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THE APPLICATION OF SERVO PRESS MACHINE TO FORMING OF SHEET METALS WITH LOW FORMABILITY

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ABSTRACT

Sheet metal forming is facing many difficult problems such as forming of hard formable materials with high strength and low ductility, high precision forming, and improvement of productivity. To deal with the recent economic and the industrial crises whether and how to establish Japan-specific technology in the globalization of production has been considered and the specific development challenges are clarified. The sheet metal forming is an integrated technology of a variety of fundamental techniques. Servo press is one of significant and promising techniques which affect the future development. In Japan a lot of servo press machines are being introduced to stamping shops. Servo press, press machine using a servo motor as a drive source, has many features compared to conventional press machine. New forming techniques have been developed utilizing the characteristics of servo press. The use of the servo press is expected to improve tool-life, increase productivity, improve processing accuracy, reduce noise and vibration, develop complex processes, and shorten forming processes. And the application of servo press has proved successful in the forming of hard formable materials such as high strength steel, aluminum alloy, and magnesium alloy. However, for more effective use of the servo press there are still technical issues to be solved.

KEYWORDS: sheet metal forming, advanced intelligent forming, on-demand production, servo press, slide motion, NC die cushion, hard formable sheet materials

1. INTRODUCTION

Sheet metal forming, which began as a primitive craft like forging of metal block, has a long history. Sheet metal forming has been a modern development by the emergence of press machine as a means of mechanical processing, and the production and stable supply of sheet by rolling, since the industrial revolution, Sheet metal forming has many advantages such as suitable for mass production, manufacturing complex shape with good dimensional accuracy, and high material yield. As a mature technology, it has been used in the manufacture of components for automobiles, telecommunication equipments, and many other industrial products. Sheet metal forming, however, is facing many problems such as environmental protection issues, response to small-quantity production of diversified products, high precision forming, forming of hard formable materials, cost reduction, and international competition. In this paper, the prospects of technology development in sheet metal forming are introduced. And serve press, which is a new type of press machine and is expected to support the future technologies, is discussed.

2. TECHNICAL TARGETS IN SHEET METAL FORMING

In Japan the strategy to establish manufacturing technology has been planned and reviewed every five to ten years. In order to deal with recent economic and industrial crises it has been considered how to establish advanced Japan-specific techniques. The issues required in sheet metal forming are classified as follows;

(1) Manufacturing of high performance products with high precision and high added value
(2) Change of manufacturing method to sheet metal forming from other techniques such as casting and machining
(3) Response to small-quantity production of diversified products
(4) Stable production of high quality, high added value, and high precision with low cost

