Creating and Identifying Practical Applications for New Metal Working Methods and Optimizing Actual Processes Aided by Numerical Analysis

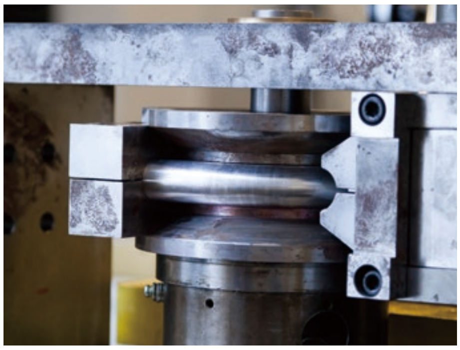
Takashi KUBOKI Laboratory

Takashi KUBOKI

Summary of Research

Study of Metalworking Methods Involving Plastic Working

Plastic working refers to metalworking that applies large stresses to materials to induce deformation. Compared to machine working, in which materials are carved, plastic working offers the potential advantage of higher production capacity and lower cost, as well as enhancing properties of finished products. However, plastic working technologies generally require extensive experience and intuition, preventing workers from rapidly acquiring the skills needed.

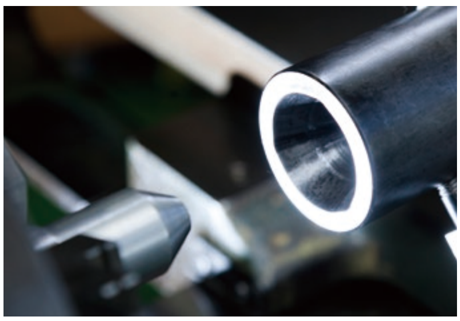


Based on a study of a totally new working method based on a theory of plasticity, our laboratory is seeking to overcome this problem and to allow any engineers and technicians to perform metalworking. Our diverse and numerous experiments and numerical analyses seek to elucidate principles, while our studies of potential applications seek to feed back real-world technologies to industry.

A Unique Method for Optimizing Current Precision Working Processes

In a joint research project with Komatsu Ltd. and entitled “Improving the Cross Section Size in Tube Bending,” we developed a method for suppressing flatness during the pipe (tube) bending process. Our goal was to improve the service life of pipes by improving the cross-sectional precision using tapered upper and lower dies for pipe bending and applying pressure to the sides of the pipe. We succeeded in reducing flatness from the 7.9% figure typically achieved by conventional processes to 2%. This method can be applied to both thin-walled and long pipes. In joint research with Amada Co. entitled “Precision Bending of Plates,” we created a high-precision prediction scheme for the springback phenomenon, whereby the bending angle in a plate decreases slightly after working, by combining a homogenization method with crystal plasticity (developed by Prof. Terada of Tohoku University) and an algorithm developed at our laboratory, work that led to real-world improvements in bending precision. In a joint project with Dymco, Ltd., entitled “Spinning Large-Diameter Thin-Walled Tubes,” we formulated guidelines for metalworking techniques based on the results of our various analyses, contributing to the development of a spinning technique for pipes of large diameter (500 mm) and thin walls (0.3 mm)—pipes difficult to process by conventional techniques.

Compared to conventional methods, the unique metalworking techniques developed at our laboratory optimize various processes and dramatically reduce the cost and time associated with precision working. In addition to optimizing existing metalworking techniques, our laboratory is developing new plastic working techniques.



One example is the free-size cold-drawing process. Conventionally, wire drawing involves one or a series of hole dies of the desired hole diameters. In contrast, our method uses only one set of two concave rolls which are positioned

Keywords

Flat plate forming, thin-walled/large-diameter tube, tube bending, metalworking, leveling, material property prediction, residual stress, spinning, precision metal working, precision bending, plastic working, plastic deformation analysis, drawn rods and tubes, composite material, micro-processing, microstructure

Affiliations	Institution of Mechanical Engineers, the UK; Japan Society of Mechanical Engineers; Japan Institute of Light Metals; Society of Material Science, Japan; Japan Society for Technology of Plasticity; Iron and Steel Institute of Japan
Member	Takashi Kuboki, Professor

in a skewed manner for the drawing process. This method can produce wires with a very wide range of diameters. Another example of our research in this area is entitled "Rotary Nosing Process Using Recessed Dies." Rotary nosing is used to form tubes with tapered ends, like those found in soft-drink bottles. Following the adoption of a cavity called the relief in the die, the results of this study made it possible to improve the nosing ratio from the typical value of 10% to an astonishing 40%.

