Thermo-electric characteristics of carbides

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P. C. Veenstra, Chr. Bus, N. A. L. Touwen, A. C. H. Van der Wolf, Eindhoven, University of Technology

Introduction

The aim of this investigation was to obtain numerical data for the relationship between thermo-electromotive forces and temperatures for several grades of carbide and workpiece material (C45N). For reasons of proper calibration, every experiment was carried out versus platinum (Pt). This metal has many advantages, such as:

- high melting point,
- great stability as far as corrosion is concerned,
- no transformation points.

Method of Test

The calibration set-up consists principally of a radiation furnace and cooling device, Fig. 1.

Both ends of the bar were connected to a platinum wire. The temperatures of the hot and cold junctions were measured by Cr/Al thermocouples and were recorded on paper-tape by means of a data-logger. At the same time the emf voltage between the hot and the cold junctions of the calibration bar was recorded on this tape. A good contact at the junctions was assured by the weight of the furnace. The hot end of the calibration bar was protected against corrosion by means of an inert gas.

The cooling device operated by water cooling and kept the cold junctions at approximately 13 °C.

Test Materials

The tests were carried out for several grades of carbides and workpiece material C45N. The carbides used are Sandvik grades S1, S2, S4, S6, HO5, Hlp, H10, H13, H20 and FO2.

Numerical Elaboration (see Fig. 2)

With a regression-program (A-2080-6) the polynomial coefficients of the calibration curve were calculated (model: calibration bar voltage versus Pt $= a.T + b.T^2 + c.T^3$) [1.]

Results

The results of all measurements are listed in Table 1. In this table the coefficients a, b, and c are given for the carbides mentioned and the workpiece material C45N. Moreover, the 2σ-value (σ = standard deviation) of every coefficient as calculated by the regression-program is given.

Discussion of Results

In general, the shape of the calibration curves are parabolic. It is possible to obtain an emf relationship between one of these carbides and C45N-steel.

Therefore, the emf of S2 versus C45N is:

$$\text{emf}\,\frac{S2}{C45} = \text{emf}\,\frac{Pt}{C45} - \text{emf}\,\frac{S2}{Pt}$$

Numerically this gives:

$$\text{emf}\,\frac{Pt}{C45} = +\,0.129 \times 10^{-1} \times T - 0.644 \times 10^{-5} \times T^2 + 0.549 \times 10^{-8} \times T^3$$

$$\text{emf}\,\frac{S2}{Pt} = -\,0.949 \times 10^{-2} \times T - 0.34 \times 10^{-6} \times T^2 + 0.497 \times 10^{-8} \times T^3$$

$$\text{emf}\,\frac{S2}{C45} = +\,0.224 \times 10^{-1} \times T - 0.610 \times 10^{-5} \times T^2 + 0.052 \times 10^{-8} \times T^3$$

(See Fig. 3)

The heating-process calibrations are less stable and they do not reproduce so well as far as the materials with a negative emf are concerned.

The data of Table 1 are obtained from three or more well repeated calibrations of the cooling-process.

The coefficients of Eq. 1 describe a curve through all the measuring-points of the calibration series with very good technical accuracy (see Fig. 3).

The C45/Pt calibration possesses in the upper range of the curve a loop. This loop is caused by the $A_{1,2,3}$ transformation energy. The A_c transformations absorb energy. During the A_r transformations the absorbed energy is released.

If no transformation should occur, the calibration curve should be in the middle of this loop, because the absorbed energy and the released energy are of the same quantity (see Fig. 3). The coefficients of the calibration curve are determined to the average value of the A_c and A_r curve.

At the moment, research is going on in our laboratory into the background of the carbide calibration curves being less stable in the heating-process.

References

1. Veenstra, P. C., Bus, Chr., Zweekhorst, E. T. W.: Preliminary report on the measurement of cutting tool temperature (WT-0072), on behalf of CIRP-Conference, Cincinnati 1963. Also published in Dutch in "Metaalbewerking", *29* (1964) no. 16, p. 1-5.

Table 1. Coefficients of Eq. 1. for several grades of carbide and steel C45N.

