Klaus Schönert

KLAUS SCHOENERT

1927–2011

Elected in 1991

"For contributions to fracture physics and fragmentation fundamentals leading to innovative technology for size reductions in ore processing."

BY DOUGLAS W. FUERSTENAU

KLAUS SCHOENERT, who died on September 24, 2011, was universally regarded as the world's leader in comminution science and engineering, that is, the size reduction of solid materials. The objective of crushing and/or grinding may be to liberate minerals in ores, produce particles of controlled size, produce fine particles, or increase the surface area of the material. Hundreds of millions of tons of materials—ores, cement, aggregate, coal, ceramics, grain, and even chocolate—are comminuted annually. Whoever he interacted with professionally in the world of comminution found Klaus to be a true friend.

Klaus Schoenert was born on June 18, 1927, in Döbeln, Saxonia, Germany, a small city west of Dresden, where his father managed a small cooperative dairy. Nearing completion of his studies in the gymnasium (equivalent to an American high school) in early 1945, he was drafted into the German army at age 17 and sent to the eastern front in Austria. After being captured by the US Army and spending a couple of months in an American prison camp in Austria, he and a friend eventually made their way back to Saxonia.

Schoenert had an arduous four years trying to start his university education. Upon returning to Döbeln, he completed his studies at the gymnasium, but at that time the communist party took over the government and began to arrest all who ran businesses or large farms, including Schoenert's parents, although they were released from prison because the cooperative dairy that his father had managed was not large. Klaus was not home at the time of their arrest and escaped capture. He went to live with relatives near Weimar, where he took the final gymnasium examination (called the Abitur).

In the spring of 1946 Klaus returned to his family and applied to enter a university to study electronics. He was denied entrance because the regime allowed admittance only to the children of workers and small farmers. He applied to several Western German universities but only older veterans were being granted admission at that time. So he studied to be an electronics technician and worked in that capacity until 1948, when he received a letter from the University of Karlsruhe (then called the Technische Hochschule Karlsruhe) stating that he would be admitted upon passing an examination. With a colleague he walked at night across the border into West Germany and went on to Karlsruhe. He passed the examination, but each student had to work six months cleaning up the bombed-out campus before they could enroll. During that time, the great devaluation of German currency took place and his money became worthless. Fortunately, he was able to get a job as an electronics technician for Siemens to support himself. In 1950 he finally was able to enroll in the physics program at Karlsruhe and in 1957 completed his studies for the Diplom Physiker. He began doctoral studies in physics, but within weeks his professor (Christian Gerthsen) suddenly died.

At this very time, Professor Hans Rumpf (1991 NAE foreign associate) had come to Karlsruhe from industry to establish an institute called Mechanische Verfahrenstechnik, that is, the mechanical processing of particles. Rumpf wanted a physicist to join the institute as his assistant and interviewed Klaus for the position. Although Schoenert's real interest was in electronics, he said that he was so impressed with Rumpf as an influential, challenging person that he decided to join the institute and served as Rumpf's scientific advisor from 1960 to 1966. Research areas at the institute included the characterization of particles, comminution, classification (size separation), mixing of powders, and the agglomeration of powders. The institute eventually grew to some 200 persons, and for two decades or so was perhaps the leading laboratory in particle science and technology worldwide.

Professor Rumpf considered comminution to be the major problem in particle production. He estimated that 3.5 percent of the world's electrical energy was consumed in the comminution of cement, minerals, coal for power plants, and chemicals. In a mineral processing plant about 80 percent of the energy is for comminution of the ore. So Schoenert started his research in the fundamentals of comminution. Rather than investigating comminution in mills, they undertook research on fundamental breakage phenomena of single particles. The objective was to ascertain how a particle is formed, how it breaks, how breakage depends on size, the energy needed to break the particle, the probability of particles breaking at different energy levels, the fragment size distribution after breakage, and the newly created surface. In some cases they determined fracture patterns and investigated how the pattern progresses through the particle.

Schoenert's initial investigation involved the breakage of spherical glass balls, and then moved to study of the comminution of particles of calcite, limestone, quartz, and cement clinker, investigating what happens in the breakage of very fine particles because it is the production of small particles that consumes energy. The largest particles that they studied were 2 millimeters in size and the smallest were 10 microns. Study of the loading and breakage of 10-micron particles under a microscope was tedious and required the design and construction of specialized apparatus. Through the years there have been numerous approaches on how to measure the energy efficiency of a grinding mill. Based on his single-particle research, Schoenert nicely defined a meaningful measure: the most efficient method of comminution is the mechanical breakage of single particles, and this should be the baseline against which to quantify process efficiency of industrial machines.

In 1966 he received the degree of Doktor-Ingenieur from the Faculty of Maschinenbau (Mechanical Engineering) und Verfahrenstechnik of the Technische Hochschule (TH) Karlsruhe for his dissertation on single particle compression and comminution dynamics. It was after this that TH Karlsruhe was renamed the University of Karlsruhe and the Department of Chemical Engineering was established. From 1966 to 1977, he served as supervisor of the Comminution Division of the Institute in the Chemical Engineering Department at the university.

