FOUNDATION OF THE QUALIFICATION SYSTEM OF GRINDING TOOLS

By

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1.1. The denotions used at present throughout the world for the indication of the quality of grinding tools (such as geometrical data, quality and size of grinding grains, type of bonding, hardness of bonding, compaction etc.) do not give sufficient information of the conditions of their manufacture and of their exceptable behaviour in use.

1.2. On the basis of the results of complex researches of the problems of manufacture and use of grinding tools and of a critical evaluation of the international literature in this field, we have found already in the first half of the 60-ies that the modulus of elasticity is and was chosen by us as the most general quality characteristic of grinding tools. Later, it was proved that indeed, of all the quality factors, the modulus of elasticity is of the greatest importance. In recent years also a great number of data of literature confirmed this fact. Our above statement has been supported at first from the aspect of the use of grinding tools (Chapter 1.3.), then proved again in two steps (Chapters 1.4., 1.5.), on the basis of an analysis of the characteristic steps of the manufacturing process to a depth of the microtissue.

1.3. A fact proved also by experiments is that during grinding the grinding grains, on contacting with the surface layers of the material to be machined, alter their position during the contact period, in a radial and tangential direction. The degree of this positional change depends on the technological conditions of grinding and on the elastic properties of the bonding materials (R. HAHN, J. PEKLENIK). The technical level of surface machining by grinding tools i.e. the quality of the machined surface (accuracy of dimensions, surface roughness, faults of the shape) are decisively affected by the rigidity of the contact between the grinding tool and the work-piece (this rigidity being expressed by the force, in kp/mm, of machining required for an elastic unit movement). The reproduction of the ground surface from time to time, depends decisively on the elastic properties of the tool provided the other given factors (such as the grinding machine, work-piece, technical parameters) are practically unchanged (R. SNOEYS, M. C. SHAW, R. P. LINDSAY). The elastic shape change of the grinding grains during grinding related to that of the bonding material is negligible, therefore the elasticity of this latter will be the determining factor. From this it follows as well that the bond formed at the phase boundary of these two components i.e. the way in which the grinding grains are embedded in the bonding material is of fundamental importance. As already mentioned, the recognition of this fact, the investigation of its details, the researches and proofs of these details and their presentation at international conferences is a decisive element of the research activities carried out by us.

Data of literature based on experiments in a wide field proved that about 85% of the energy consumed during the grinding is converted during the contact with the work-piece into heat taken up by the surface of the work-piece. The temperature increase in the surface layers of the machined material caused by this heat uptake depends on the length of the heat source i.e. on the length of the actual contact between the grinding tool and the work-piece. This contact length, in turn, depends on the modulus of elasticity of the grinding tool and of the bonding material.

The principal aim of the manufacture of up-to-date grinding tools of corundum and silicon carbide must be on the basis of what has been said above, the production of tools of optimum elasticity property.

1.4. The grinding tools are dissipated and consumed under the constant and periodic effects of various exposures. When e.g. a grinding disk is used for machining at a rate of 5000 r. p. m., then the grinding grains and bonding material bridges located on their superficies are exposed to 5000 impacts per minute.

Today, when the peripheral speed exceeds sometimes even 100 m/sec, the bonding material must very strongly adhere to the surface of grinding grains. However, bonding materials adhering strongly are less resistant to temperature changes occurring on grinding, and thus the changes in volume which follow the rapid heat impacts destruct the bond at the adhering surface of grinding grains. The strength stresses are increased also by the fact that during use the grinding grains are moving in directions perpendicular and tangential to the surface, and meanwhile extremely high temperatures of about 2000 °C are created on the cutting edges.

Only a very strong and at the same time elastic bond is capable of accepting and following the periodically repeated rapid displacements of the grinding grains, the volume fluctuations due to heat impacts, and the simultaneous tensile, compressive, bending, impact and shearing stresses. In case of a bonding material of high modulus of elasticity a great force is needed for attaining deformation and inversely, in case of a high modulus of elasticity great stresses are created in the bonding material on the effect of the impact-like volume changes of the grinding grains. These stresses may exceed the tensile and bending strengths and thus destruct the bond.