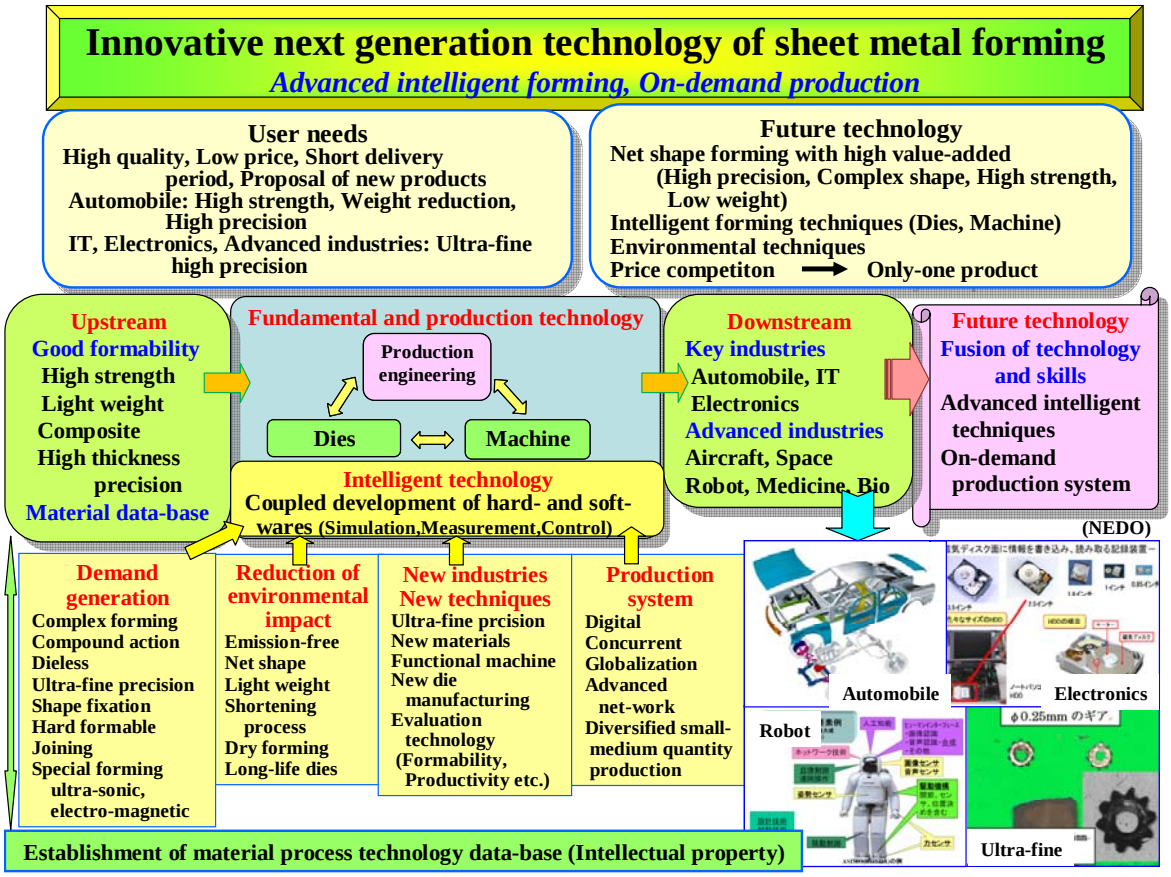


Fig. 1 The near future challenges of development in sheet metal forming [1]

(5) Development of manufacturing techniques and products with less environmental impact
(6) Development of techniques and products to meet the needs of new industries
(7) Development of production facilities corresponding to global production
(8) Development of advanced simulation technology

The near future challenges of development in sheet metal forming are summarized as shown in Fig. 1.[1] The following issues are the innovative next generation techniques related to sheet metal forming.

A. Improvement and development of processed sheet materials
B. Development of forming techniques for hard formable materials
C. Development of light weight product by sheet metal forming
D. Development of advanced forming technology for low cost, high precision and flexibility
E. Forming technology of products for new users (Development of new industries)
F. Development of fundamental techniques for the advancement of sheet metal forming
G. Development of environmentally sound forming technology
H. Development of processing techniques corresponding to global production

As the above-mentioned, there are many issues for the development of sheet metal forming technology and most subjects cannot be resolved immediately. It is important to develop simultaneously materials, forming techniques and fundamental techniques to support processing. At the same time the securing human resources is a big problem.

3. SERVO PRESS TO SUPPORT THE ADVANCEMENT OF SHEET METAL FORMING

Sheet metal forming is a comprehensive process that consists of many elemental techniques as shown in Fig. 2. The progress of individual elemental techniques promotes the advancement of sheet metal forming technology. For the press machine the invention and application of servo press is expected to be a breakthrough in sheet metal forming technology.

3.1 Characteristics of servo press

The servo press is a press machine using a servo motor as driving source, and there are various types of machines. Press machine manufacturers are at present producing and selling a variety of servo presses, for example, a mechanical servo press where the power

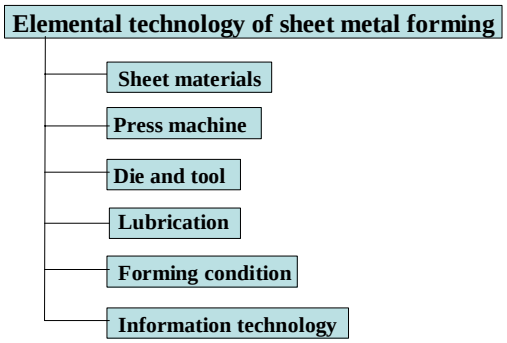


Fig. 2 Elemental techniques of sheet metal forming

of a servo motor is transmitted by rotating mechanism as a crank or by direct drive mechanism as a ball screw, and a hydraulic servo press where the power of a servo motor by means of hydraulic pressure. Fig. 3 shows an example of a system configuration of a mechanical servo press.[2] A system for moving the slide that includes a servo motor, a servo amplifier (inverter circuit), a feedback detection device, electrical braking equipment, and a control equipment (a controller).

The history of servo presses is only about 10 to 15 years, but the introduction of servo press to stamping shops has accelerated in recent years, and the application to manufacturing industries has expanded.

