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92:53

KIRILL IVANOVICH SHCHELKIN (Obituary)

D. A. FRANK-KAMENETSKIĬ

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THE creative work of Kirill Ivanovich Shchelkin is characterized by a wide range of scientific interests, from combustion and explosions to the atomic nucleus and elementary particles. At the same time he maintained all his life a touching devotion to his first theme —gas explosions. Shchelkin was trained as a scientist in the scientific milieu at the Institute of Physical Chemistry of the USSR Academy of Sciences, with which he never broke ideological contact. Following the traditions of N. N. Semenov's school, he chose for himself a field in which physics and chemistry intermingle fancifully. This field is very precisely described in the introduction to his first monograph "Rapid Combustion and Spin Detonation of Gases," which appeared about 20 years ago. Two problematic phenomena were examined: the transition from combustion to detonation, and detonation spin. Shchelkin made an important contribution to the understanding of both phenomena.

In order to speed up the transition from combustion to detonation in pipes, Shchelkin proposed an elegant mechanism of feedback via the turbulence. The flame causes motion of the gas, a turbulence arises and speeds up the flame, which in turn increases the turbulence. This idea turned out to be extremely fruitful. It led directly to two further directions: turbulent combustion, and the structure of detonation waves.

Shchelkin contributed a great deal to the understanding of the interaction between the turbulence and the flame. The formula proposed by him for the velocity of turbulent flames can now be found in textbooks. The roughness of the walls acts on the turbulence—and Shchelkin set up experiments in the transition from combustion to detonation in rough tubes. The results not only confirmed the role of turbulences in detonations, but also led to an important discovery: in a rough tube, the velocity of the detonation may be 40–50% smaller than in a smooth tube, and it depends on the degree of roughness. Apparently a paradox! Detonations in smooth tubes are precisely described by thermodynamic theory, using only the laws of conservation of matter, momentum and energy. These results prompted a careful re-examination of the entire structure of classical detonation theory. It turned out that, in addition to laws of conservation, certain tacit assumptions are at the basis of the theory, and these cannot be maintained for large degrees of roughness.

Further work by Shchelkin was on the structure of detonation waves. In 1926, Campbell and Woodhead discovered that in certain cases of detonation, the center of combustion rotates around the tube axis and describes a helix. This phenomenon was named detonation spin. But its nature was finally elucidated much later. K. I. Shchelkin proposed here also a clear and beautiful idea: spin detonation is the limiting case of pulsating detonation which is related to the instability at the front of straight detonation waves. By means of simple qualitative arguments, Shchelkin proved the presence of such an instability and derived an approximate criterion for its formation. In experiments conducted by Shchelkin and Ya. K. Troshin, pulsations of the detonation front left clear traces on smoked glass. Excellent photographs of such traces—a genuine masterpiece of experimental art—embelish the monograph by K. I. Shchelkin and Ya. K. Troshin "Combustion Gas Dynamics," published in 1963. We present several quotations from this book, which is written in an excellent and fresh language (the book had a printing of only 3000 copies and is not readily available). These quotations give an example of Shchelkin's style.

Kirill Ivanovich Shchelkin
(1911-1968)

"Segments of a wide spin tape ... show clearly its fine structure—oblique intersecting lines, several lines to each stripe. This is a very interesting phenomenon, and the photographs are unique ... One may say, a spin on top of a spin ..."

"More than thirty years were required to understand one of the mysterious phenomena of nature—spin detonation. But details of the structure of the spin nucleus near the limits of attenuation of the detonation have not yet been fully deciphered ..."

"As happens frequently in nature, new concepts, which specify and delimit the range of previously developed concepts, do not negate them entirely and are not in contradiction to them. Thus, pulsating detona-

tions are on the whole sufficiently well described by thermodynamic theory. Thermodynamic theory, if one neglects the structure of the wave front, also describes approximately spin detonation, although in principle to a lower accuracy than pulsating detonations. In spin detonation, if one examines separately the motion of the spin nucleus, the notion of a stable strong detonation, unknown before thermodynamic theory had been worked out, may be of use."

Shchelkin's work with his co-workers enriched substantially our understanding of detonations. It turned out that a plane detonation front is always unstable—breaks form along it. Upon approaching the limit beyond which detonations vanish, the number of breaks decreases. Near the limit only one break remains—this is then spin detonation.

In the eternal struggle in the science of combustion for primacy between gas dynamics and chemical kinetics, Shchelkin has completely favored until now gas dynamics. He explained the formation of detonations as the action of a purely physical factor—turbulence. The instability of a plane front is derived from gas-dynamical considerations. The subsequent approach becomes thus even more interesting—the estimate of the number of breaks, based on chemical kinetics. As in all Shchelkin's scientific work, the simplicity and clarity of the idea is once more impressive. The dimension of the instability is determined by multiplying the time of chemical reaction by the velocity of detonation. It is possible to determine from this, according to the number of breaks on the front, reasonable values of activation energies of chemical combustion reactions. We note that an essentially non-linear problem has been solved here: not only is the condition for the formation of instabilities determined, but also the final state to which it leads. This is done almost without the use of mathematics, with the aid of the simplest reasoning.

We have attempted to present the basic ideas which Shchelkin contributed to the science of detonations. Stopping on neither the further development of these ideas, nor on encountered difficulties, nor on the work of other scientists in this field, let us only name some of these scientists: Ya. B. Zel'dovich, B. V. Voĭtsekhovskiĭ, and R. I. Soloukhin.

Shchelkin was a man of great personal courage. At the beginning of the war he volunteered for the front, was caught in a very difficult situation, and his life was miraculously spared. At the time of the unfolding of work on the nuclear problem, Shchelkin became one of the closest brother-in-arms of I. V. Kurchatov. Here, new sides of his multiple nature were revealed. He headed a large scientific-technological group, and directed comprehensive work in various fields of science and technology. Shchelkin was awarded for his important work with the highest governmental prizes. He was three times named Hero of Socialist Labor.

In the last years, his poor health forced him to relinquish managerial work. But he untiringly worked as scientist to his last day. Shchelkin was also much responsible for popularizing science, was an enthusiastic member of the society "Znanie" (Knowledge), and an active collaborator of the journal "Priroda" (Nature). His excellent and popular essays "Fizika mikromira" (Physics of the Microscopic World) were published in several editions and recently were awarded the first prize in the All-union competition of popular science books.

Schelkin headed the Department of Combustion at the Moscow Physico-technical Institute, presented lectures to students and popular lectures to large audiences. Upon meeting Shchelkin, already seriously ill, walking boldly with the aid of a heavy cane, upon listening to his stories, full of occasionally good-natured and occasionally ruthless humor, his friends were involuntarily reminded of Igor Vasil'evich Kurchatov. Despite the differences in these vivid and unique individual traits, there was undoubtedly some unifying element in them. It is not in vain that Shchelkin read with such pleasure public lectures on Kurchatov.

Our country and our science owe much to this remarkable man.

Translated by L. C. Garder