In case of a lower modulus of elasticity the bonding materials are more resistant to rapid changes of temperature.

On surveying the behaviour of the individual ceramic products, glazes and refractories against mechanical and thermal effects (each of which effects can be more or less comparable to the behaviour of grinding tools and of their bonds), relatively few precise relationships can be found.

In case of grinding tools the situation is even more complex, due to the presence of heterogeneous phases, to the variation of their ratios and to the manifoldness of the conditions of their use.

Of the methods of investigation most appropriate from the aspect of the structural properties of grinding tools and meeting also the requirements of their use, the measurement of the modulus of elasticity proves to be the most adequate.

The fundamental thesis of stress analysis, the law of Hooke, in addition to being simple, characterizes quite well the behaviour of most materials. The elasticity factors expressing the proportionality are the most important characteristics of the material properties.

Owing to the great difference between the moduli of elasticity of ceramic bonding materials and of corundum grains it is possible to investigate the bonding of grinding tools and of their moduli, respectively, by extension measurements without any interfering effects of the corundum phase.

In the beginning, our measurements were carried out with an extensimeter based on the measurement of the electric resistance, a device suitable for the dynamic measurement of mechanical changes of shape.

Some of the prisms compressed from a 85 : 15 per cent by weight mixture of corundum grains and bonding material were fired at 1250 °C while others at 1300 °C. During these investigations the following data were measured and calculated:

a) Specific longitudinal extension of the specimens as a function of the load.

b) Transversal specific shrinkage as a function of the load.

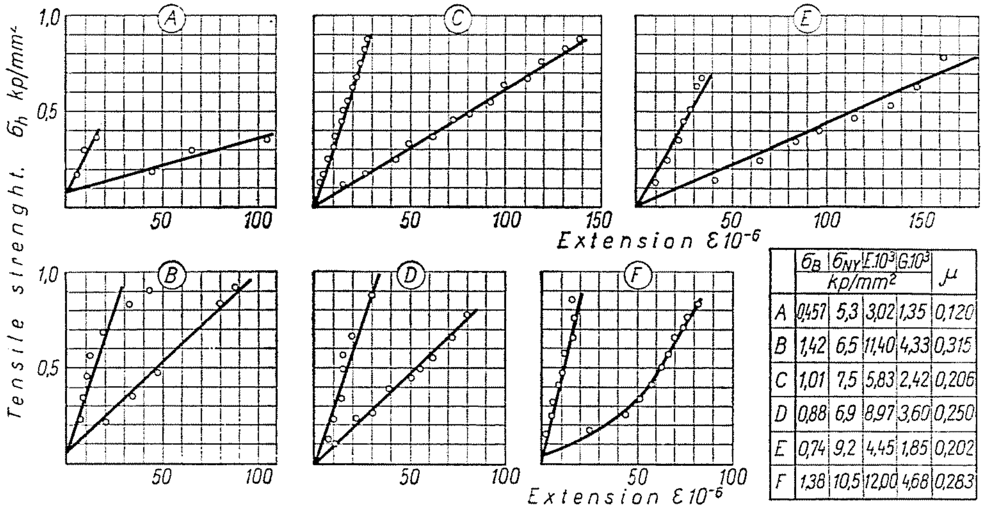
c) The modulus of elasticity (E) of the individual specimens calculated from the data of measurements.

d) The shearing elasticity factor, calculated in the knowledge of the modulus of elasticity and of Poisson factor (μ), with the use of the relationship:

$$G = \frac{1\mu}{2\mu + 1} \cdot E \,.$$

e) The tensile strength (σ_B), obtained by increasing the load until the specimens were broken.

The results of our measurements are presented in Table 1 and Fig. 1. In the figure the values of the specific longitudinal extension and the



corresponding specific transversal shrinkage (steeper straights) are indicated in a combined form.

The data of Table 1 and Fig. 1 prove that under given conditions the properties of grinding tools depend mostly on the technique of heat treatment. The moduli of elasticity and together with them also the rigidity of the bonding material are increased by firing at higher temperatures.