Materials versus Pt	emf coefficients with 2σ-values					
	a	2σ	b	2σ	c	2σ
carbide grade S1	-0.349×10^{-2}	0.3×10^{-4}	-0.198×10^{-5}	0.8×10^{-7}	$+0.479 \times 10^{-8}$	0.6×10^{-10}
carbide grade S2	-0.949×10^{-2}	0.4×10^{-4}	-0.343×10^{-6}	0.100×10^{-6}	$+0.497 \times 10^{-8}$	0.7×10^{-10}
carbide grade S4	-0.729×10^{-2}	0.4×10^{-4}	$+0.746 \times 10^{-6}$	0.111×10^{-6}	$+0.387 \times 10^{-8}$	0.8×10^{-10}
carbide grade S6	-0.1015×10^{-1}	0.5×10^{-4}	-0.426×10^{-5}	0.15×10^{-6}	$+0.830 \times 10^{-8}$	0.11×10^{-9}
carbide grade HO5	-0.1090×10^{-1}	0.9×10^{-4}	$+0.807 \times 10^{-6}$	0.260×10^{-6}	$+0.475 \times 10^{-8}$	0.19×10^{-9}
carbide grade H1P	-0.866×10^{-2}	0.5×10^{-4}	$+0.164 \times 10^{-5}$	0.16×10^{-6}	$+0.374 \times 10^{-8}$	0.11×10^{-9}
carbide grade H10	-0.914×10^{-2}	0.8×10^{-4}	-0.569×10^{-5}	0.23×10^{-6}	$+0.865 \times 10^{-8}$	0.19×10^{-9}
carbide grade H13	-0.841×10^{-2}	0.7×10^{-4}	$+0.571 \times 10^{-7}$	0.22×10^{-6}	$+0.493 \times 10^{-8}$	0.16×10^{-9}
carbide grade H20	-0.997×10^{-2}	0.10×10^{-3}	-0.496×10^{-5}	0.30×10^{-6}	$+0.849 \times 10^{-8}$	0.22×10^{-9}
carbide grade F02	$+0.430 \times 10^{-2}$	0.5×10^{-4}	$+0.454 \times 10^{-5}$	0.16×10^{-6}	-0.106×10^{-8}	0.12×10^{-9}
steel C45N	$+0.129 \times 10^{-1}$	0.1×10^{-3}	-0.644×10^{-5}	0.42×10^{-6}	$+0.549 \times 10^{-8}$	0.30×10^{-9}

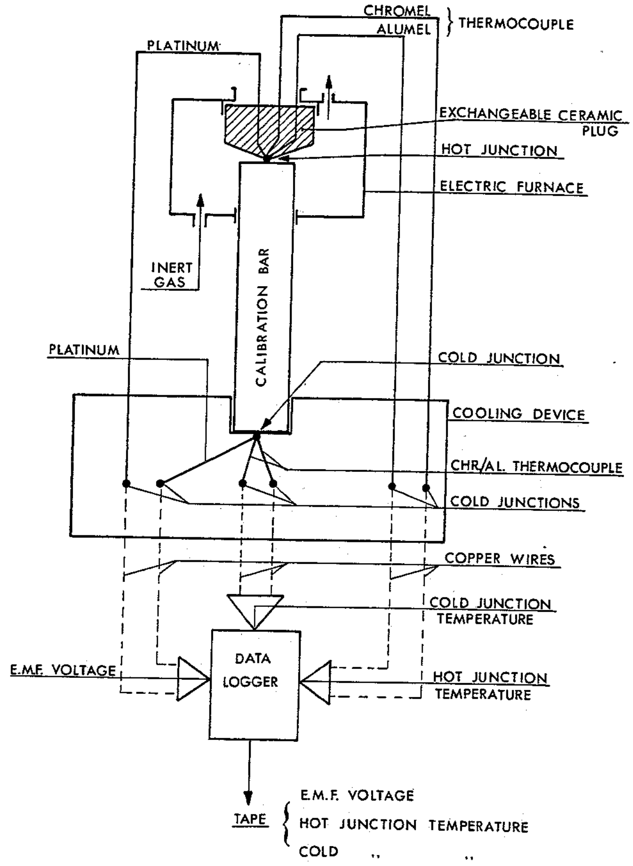

Fig. 1. Calibration set-up.