Sheet metal forming is originally a very simple manufacturing process, in which sheet materials mounted on a die-set are stamped by a press machine. The forming speed and force of press machine are fixed regardless of operator's intent. The servo press is a new type of machine which is controlled by software operations. The servo press is equipped with many features, and especially the slide motion is controlled freely. The slide motion of conventional press machine is determined by the driving mechanism such as the crank.

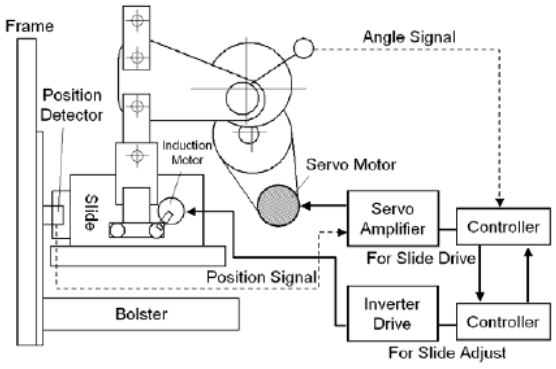


Fig. 3 Example of a mechanical servo press system configuration [2]

3.2 Slide motion of servo press

The largest advantage of the servo press is free motions of the slide. Fig. 4 shows examples of slide motions of servo press. The crank motion (a) is a typical slide motion of conventional mechanical press. The link motion (b) changes the slide speed to be slow and smooth in the processing from a fast speed, and after processing the slide moves fast upwards. The soft motion (c) is a similar movement of slide of the link motion, but the upward slide movement is faster. In the pulse motion (d, e) the slide moves up and down like a pump. The program motion (f) is an arbitrary movement of slide according to the numerical control by programming. The pendulum motion (g) changes the stroke displacement short and repeats the same movement of the slide. The repetitive motion (h) changes arbitrarily the bottom dead position. The coining motion (i) is a short slide stroke length and the number of times passing through the bottom dead can be set.

The above-mentioned motions of slide are available from the following characteristics of the servo press.

(1) Reverse motion of slide

The movement of slide is as follows. The slide moves downward at the set speed, and alternatively rises in the middle. After rising a little the slide moves again downward. The system repeats this motion as the pulse motion 2. When the slide motion change from down to rise, the forming force becomes zero and the elastic deformation of dies and machine recovers. As a result, the accuracy of product is expected to be improved. The frictional behavior is also changed. The production rate becomes generally slow.

(2) Variable-speed slide, and acceleration and deceleration function

The speed of slide movement can be changed. The touch speed of upper and lower dies can be decreased to avoid the impact, and after forming the slide movement upward changes fast. The slide speed in the forming stage can be controlled constant, accelerated and decelerated as necessary. In these slide movements mechanical properties of materials and frictional characteristics between dies and sheet material are expected to change, but these behaviors are not clear and still under investigation.

(3) Stationary function of the slide at the bottom dead

The slide can stop at the bottom dead. It is an important feature of the servo press. This feature is available for the conventional hydraulic press. For the conventional mechanical press the slide can not stop at the bottom dead and the forming force at the bottom becomes zero. Using the stationary function coining pressure can be applied to the sheet material at the bottom dead in order to ensure shape and dimensional accuracy of formed product. This feature will lead to develop new processing methods.

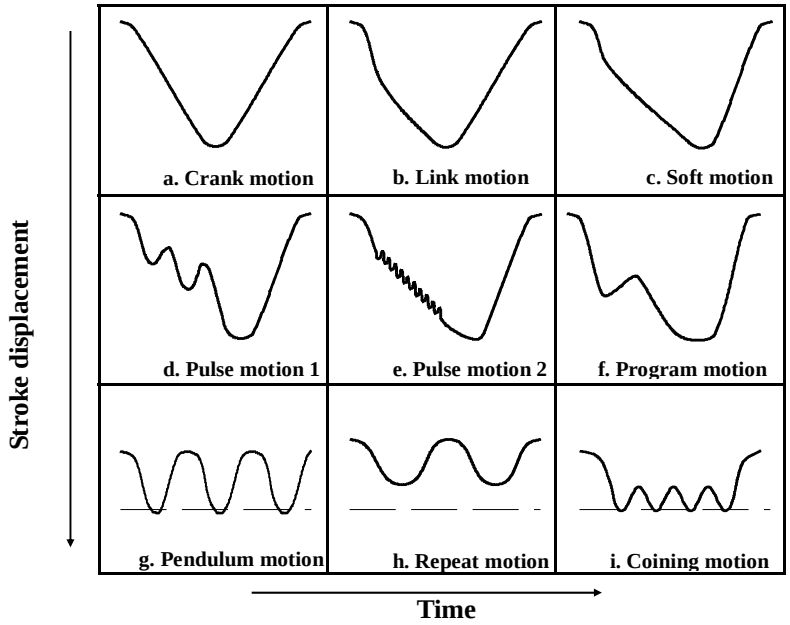


Fig. 4 Examples of slide motions of servo press (Amada Co. Ltd.,)