Developing and Applying a New Numerical Analysis Technology

Oil is a common metalworking lubricant, although the effects of using oil are not yet fully understood. In addition to analyzing plastic deformation, we have attempted a numerical analysis of the fluid behavior of the lubricant. Based on the application of numerical analysis, efforts are currently underway to achieve an environmentally-friendly metalworking process that uses high-pressure water instead of oil.

Advantages

Extensive Experience and an Environment That Promotes Smooth and Efficient R&D

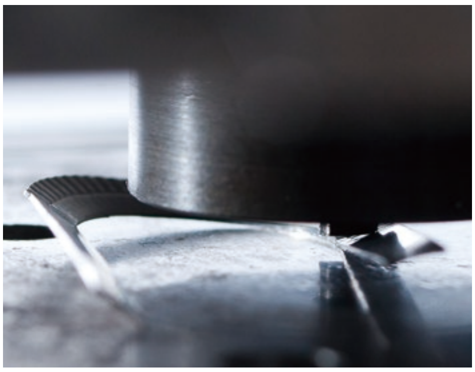
Our laboratory offers considerable experience in joint research projects with private sector entities, including Nippon Steel & Sumitomo Metal (formerly Sumitomo Metal Industries, Ltd.), Amada Co., Ltd., Komatsu Ltd., and Dymco, Ltd. In each project, we identified the actual problems confronting the industry and customized processes to achieve solutions.

"Improving the Cross Section Size in Tube Bending," the project undertaken with Komatsu, and "Precision Bending of Plates," the project undertaken with Amada resulted in real-world methods that met specific manufacturing needs. We offer the capacity to perform numerical analysis and experiments within our own laboratory, allowing quantitative investigations of phenomena difficult to observe experimentally. Conversely, through experiments, we can identify real-world effects not easily reproduced by numerical analysis. These factors allow us to execute our R&D activities smoothly and efficiently. This is our greatest strength.

Exchange and Joint Research with Domestic and Foreign Universities

Our laboratory has established close ties with other universities and research institutes specializing in numerical analysis, and we engage in frequent dialogue to exchange information and results. For example, we have maintained ties to the University of Wales in the UK for over 10 years. This allows us to consult when needed with experts there on issues related to numerical analysis. In the field of crystal plasticity, we work with Tohoku University; in areas related to fluid dynamic analysis, we work with Hokkaido University.

These collaborative efforts allow both parties to contribute their own knowledge and to benefit from research efforts by the counterpart. Professor Kuboki's work has been recognized by the Japan Society for Technology of Plasticity, which conferred the Plasticity Award in 2002 and 2004. His work has also been recognized by a silver certificate award for the ferrous division of Wire Association International in 2003.



Future Prospects

Contributing Knowledge and Experience to Composite Material Research and Medical Instrument Development

In our studies of plastic working, our laboratory has always emphasized the importance of practical applications. We hope to continue to contribute to industry through our efforts. Going beyond the fields to which we have already made contributions, we plan to venture next into studies involving composite materials.

Widely used in high-tech materials, composite materials are difficult to deform and effective processes have not been established. We plan to draw on our accumulated experience and knowledge to tackle this issue. Among related efforts, we have launched a joint research project with Hakusan Corporation under the title "Shearing Work for Composite Materials." We are also seeking to identify applications of plastic working in the field of medical instruments. Most medical instruments are currently produced with precision machining techniques; for example, a flexible forceps unit for medical robots contains an assortment of micro-fabricated components. If our precision plastic working techniques can be applied effectively to this field, Professor Kuboki believes the cost of producing expensive medical instruments can be reduced significantly, thereby promoting widespread use.