Essay

Energy-Saving Effects of Micromachine Technology

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Apparently the term "downsizing" originally denoted the trimming down of a company or other organization, although recently it has been used to mean making mechanical systems more compact. The first portable tape recorder, developed by Tokyo Tsushin Kogyo (present-day Sony Corporation), weighed eight kilograms and was driven by a spiral spring. The tape recorder was called "Densuke" by an NHK reporter who carried it on his shoulder while conducting interviews throughout the country. Current cassette recorders weigh about 200 grams, including the power source, or about 1/40 of the Densuke.

Development of the integrated circuit brought about downsizing of sound and data transmitting devices and the current trend of portable equipment. While Densuke required the user to frequently rotate a handle for recharging, today's cassette recorders can operate for nearly ten hours on one AA battery. The difference is primarily due to reducing the size of the mechanism's components from centimeters to millimeters. Accordingly, the energy-saving effects of downsizing were realized.

Since micromachines are characterized by being small and lightweight, technologies for manufacturing and operating these micromachines (micromachine technologies) have emerged to support expectations that micromachines will be exploited in numerous industrial fields. R&D on micromachines to date has yielded a variety of micromachining methods and diverse microdevices. These devices are already being used in areas unseen to us. The Micromachine Center calculated that the production of micromachines has already reached one trillion yen per year and predicts that production will expand rapidly in the future.

The objective of technological development is to create safe and rich lifestyles, but these developments are also increasing the amount of energy consumption. Micromachine technology produces machines on the order of three digits smaller than conventional machines, resulting in an extremely large energy savings. However, this point has been less emphasized. Although the power consumed by mechanical systems should be proportional to the square or cube of its dimensions, a comparison of a previously developed microlathe and a working lathe revealed a proportional power consumption on the order of $10^{1.5}$. The amount of energy saved by this downsizing was not as large as expected. Apparently various micromechanical devices developed to date have exhibited similar results.

The main reason for these results is thought to lie in the micromachining process. A rough estimation of power loss in mechanisms of conventional machines is approximately 10-30%. This value is reached mainly by achieving a form accuracy of 10^{-3}-10^{-4} of the element dimensions. Applying this to micromachines, accuracy of 1 nm to 1 Å is required for element dimensions of 1μm. Currently, however, most micromachine methods have stalled at a precision of 100 nm, which is 10^{-1}-10^{-2} of the element dimensions. While physical phenomena, such as adhesion force are prominent in the microworld, it will be necessary to achieve pinpoint machining control at the nanometer level to actively apply or remove the effects of these phenomena. In other words, nanometer technology is indispensable for further advancing micromachine technology. With this technology, power loss in micromechanical devices can be dramatically reduced. I expect the Micromachine Center to work, from the perspective of energy savings, on advancing micromachine technology that incorporates nanotechnology.