(4) Servo press incorporating NC die cushion

Servo presses incorporating variable die cushion by numerical control are sold in the market. The combination of NC die cushion pressure and the slide motion control seems to result in excellent performance in the sheet metal forming process. The optimal control of NC die cushion and slide motion is necessary to be examined.

3.3 Expected benefits to servo press

The servo press with many characteristics is expected to be more effective in sheet metal forming. One of effective uses of servo press, for example, is the forming of hard formable metal sheets as described in the next chapter. There are also innovative uses of servo press.

(1) Productivity improvement and energy-saving effect

The length of slide stroke of a servo press can be changed, because the variable stroke function is granted by reverse rotation of the servo motor. Therefore the slide stroke is able to be optimized depending on the processing. In the progressive press forming the shortening of slide stroke improves the productivity and reduces the energy (electric power) consumption.

(2) Noise and vibration reduction

The noise is significantly reduced by lowering a slide speed in the shearing process. However, when shearing high strength steels or high carbon steels the arrangement of clearance and structure of dies is required in addition to the control of slide speed because the fracture occurs easily.

4. FORMING OF HARD FORMABLE METAL SHEETS

One of the purposes of the use of servo press is the forming of sheet metals with low formability such as high strength steel and aluminum alloy.

4.1 Forming of aluminum alloy sheet

The application of aluminum alloys to autobody parts has steadily expanded for weight reduction of automobile. The formability, especially the deep-drawability, of aluminum alloy sheet is inferior to that of steel sheet, and the application is limited to relatively simple and easily workable parts like a hood panel and a trunk lid panel. The project titled by "Aluminum production and fabrication technology development useful for automobile light-weighting" was conducted as a way to solve this problem. [3] New aluminum alloy sheets with high r value over 1.0 and excellent formability were developed in this project.

(a) Panel formed at low velocity (41mm/s)

(b) Panel formed at high velocity (103mm/s)

Fig. 5 Door inner panel (6000 series Al-Mg-Si alloy)

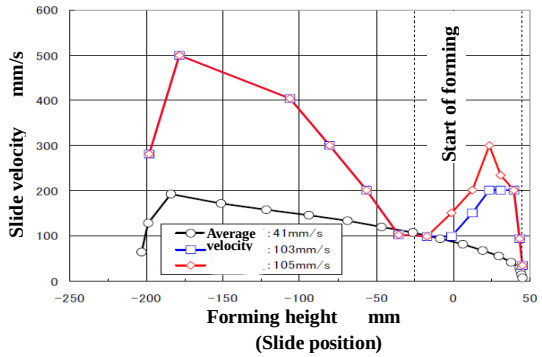


Fig. 6 Relationship between slide velocity and slide position (Forming height)
(Furukawa-Sky Aluminum Corp.)

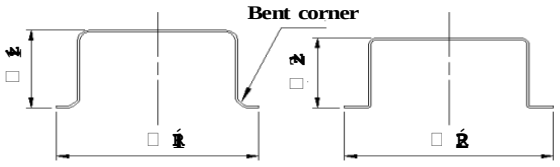
The developed aluminum alloy sheet was proved to be improved the limiting drawing ratio of cylindrical cup in the laboratory test. This alloy sheet was also attempted to apply to a door inner panel, one of the most difficult parts in the forming. The crack appeared in the conventional forming way in the forming of a modified door inner panel. It is known that the formability of aluminum alloy is improved with the increase in forming rate. Then the high speed forming was conducted. The increase in forming speed only has not enough effect, but the accelerating effect of forming rate was found. Fig. 5 shows modified door inner panels formed by a servo press at different slide motion patterns. (a) was a formed panel with a large fracture at the average slide motion velocity of 41 mm/s, and (b) was a formed panel without any fracture and any necking at the average slide motion velocity of 103 mm/s. Fig. 6 shows the changes of slide velocity with the slide position. In case of low speed forming the slide velocity decreases in the forming stage. The slide velocity in the high speed forming is accelerated in the forming stage. It is clear that acceleration effect exists on the formability. The forming rate dependency and the acceleration rate dependency of material properties and the change of frictional characteristic may affect the forming performance in this case, but the detailed investigation is not done yet.

