Mineral Energy Resources and Reduction of CO_2 Emissions

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On-site test overseas to prevent spontaneous combustion of low rank coal (Grant-in-Aid for Scientific Research (B))
Measurements of the combustion and gasification characteristics of coal by rapid heating in high-pressure atmospheres (Grant-in-Aid for Challenging Exploratory Research)

I entered graduate school in 1979 to embark on my master's course, meaning that more than 30 years have now passed since the five years I spent conducting experiments as a graduate student. Since it was so long ago, I was in two minds over whether to write about this period. However, I feel that it was an important part of my development—as I will explain below. After completing graduate school, I have conducted research on the flow of complex systems, including heat and mass transfer, such as turbulent diffusion in underground roadways and multi-phase flows in porous media/reservoirs, as well as research into the production of mineral energy resources. During this time, the heat and fluid fields have undergone major changes in research methodology. For example, rapid advancements in computing power have made it possible to utilize particle image velocimetry (PIM) during flow experiments, as well as simulation software of computational fluid dynamics (CFD) for use in numerical analysis. This sophistication of research tools and the findings they have contributed to are quite remarkable.

When I was a graduate student, students in the laboratory would generally design the analysis programs, experimental apparatuses and instruments, and also make measurement systems by ourselves with assistance from the technical staff based in the laboratory. Our understanding of the measurement principle and the precision of the instruments came from intuition based on experience and I remember working to add new dimensions or measurement items and striving to improve the precision of measurement by making modifications and alterations repeatedly. While this may at first sound like a "pure" research process, in reality we encountered many failures and experienced times of bitter struggle. This is why, to be honest, I am a little hesitant to communicate this experience to current students in such a straightforward manner.

Well-funded research projects will have access to a range of tools, including sophisticated instruments and/or commercial simulation software. By performing measurements, data analysis and numerical simulations in line with the manuals, graduate students can participate in advanced research even in nanoscale or cosmic-distance scale, for example, from the very outset. In addition, during numerical analysis, results are displayed as 3D images with a color index, making it possible, to a certain extent, to obtain results without conducting experiments/tests that take a lot of time and trouble. This makes it possible, in many cases, to generate research results in a short period of time. On the other hand, the inner workings of these measurement devices and analytical tools used during research are increasingly becoming "black boxes," which makes it difficult to judge the appropriateness of the measurement or analysis results. This creates a dilemma, as students are inclined to take results at face value and devices cannot be easily changed or reworked to reflect new hypotheses or approaches. Furthermore, the decline in the number of technical staff at Japanese universities has led to operational worries due to the difficulty in performing ongoing maintenance of devices, instruments, and computer programs installed in the laboratory.

Major topics of my research, which I have carried out from around 1990, are the production of hydrocarbon energy resources and the utilization and geological storage of CO_2. In particular, since that time it has been increasingly noted that the excavation and combustion of fossil fuel resources such as coal, crude oil, and natural gas excavated from underground, leads to the generation and atmospheric accumulation of greenhouse gases that cause global warming. Accordingly, I have conducted research on behavior analysis related to energy resources and geological storage, including utilization of CO_2, as well as evaluation of system performance. Today, the reduction of greenhouse gases such as CO_2 is emerging as a key issue that must be tackled, not only in Japan but also through global cooperation. At the 2015 United Nations Climate Change Conference (COP21) held in Paris, France, in December 2015, 190 participant countries discussed and agreed upon a framework for global warming countermeasures from 2020 onward. In other words, reducing the emission of CO_2 into the atmosphere has become a key policy issue that requires action without delay, and in order to realize this goal there are many issues that must be solved with science and technology. In particular, the "North-South disparity," and use of coal—which emits high volumes of CO_2—have become symbolic contentions of the difficulties involved. Carbon Capture Utilization & Storage (CCUS) and Carbon Capture & Geological Storage (CCS) systems combine separation and capture of CO_2 from large-scale CO_2 emission sources, such as coal-fired power plants, with their sequestration and storage underground where those carbons were originally stored for a long period of time. If such systems could be made into economically feasible projects, they would contribute to both energy supply and the prevention of global warming. In addition, geological storage of CO_2 is one of the essential measures required to prevent further disruption to the earth's carbon cycle balance, which spans the atmospheric, ocean, soil, and subterranean areas. Competition between countries to develop solutions to this issue is becoming increasingly fierce, and there is anticipation that Japan's prowess in science and technology will contribute proactively to the development of solutions.

For research that involves a scientific examination of the issues facing humanity, such as that described above, I believe that the Grants-in-Aid for Scientific Research (Kakenhi) is the most appropriate competitive funding program that places no limits on the research topics that can be applied for, and is based on peer review and ethical operation. Thus, it is managed in a manner closest to ideal, compared to the other research grants available in Japan. I surmise that the reason for this is the guarantee of academic freedom—in contrast to research grants from industries—and the efforts of the numerous researchers who have helped maintain and expand the program. I also feel that from the perspective of those such as graduate students engaged in research, the Kakenhi program supports fundamental science research (partly education) in universities, as there are generally no limitations placed on external publication of research results and findings.

I have been involved in the Kakenhi program, serving as a program officer at the Research Center for Science Systems for two and a half years from September 2003 to March 2006, where I engaged in work related particularly to the Integrated Engineering in the Engineering Sciences Group. Its area of responsibility spans a broad range of scientific fields, including the earth and earth's crust, atmosphere and aerospace, marine studies and shipbuilding, mineral resources, and energy and nuclear sciences. Although there were social needs for these sciences, in many cases there was not sufficient demand for human resources from industry. Due to these circumstances, there was, at one stage, serious concern that the development of young researchers was suffering in those areas. Accordingly, although global warming is precisely the type of issue that requires interdisciplinary research, including collaboration with the social sciences, I have included the fact that the problem demands particular effort from the integrated engineering side in my proposals and keywords addressed to this field.

Proper development and support of young researchers who can observe and identify the “unseen factors”—such as those in the earth and its subterranean environment—and boldly tackle the issues must be the absolute foundation for solving the problem of global warming that goes beyond the individual interests of industries, regions, and countries. Finally, I would like to emphasize to young researchers and graduate students that performing research “by hand” rather than “by manual” may develop their potential for new breakthroughs.