All through these years Schoenert (and Rumpf) published extensively on the results of their research on comminution. Rumpf established the European Comminution Symposium under the auspices of the German Chemical Engineering Society to disseminate and discuss research results. From 1966 to 2004, I participated in European Comminution Symposium meetings. I first met Professor Rumpf and Klaus Schoenert in 1965 when they attended the Engineering Foundation Research Conference on Particulate Systems in Milwaukee. This was the first occasion where many Americans and others met Rumpf and Schoenert. After that Klaus participated actively in Engineering Foundation Conferences and other technical meetings.

In 1969–1970, Schoenert spent six months as a visiting associate professor in the Department of Materials Science and Engineering at the University of California, Berkeley. He taught an undergraduate course on particulate materials and I suggested that he also teach a two-unit graduate seminar course on fracture physics. I told him that there would be a few graduate students in the seminar course. Klaus said that when he walked into the classroom he was shocked to see that it was nearly full of students plus three other professors. He said he never worked so hard in his life preparing lectures as he did for these weekly two-hour sessions. His family was with him and our families became close friends from that time onward.

To become a professor in Germany, an additional dissertation after the doctorate is required, called the habilitation. After returning from Berkeley, Schoenert began to work on his habilitation in chemical engineering. His dissertation, completed in 1971, was on the mathematical simulation of comminution processes in continuous mills, which was a step toward his study of the behavior of actual grinding mills. In 1973, he and a colleague, Fritz Loeffler, were both appointed (ausserordentliche) professors in the University of Karlsruhe and, together with Professor Rumpf (ordentliche professor), ran the Institute as what they called a three-member Directorium. When Professor Rumpf retired in 1977, Schoenert became the speaker of the Directorium, but he could not be the director since only ordentliche professors can hold that title, and in Germany you cannot become ordentliche professor in the university from which you received your doctorate unless you have held a regular appointment elsewhere.

After Schoenert's group had thoroughly studied the breakage of single particles, they investigated the breakage of confined beds of particles in a piston-die press. Breakage of particles in a confined bed is less efficient than single particle breakage, but still far more efficient than comminution in ball mills. In particle-bed comminution, energy is supplied directly to the material by compression. The workhorse of fine grinding is the ball mill, a huge rotating tube filled with balls to about 35 percent of its volume. Rotating the tube provides energy to the balls as they are lifted inside the mill. When the material to be ground is fed into the mill, the balls strike the particles to be broken by a hit-and-miss process—a highly stochastic process that results in a lot of wasted energy.

Schoenert considered that he might use particle-bed comminution as a process by passing the particles between two counterrotating rolls at very high pressure. To test his ideas, he designed and constructed a laboratory-scale high-pressure roll mill. When the bed of feed particles pass through the gap between the rotating rolls, they are compacted and fractured with the very high pressure. However, he found that the material came out from the rolls as an agglomerated cake of broken particles. He said that at first he was perplexed that instead of making small particles, they were making agglomerates! But it turns out that very little energy is required to deagglomerate the material and to classify it.

With the small lab-scale machine, they investigated the operating variables to determine the performance of the system. After finding the same results as those predicted from the piston-die press, Shoenert applied for a patent, because this new high-pressure process could save significant energy. The university released the invention to Schoenert and the original German patent (Deutsches Patent DE-2 708 053) was issued in 1977, with an essentially identical patent issued in the United States in 1982 (US Patent 4357287). These patents proved valid in court because they were process patents and not machine patents.

Schoenert first approached Polysius (now called Krupp Polysius) to license the patent because he had had earlier contact with them about cement clinker comminution, and they eventually agreed to design and manufacture an industrial-scale machine. After about three years the first industrial application was achieved in the cement industry, and eventually about 300 machines were sold in the industry. Schoenert told me that he thought that the real success of the high-pressure grinding roll (HPGR) was because the cost of electrical energy is so high in Germany. He then negotiated with a second company, KHD (Klöckner-Humboldt-Deutz), a well-known name in the manufacture of processing equipment in Germany, to manufacture HPGRs for application in the mineral industry. Although wear of the rolls was low, it still was a major problem that each company worked on extensively and solved satisfactorily.

The first application of HPGRs in the mineral industry was at the diamond mines of DeBeers, where the rolls were installed not for energy but for diamond liberation. Better liberation of the diamonds from the matrix rock is attained because of the shear forces acting between the gangue matrix material and the hard diamonds as the ore passes through the gap between the rolls. The compressed diamond ore forms a cake that can readily be broken down by putting it into water, freeing the diamonds. With the roll mill, not only is diamond liberation increased but big diamonds are not broken (standard crushing machines cannot avoid breaking some of the larger diamonds). The first high-pressure roll mill delivered to DeBeers was a massive machine with rolls 2.8 meters in diameter. They were so successful that eventually DeBeers installed about a dozen such roll mills.

