Serafim Nikolaevich Zhurkov (on his eightieth birthday)

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Academician Serafim Nikolaevich Zhurkov, the founder and director of the Laboratory of the Physics of Strength of Materials at the A. F. Ioffe Physicotechnical Institute, Academy of Sciences of the USSR, Leningrad, and Hero of Socialist Labor, reached 80 on 29 May 1985.

Determining the physical nature of the strength of solids has become the thrust of the extensive creative work by S. N. Zhurkov. For more than half a century he has worked enthusiastically and fruitfully on solving this exceedingly important problem.

At the beginning of his scientific activity, a mechanical concept dominated the thinking about strength of materials. It was assumed that fracture was simply a brute-force effect which occurred when the stress applied to an object reached a critical level called the "tensile strength." This quantity was assigned the meaning of a physical characteristic of the material. As research was pursued, however, the results indicated that tensile strength is affected by the rate of loading, the time over which the object is subjected to the load, and the temperature. Attempts were made to explain these results within the framework of the mechanical concept by means of time-varying changes in the effective stresses and effects of corrosion. S. N. Zhurkov suggested a qualitatively different explanation which involved discarding the mechanical concept and adopting a fundamentally new concept of fracture: a kinetic concept. According to the kinetic approach, the basic strength characteristic is the time over which the rupture of a solid can be expected at a given stress (the longevity).

The systematic study of the longevity of various materials (crystals with ionic and covalent bonds, metals, alloys, polymers, glasses, and composites) which S. N. Zhurkov carried out in the 1950s established the exponential decay of longevity with increasing load and temperature (the Zhurkov formula). This research revealed the physical nature of fracture: It occurs by virtue of thermal fluctuations which break stressed interatomic bonds; thus a certain time (the fracture expectation time) is required for fractures to occur.

Carefully planned experiments were carried out in his laboratory with the help of some methods of experimental physics which were novel to research on strength (infrared and Raman spectroscopy, NMR, electron paramagnetic resonance, optical and x-ray diffraction, mass spectrometry, calorimetry, and electron microscopy, among others). This work confirmed and fleshed out Zhurkov's fundamental conclusion that the mechanical fracture of solids is of a thermal-fluctuation nature.

This stage of research clearly demonstrated the scientific method of Serafim Nikolaevich: the combination of profound physical intuition and daring hypothesis with careful experimental tests based on the newest techniques available.

SERAFIM NIKOLAEVICH ZHURKOV

The new approach to strength which was marked out by S. N. Zhurkov has been acknowledged widely in the Soviet Union and elsewhere. S. N. Zhurkov has been selected vice president of the International Congress on Fracture, and his 70th birthday was noted with the publication of a special anniversary issue of the international journal *Fracture* (in 1975).

S. N. Zhurkov has devoted the last decade of his work to the development of the kinetic concept of strength and to the application of kinetic ideas to practical problems.

The fluctuation nature of fracture which has been established requires a determination of the detailed mechanism for the rupture of interatomic bonds caused by fluctuations. By appealing to new methods (Brillouin scattering and numerical simulation of molecular dynamics) and also by means of theoretical analysis, Zhurkov has been studying the degree of cooperation among fluctuational events and the conditions for the nucleation and evolution of the fluctuations which lead to the rupture of bonds. The phonon model of these fluctuations which Zhurkov developed has allowed him to relate the parameters in the formula for longevity to the thermal characteristics of solids (the specific heat, the thermal expansion, etc.)

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Serafim Nikolaevich has called attention to the circumstance that not only mechanical destruction but also electrical destruction (dielectric breakdown) and optical (laser) destruction are of a kinetic nature. Research has demonstrated that the dependence of the longevity on the force and the temperature in the different effects have a common nature. This study has raised the question of the development of a common mechanism for fracture on a fluctuation basis. Research is being carried out on the kinetics of fracture at low temperatures (below the Debye temperatures), at which one can expect an effect of the transition from classical statistics to quantum statistics. The participation of electronic processes in bond rupture events is being studied experimentally and theoretically.

S. N. Zhurkov assigns major importance to surface regions in the kinetics of the fracture of materials. Accordingly, the dynamics of surface layers in stressed objects are being studied experimentally by low-energy electron diffraction, soft-x-ray diffraction, Auger spectroscopy, and other methods.

Research on the kinetic fracture process which occurs in a stressed object has led to the possibility in principle of predicting macroscopic fracture: a problem of major practical importance. Studies which have used a method of acoustic emission to study crack formation have already gone beyond the confines of the laboratory and are being used with large structures. They are also being applied to the problems of predicting rockbursts and earthquakes. We must emphasize that the ideas regarding the kinetics of fracture which were developed by S. N. Zhurkov are also being used to analyze large-scale phenomena which occur at seismic foci.

A systematic approach to fracture as a process requires a study of, in addition to the kinetics of the growth of cracks, a study of the kinetics of the counterprocess, the healing of cracks. On this basis, methods have been developed in Zhurkov's laboratory for restoring and substantially increasing the service life (useful longevity) of articles and constructions by means of a deliberate periodic healing of microscopic cracks which accumulate during use. Some of these methods have already been adopted in industry.

Improving the strength of materials is a natural problem in the development of the science of strength. It is pertinent to recall that as far back as the 1930s, at the Physicotechnical Institute, S. N. Zhurkov achieved strength values which were unprecedented at the time: 1300 kgf/mm^2 for quartz glass and 600 kgf/mm^2 for silicate glass. These results provided a major stimulus to the development of research on the strengthening of materials. The highest known strengths of polymer fibers (up to 1000 kgf/mm^2 and above) have now been achieved in Zhurkov's laboratory through the optimization of the kinetics of orientation. The question now is whether the strength of technical fibers can be sharply increased.

The multifaceted fruitful work of Serafim Nikolaevich Zhurkov has breathed new life into the science of strength as a field of modern solid state physics, and it has laid a new foundation for the solution of urgent practical problems.

As Serafim Nikolaevich turns 80, he is involved in an active search for solutions for progressively more complicated problems of the physics of strength. As before, his work is distinguished by the depth to which he penetrates to the essence of a problem, his originality of approach, his generation of new ideas, and the subtlety of his experiments. There is every reason to expect important new results from the creative work of Serafim Nikolaevich Zhurkov and his school.

Translated by Dave Parsons