Our investigations by thermoanalysis and X-ray diffraction indicated concordantly also earlier that the reactions accompanying the bond formation in bonding materials are accelerated when the surfaces of the reacting components are increased or at the same composition the bond is formed at lower temperatures on using bonding materials with higher specific surface. Whereas

Table 1

Data of the strength of ceramically bonded grinding tools

Symbol	Name of specimen	Firing tempera-ture, °C	Tensile strength kp/mm²	Compressive strength kp/mm²	Modulus of elasticity (E) en tension 10^3 kp/mm²	Poisson factor μ	Stearing modulus of elasticity (G) 10^3 kp/mm²
A	Illitic bond	1250	0.457	5.3	3.02	0.120	1.35
B	Illitic bond	1300	1.42	6.5	11.40	0.315	4.33
C	Modified illitic bond	1250	1.01	7.5	5.83	0.206	2.42
D	Modified illitic bond	1300	0.88	6.9	8.97	0.250	5.60
E	Fritted bond	1250	0.74	9.2	4.45	0.202	1.85
F	Fritted bond	1300	1.38	10.5	12.00	0.283	4.68

the properties of specimen of illitic bond are from the aspect of tensile and compressive strength more favourable at 1300 °C than on firing at a temperature lower by 50 °C, in case of a modified illitic bond (using finely ground illite), firing at 1250 °C is optimal from this aspect, and a higher heat treatment already reduces the strength. In this case, higher strength and lower rigidity (lower moduli of elasticity) are combined in the specimen with modified illitic bond.

1.5. On comparing the conditions of manufacture of grinding tools with our data of the modulus of elasticity measured by sonic frequency, we can experience as well that the modulus E can be sensitively influenced by varying the production parameters. Details concerning the modulus of elasticity of grinding tools which are of importance from the aspect of both their manufacture and their use are summarized in Fig. 2. Parts of this Figure denoted as 2/g and 2/h contain our own data of measurements. Part denoted as 2/g shows that the modulus of elasticity changes linearly with the amount of bonding material. Also the important role of the firing conditions is disclosed quite unequivocally. Part denoted as 2/h exhibits in turn the data of the modulus of elasticity of disks containing 85% by weight of electrocorundum and 15% by weight of bonding material, of a dimension of $50 \times 10 \times 15$ mm, fired for various periods at 1300 °C. The moduli of elasticity were measured by sonic frequency.

In the course of these investigations all the parameters, with the exception of the heat treatment periods which were varied, were practically constant, and thus the differences between the moduli of elasticity show actually the effect of the formation of the bonding layer. Changes in the composition of the environment of the phase boundary and the rearrangements of the microtissue connected with them appeared in our measurements of the modulus of elasticity carried out by sonic frequency in the initial, shorter part of the heat treatment process relatively sharper. Later, the degree of changes was already not significant. At present even throughout the world often a great number of bonding material varieties and compositions are tentatively used for obtaining various special properties. In contrast to that trial-and-error method, a knowledge of adequate deepess of the important details of the processes taking place during firing may offer, in addition to the above informations, also further novel and sensitive possibilities of variation. Obviously, their adequate utilization requires precisely designed and controlled, up-to-date conditions of manufacture. As indicated also by the title of the present paper, we desired to prepare the creation of the fundamentals of a novel quality and classification system of grinding tools, by the complex evaluation of our researches concerning the investigation of the modulus of elasticity and by drawing practical conclusions from this evaluation.

