significant, as the measurement of force and indentation is continuous.
- Is a time effect present? The analysis done at different loads, that means different indentations and different time, did not show a significant effect. So, being not likely that the effect of time is completely compensated by force and indentation effects, one should conclude that the time is not significant (to reach this conclusion it could be better to use and experimental plan with independent variations of velocity and time).

As one can see, many problems have to be investigated, therefore the best conclusion is to invite again the researchers to perform independent tests, to evidence the reasons of such a phenomenon.

References

[1] Barbato, G., Desogus, S., Germak, A., 1998, *Experimental analysis on the influence quantities in the Rockwell C hardness Test*, Proc. HARDMEKO '98, Beijing, China, Sept. 21-23, 1998, pp.67-73.
[2] Barbato, G., Desogus, S., Germak, A., 1994, *Hardness measurement from empiricism to metrology an application to Rockwell C scale*, from "Basic metrology and applications", Ed. Levrotto & Bella, 1994, pp. 112-117.
[3] Marriner, R. S., Wood, J. G., 1972, *Comparisons of international Rockwell C and Vickers HV30 Hardness scales during 1970 and 1971*, NPL report MC8, 1972.
[4] Ullner, C., Quinn, G., 1997, *Round Robin on Recording Hardness*, VAMAS, Technical Working Area 3, DRAFT 2, July 16, 1997.
[5] ISO/DIS 14577-1,2,3, 2000, *Metallic materials – Instrumented indentation test for hardness and materials parameters*.