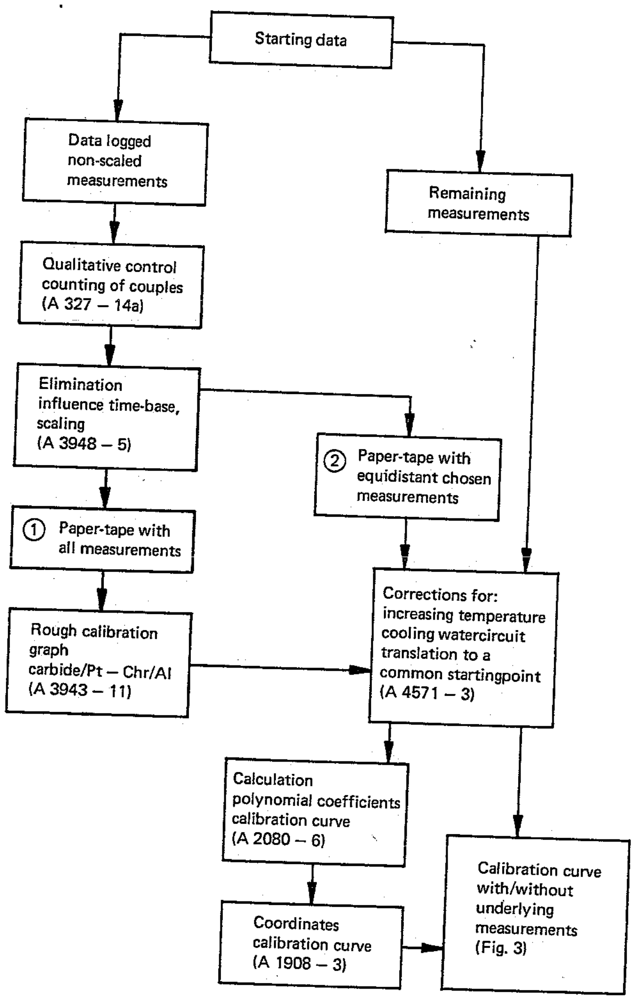

Fig. 2. Flow-chart of the numerical elaboration.

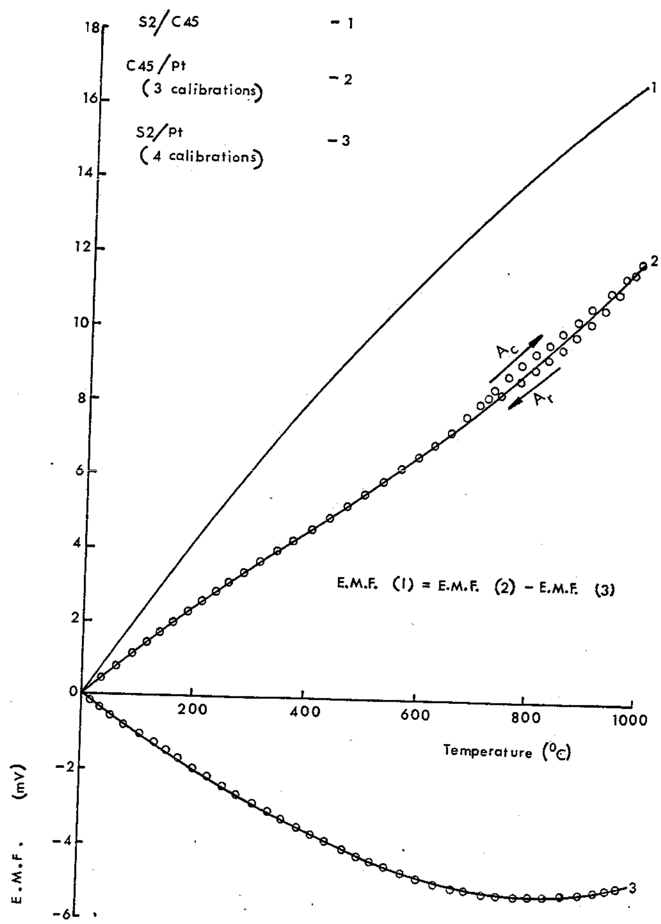

Fig. 3. E.M.F. $\frac{S2}{C45}$, E.M.F. $\frac{C45}{Pt}$ and E.M.F. $\frac{S2}{Pt}$ as a function of the temperature. The curve through the plotted loop is the average value of the A_c and A_r energy.