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Determination and uncertainty propagation of sensitivity coefficients in rockwell hardness measurements

Original

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$$u_Y^2 = \sum_{i=1}^N \left(\frac{\partial \mathcal{F}}{\partial X_i} \Big|_{X_0} \right)^2 u^2(X_i) +$$

$$2 \sum_{i=1}^{N-1} \sum_{j=i+1}^N \frac{\partial \mathcal{F}}{\partial X_i} \Big|_{X_0} \frac{\partial \mathcal{F}}{\partial X_j} \Big|_{X_0} u(X_i, X_j),$$

$$Q : \ddot{u} \quad Q : \ddot{u} \dot{\gamma};$$

$$: \ddot{u} \dot{\gamma}$$

sensitivity coefficients

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$$c = c(X_1^{\text{ref}}, \dots, X_N^{\text{ref}}),$$

$$X_0 = (\delta X_1 + X_1^{\text{ref}}, \dots, \delta X_N + X_N^{\text{ref}})$$

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$$u_Y^2 = \sum_{i=1}^N c_i^2 u^2(X_i) + 2 \sum_{i=1}^{N-1} \sum_{j=i+1}^N c_i c_j u(X_i, X_j)$$

3. CASE STUDY: HARDNESS MEASUREMENTS AND THE PROBLEM OF TRACEABILITY

2.2 Sensitivity coefficients with non-negligible uncertainties

$$Y = \tilde{\mathcal{F}}(c_1, X_1; \dots; c_N, X_N)$$

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$$\sum_{i=1}^N \left(\frac{\partial \mathcal{F}}{\partial c_i} \Big|_{c_0, X_0} \right)^2 u^2(c_i) +$$

$$+ 2 \sum_{i=1}^{N-1} \sum_{j>i}^N \frac{\partial \mathcal{F}}{\partial c_i} \Big|_{c_0, X_0} \frac{\partial \mathcal{F}}{\partial c_j} \Big|_{c_0, X_0} u(c_i, c_j) +$$

$$+ \sum_{i,j=1}^N \frac{\partial \mathcal{F}}{\partial c_i} \Big|_{c_0, X_0} \frac{\partial \mathcal{F}}{\partial X_j} \Big|_{c_0, X_0} u(c_i, X_j),$$

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$$HR = N - \frac{h}{S}$$

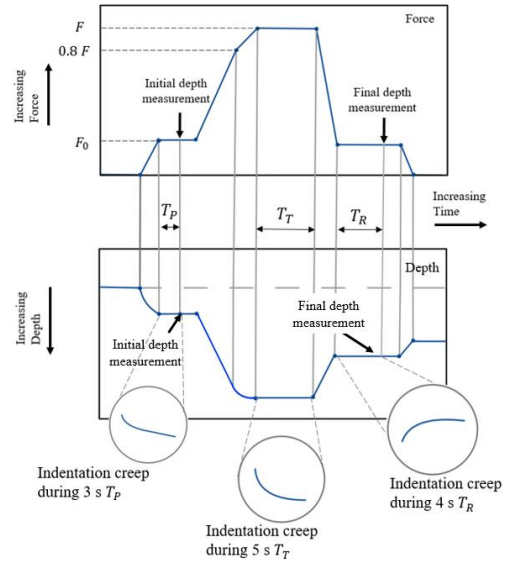
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$$HR = N - \frac{h}{S} + \sum_{i=1}^N c_i X_i,$$

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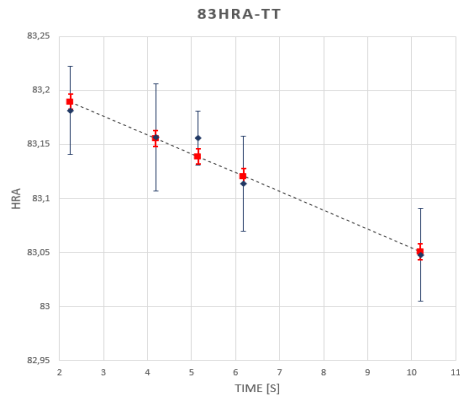
7 = 9 -

Nominal	c_P /(HRA/s) (3s)	c_T /(HRA/s) (5s)	c_R /(HRA/s) (4s)
83 HRA	0.0004 ± 0.0098	-0.0149 ± 0.0072	0.0038 ± 0.0065
73 HRA	0.0120 ± 0.0173	-0.0210 ± 0.0102	0.0067 ± 0.0945
63 HRA	0.0347 ± 0.0301	-0.0490 ± 0.0512	0.0256 ± 0.0298

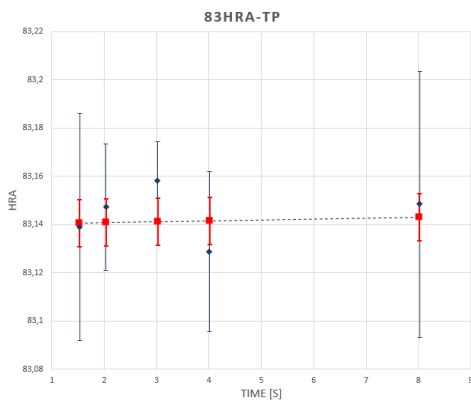
3.1 Case A: Evaluation of the sensitivity coefficients

P R T

$$HR = N - \frac{h}{S} + c_P \delta T_P + c_T \delta T_T + c_R \delta T_R,$$



a



b

3.2 Case B: Evaluation of the combined standard uncertainty

the international ‘Guidelines on the estimation of uncertainties’

$$r = \frac{F}{4} \cdot \frac{v}{\alpha} \quad (4)$$

r , indenter angle α , preliminary test force dwell F_4

and α , since those quantities were obtained via an

$7 = 9$

	Estimate	U
c_{F_0} [HRC/N]	0.05	0.02
c_F [HRC/N]	0.02	0.003
c_α [HRC/°]	0.04	0
c_r [HRC/ μm]	0.05	0
c_h [HRC/ μm]	0.5	0
c_v [HRC/($\mu\text{m}/\text{s}$)]	0.03	0.01
c_{t_0} [HRC/s]	0.004	0.003
c_t [HRC/s]	0.03	0.02

$4 \# \hat{\sigma}_F \cdot 4 \# \hat{\sigma}_\alpha$

Such a model (for r and α) could not be fully

$$HR = N + c_h h + \sum_i c_i \delta X_i,$$

$$\sigma = -1/S$$

σ

		U
a	HRC EURAMET [4] $\delta X_i = 0$	1.26
b	HRC MODIFIED $\delta X_i = 0$	1.27
c	HRC EURAMET [4]	0.07
d	HRC MODIFIED	0.11

4. CONCLUSIONS

σ

σ

$$u_{HR}^2 = \frac{u^2(h)}{S^2} + \sum_i c_i^2 u^2(\delta X_i) + \sum_i \delta X_i^2 u^2(c_i)$$

σ

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5. REFERENCES

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• σ_a

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test, Proc. of the HARDMEKO '98, Sept (1998) 21-

“guide to the expression of uncertainty in measurement”, Propagation of distributions using a