Late in 2006, at Cerro Verde in Peru, Freeport-McMoRan Copper and Gold Inc. commissioned a new 125,000-ton-per-day concentrator that uses four 2.4-meter diameter HPGRs instead of two 12.2-meter diameter SAG (semiautogenous grinding) mills. This is the first base-metal application of HPGRs. About that, John Marsden (NAE, 2010) and his colleagues wrote, "Since SAG milling is a mature technology, limited gains or improvements are expected in the future. HPGR, being a relatively new technology, is expected to offer excellent opportunities for operational and maintenance improvements." The comminution energy consumed by the HPGR/ball mill system is only 64 percent of that required for a traditional SAG/ball mill system! A great deal of test work is under way worldwide for further mining industry applications.

In 1981, Schoenert received a call to join the faculty at the Technical University of Clausthal as ordentliche professor and director of the Institut für Aufbereitungstechnik (Institute for Mineral Processing). The university is in Clausthal-Zellerfeld in the Harz Mountains, a major mining region going back to the Middle Ages. Nearby in Goslar was the very rich Rammelsberg Mine, which closed in 1989 after continuous operation for 1,000 years.

At Clausthal, Schoenert was in the Department of Mining Engineering, not chemical engineering as he had been at Karlsruhe. He taught mineral processing, which involved all of the physical (but not chemical) processes used in the recovery of minerals from ores, more than just a course on comminution and the particulate processing operations of agglomeration and classification that he had taught at Karlsruhe. Similarly, he broadened his research, though still heavily involved with comminution, to include such topics as electrical separation of minerals, magnetic separation of minerals, classification, and the separation of minerals based on differences in their density. In each area his research was innovative and showed the Schoenert touch. From 1989 to 1991, he was dean of the Department of Mining and Raw Materials. In 1992, he retired as professor emeritus.

Thanks to Klaus Schoenert, I was awarded in 1984 a Senior American Scientist Award from the Alexander von Humboldt Foundation, through which we spent a year or more in Clausthal spread out over 1984, 1987, and 1996. During that time, I was involved in research on HPGR comminution and several joint publications with Schoenert.

A characteristic of Rumpf's and Shoenert's laboratories was that they designed most of their own research apparatus and had outstanding machinists and technicians to construct the equipment. While I was in Clausthal, Schoenert was planning on constructing an improved laboratory high-pressure roll mill, so I decided to have them construct a similar small-scale high-pressure roll mill for my laboratories in Berkeley. The Clausthal machinists constructed the rolls, their housing, and gear drive for me, and the rest of our system was designed and assembled in Berkeley. Our HPGR was used for several research projects related to particle-bed comminution and increasing energy efficiency for the comminution of minerals and coal.

Schoenert was very active in professional society affairs in Europe. From 1975 to 1993 he chaired the German Working Party on Comminution of the GVC, and from 1977 to 1994 he chaired the European Working Party on Comminution, Agglomeration, and Classification of the European Federation of Chemical Engineering. He organized and chaired numerous symposia on comminution and particle technology during this period and delivered a large number of invited and plenary lectures around the world.

Klaus Schoenert was widely recognized for his contributions. In 1970, he received the Arnold-Euken-Preis, DECHEMA (Gesellschaft für Chemische Technik), Frankfurt; in 1971 the Venia Legendi für Mechanische Verfahrenstechnik, TH Karlsruhe; in 1987 the Antoine M. Gaudin Award (named after A.M. Gaudin, a founding member of NAE), Society of Mining Engineers, American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME); in 1991 the Hans-Rumpf-Medaille, DVCV (Deutschen Vereinigun für Chemie und Verfahrenstechnik). In 1991 he was elected a foreign associate of the National Academy of Engineering. In 1994 he received the Distinguished Service Award, International Comminution Research Association (ICRA); in 1996 the Frank F. Aplan Award of the US United Engineering Foundation; in 1997 the International Mineral Processing Lifetime Achievement Award, International Mineral Processing Congresses; in 2002 the Ehrenmedaille, VDI (Gesellschaft Verfahrenstechnik und Chemieringenieurwesen); and in 2004 a Doktor-Ingenieur Honoris Causa, TU Bergakademie Freiberg.

Klaus married Annelene (Anna Magdalena) Werner in 1960 in Karlsruhe. She was a wonderful and giving hostess to students, colleagues, visitors, and their many professional and personal friends. Klaus's lovely and caring wife predeceased him. He is survived by his three sons Axel, Stefan, and Frank, their wives, seven grandchildren, and many friends worldwide. For more than 40 years, we were close family friends, visiting in Germany, Berkeley, and elsewhere together.

Klaus Schoenert leaves a huge technical legacy with regard to raw materials processing. Frank Aplan (NAE, 1989) stated, "In my opinion, in terms of advancement in processing, Schoenert's high-pressure grinding rolls are equal to what flotation did a century ago. What is so impressive to me is that Schoenert's success came from a careful study of the first principles of particle breakage."

In March 2012 in Bad Dürkheim, the ProcessNet-Fachgruppe Zerkleinern und Klassieren of DECHEMA held a Gedenkkolloquium in honor of Prof. Dr.-Ing. Klaus Schoenert and announced the establishment of the Klaus Schoenert–Preis in recognition of his tremendous contributions and stature in research and education.