# Notes on cooperative research in the measurement of Gottwein-temperature

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# NOTES ON COOPERATIVE RESEARCH IN THE MEASUREMENT OF GOTTWEIN-TEMPERATURE

Notes on Cooperative Research in the Measurement of Gottwein - temperature.

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1. It proves to be impossible to collect on short term a substantial amount of relevant data of temperature measurements from the literature available in order to judge of reliability and scatter. So much the more this holds for the machining of specific steels like Ni.Cr and Cr.Mo steels.
   Nevertheless this work of searching in my laboratory will be continued and possibly with the worthful help of cooperative members of the group be expanded.

2. The general impression is that - like in every technological absolute measurement - the main difficulties and the major reasons for discrepancies arise from the calibration of the thermo-electric characteristic of the system workpiece/tool material.
   It is obviuous that in no calibration device the real conditions inherent to machining can be imitated. This refers particularly to the presence of the source of heat in the very plane of contact between the elements of the couple, the state of active cleanness of the freshly cut surface which may cause surface layer reactions, the quasi-static character of the process, the extreme state of deformation of the material in the chip and finally the extreme pressures prevailing in the contact area.

3. However there is no other choice than designing a calibration unit provided with external heating of the thermocouple to be investigated.
   A first step in cooperative research might be the careful specification of the construction and physical operation of the unit.
   Points of predominant importance are:

- calibration in high-vacuum or in an inert atmosphere
- the measurement of the temperature in the contactplane and in connection the avoiding of heat transfer through the contactplane
- the influence of pressure in the contactplane
- the heating time in connection with surface layer reactions, especially decarbonizing and alloying
- the thermal effects caused by allotropic conversions

My laboratory is prepared to perform regression analysis on the measuring points in order to make the calibration curves comparable in an analytical way.
This comparison must be the next step in cooperative work, the ultimate goal being the definition of standard calibration curves for a number of combination of workpiece materials and tool materials.

4. The development of methods of temperature measurement arises from the very sensitive dependence of wear-rate on temperature. Hence the temperature may be a useful criterion of machinability in terms of tool-life.
Refering to the Gottwein temperature - what soever its precise physical definition may be - it is tacidly assumed that it represents a quantity predominantly controlling the wear rate and possibly connected in an unique way with different definitions of temperature.
There however is evidence that the Gottwein temperature represents the average temperature in the chip/tool contact area.

5. In order to arrive at a thermal analogue of Taylor's equation the dependence of temperature on cutting conditions and material properties has to be determined, which is the next aim of temperature measurements.
There is ample experimental evidence that in the range of cutting speeds beyond the formation of B.U.E. the Gottwein temperature obeys

$$\Delta\Theta = \Theta_o \left\{\frac{V}{V_o}\right\}^n \left\{\frac{S}{S_o}\right\}^m$$

provided that the depth of cut exceeds the value of the nose-radius by a factor 4 or 5.

This relation gives a possibility for cooperative research based on absolute measurements as well as on relative measurements.
The former requires the determination of the quantity $\Theta_o$, which represents the Gottwein temperature at the standardconditions $\{V_o, S_o\}$, in terms of $^oK$.
The latter is contented with a definition of $\Theta_o$ in terms of E.M.F., but allows for comparison of the exponents n and m obtained in different laboratories.
In this way an objective means becomes available to evaluate the reliability of the several methods of Gottwein measurements.
Again my laboratory is prepared to deal with the numerical analysis of the data gathered.

6. Theoretical analysis shows that the foregoing relation can be generalised by

$$\Delta\Theta = \Theta_q \{\frac{V}{V_o}\}^{n_q} \{\frac{q_o}{q}\}^{m_q}$$

where q represents the chip equivalent, a quantity accounting both for the influence of the toolgeometry and the chipgeometry. The correctness of the relation has been proven in an extensive program of measurements regarding the combination Ck 45 - P 20.
It is remarked that a given value of q can be achieved by choosing numerous combinations of chip geometry and tool geometry. The experiments however prove that the Gottwein temperature is uniquely determined by the q-value, independent on the particular geometry chosen.
Hence q is considered to be the technological quantity determining tool temperature, feed and depth of cut rather being geometric quantities.

7. The factor $\Theta_q$ representing the Gottwein temperature at $V = V_o$ and $q = q_o$ again can be introduced in an absolute way measured in $^oK$, or in a relative way when expressed in units of E.M.F.
A same procedure of comparison between results as mentioned before may be accepted here.

8. More important however is that the factor $\Theta_q$ can be shown to depend on

1. the specific energy fed into the system, i.e. on cutting forces and chip cross-sectional area.
2. the chip contact length
3. the thermal properties of the material machined
4. the thermal properties of the tool material

Remarks: -as the cutting forces and hence the specific energy depend on the rake angle $\Theta_q$ depends on the value of that angle.
-according to Lenz the quantities 2 and 4 are not independent.

My laboratory disposes of a computer program designed to calculate $\Theta_q$ from the different dynamometric and thermal values mentioned. Thus an opportunity is created to measure $\Theta_q$ by means of thermo-electric calibration on the one hand and to calculate it from dynamometry on the other

9. Examples of comparison

Lowack (thesis Aachen 1967) concludes to the relation

$$\log \Theta = \log 835 + 0{,}2678 \log \frac{V}{50} + 0{,}161 \log \frac{S}{0{,}25}$$

valid for the combination Ck 53/N/P 20 and the tool geometry

$$\alpha = 6^{o},\ \gamma = 6^{o},\ \lambda = 0,\ \varepsilon = 84^{o},\ \kappa = 70^{o},$$

$$r = 0{,}75 \text{ mm}.$$

As shown in fig. 33 when choosing the chipgeometry a.S = 2.0,25mm$^2$ a Gottwein temperature of 910$^{o}$C is obtained at a cutting speed of 80 m/min.
It is observed that at this value of depth of cut the temperature has not yet become independent on this quantity.

When choosing a.S = 3.0,315 mm$^2$ a temperature of 1183$^{o}$C is reached at a cutting speed of 160 m/min.

Veenstra obtained a generalised equation for the rise of temperature in the case of Ck 45/P 20

$$\Delta\Theta = 863\ V^{0,24} \left(\frac{1}{q}\right)^{0,126}$$

where V in m/s

q in 1/mm

The first case mentioned above renders

$$q = 5,280$$

and $$\Delta\Theta = 755^{o}C$$

It can be shown that the constant in the generalised equation is strictly proportional to the tensile strength of the material machined, provided that the thermal properties are about the same. Lowack states for Ck 53 N the value $\sigma_b = 71$ kgf/mm$^2$, while tensile tests on Ck 45 carried out in my laboratory result in $\sigma_b = 60$ kgf/mm$^2$. It follows

$$\Delta\Theta_{Ck\ 53N} = 893^{o}C$$

and hence

$$\Theta \approx 915^{o}C$$

For the second case chosen the geometry can be represented by

$$q = 3,953$$

resulting in

$$\Delta\Theta = 925^{o}C$$

Correction for the tensile strength gives

$$\Delta\Theta_{Ck\ 53\ N} = 1094^{o}C$$

and $$\Theta \approx 1115^{o}C.$$