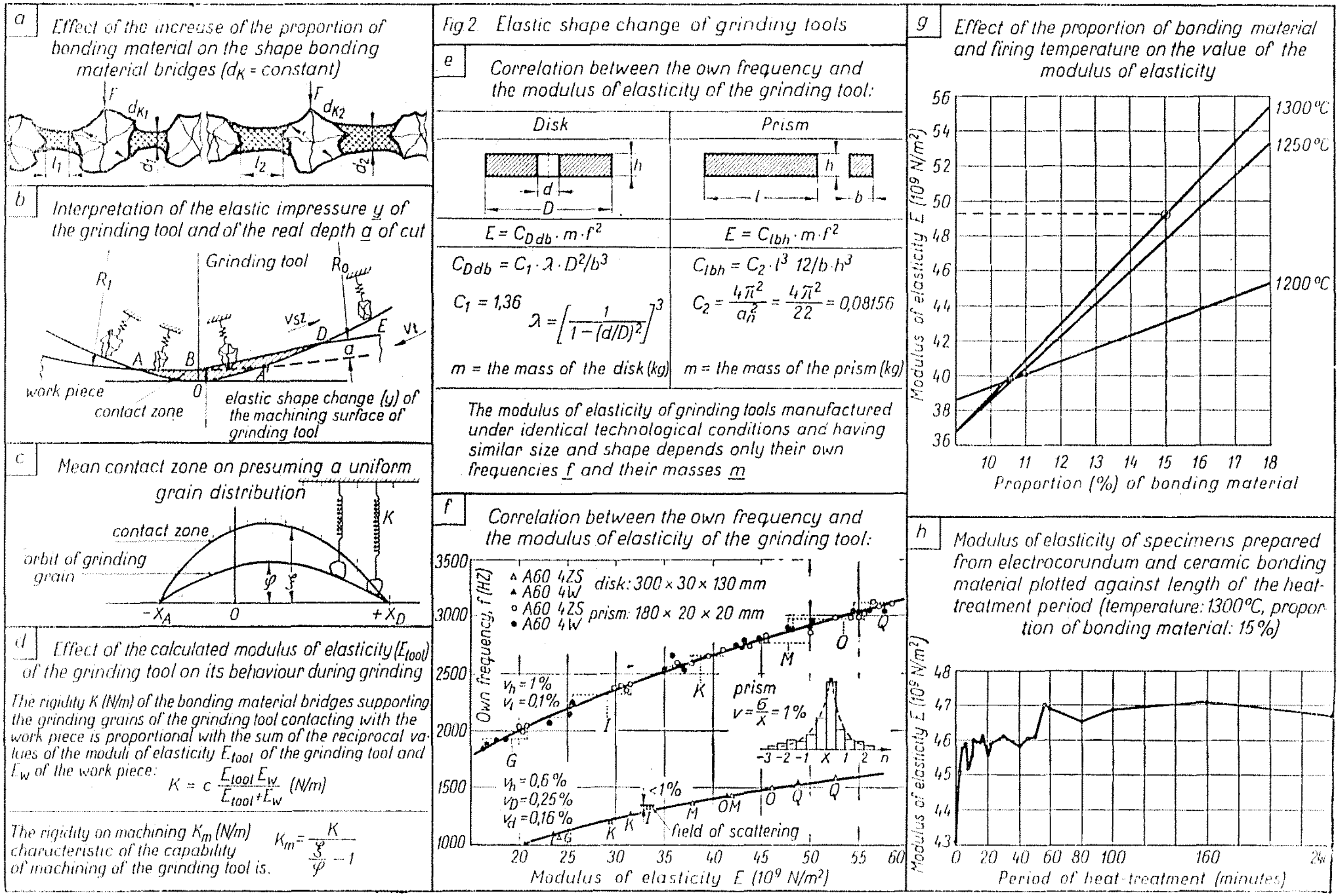


Fig 2. Elastic shape change of grinding tools

The thorough and complex investigation of the microtissue and of the mechanical properties must play a role not only in case of the corundum and silicon carbide ceramics but also at the up-to-date manufacture and classification of all the technical ceramic products.

Summary

Of the methods of investigation most appropriate from the aspect of the structural properties of grinding tools and meeting also the requirements of their use, the measurement of the modulus of elasticity proves to be the most adequate.

Our above statement has been supported at first from the aspect of the use of grinding tools (Chapter 1.3.), then proved again in two steps (Chapters 1.4., 1.5.), on the basis of an analysis of the characteristic steps of the manufacturing process to a depth of the microtissue. The elastic shape change of the grinding grains during grinding related to that of the bonding material is negligible, therefore the elasticity of this latter will be the determining factor. From this it follows as well that the bond formed at the phase boundary of these two components i.e. the way in which the grinding grains are embedded in the bonding material is of fundamental importance. As indicated also by the title of the present paper, we desired to prepare the creation of the fundamentals of a novel quality and classification system of grinding tools, by the complex evaluation of the modulus of elasticity and by drawing practical conclusions this evaluation.

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