In this experiment the die cushion pressure (binding force) is kept constant. A suitable combination of variable die cushion pressure and slide motion is expected to improve the forming performance.

4.2 Improvement of formability and shape fixability of high strength steel sheet

The application of high strength steels to autobody parts has played a very important role for automobile weight reduction. The strength level of high strength steel reaches to over 980 MPa of tensile strength. In the forming of high strength steel sheets not only easy appearance of fracture due to low formability but also the control of springback are difficult problems.

A new forming technique using a servo press is developed to eliminate dimensional inaccuracy of a hat-shape product of high strength steel sheet. Conventionally additional bending or sizing is applied to the workpiece after forming in order to modify springback and side wall curl. The developed technique is a restriking operation at the bent corner to add tension as shown in Fig. 7. Two processes of draw-bending and restriking are conducted in one stroke of slide using the servo press feature. The workpiece is formed deeper in the draw-bending and the depth of formed part is shallow in the restriking process. Fig. 8 shows the workpieces after forming.



α1 > α2 β1 < β2
α2 : Product dimension

Fig. 7 Forming process of hat-shape
(Aida Engineering Ltd.)

Fig. 8 Hat-shape workpieces (HS 590 MPa TS)
(Aida Engineering Ltd.)

This part is asymmetric and the residual stresses distribute complicatedly on the stretch flange and the shrink flange. A good shape product is obtained by considering the Bauschinger effect of sheet material.

Fig. 9 shows the deep-drawn cups of ultra-high strength steel sheets with TS of 980 MPa by multi-stage deep drawing using a servo press. Intermediate annealing is needed in the processing. The well controlled slide motion can make products such as deep.

Fig. 9 Deep-drawn cups of high strength steel sheet (980 MPa TS)
(Aida Engineering Ltd.

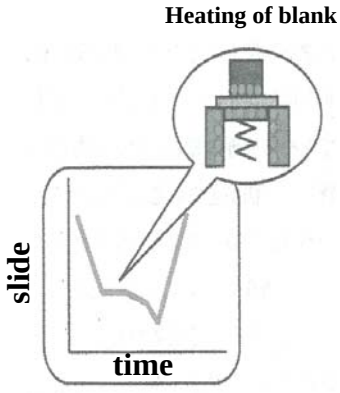


Fig. 10 Slide motion of Mg alloy warm forming
(Aida Engineering Ltd.)

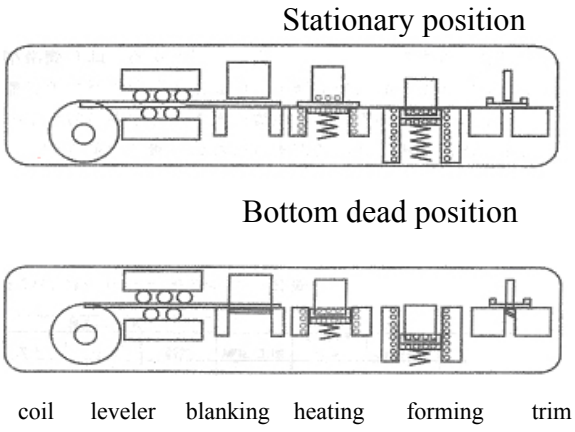


Fig. 11 Warm stamping line of Mg alloy
(Aida Engineering Ltd.)

4.3 Improvement of productivity of warm forming of magnesium alloy sheets

The warm forming is usually applied to magnesium alloy sheet because it is difficult to be formed at ambient temperature. The most important technique is temperature control of the blank. It is possible that Mg sheet heated is extracted from the furnace and formed in the press machine, but the temperature drop of Mg blank is large. The coefficient of heat expansion of Mg is large, and the temperature distribution affects shape and dimensional accuracy. New forming system of Mg alloy is developed as follows. Mg sheet is heated at the pre-heated dies and the slide stops during heating for a few seconds as shown in Fig. 10. The temperature of workpiece reaches the level required (around 250°C) for approximately 3 seconds. The slide moves downward to form the workpiece. This method can precisely control the temperature and guarantee the accuracy of formed part. Moreover the space of furnace is not necessary. Space-saving and energy-saving system of forming is realized.

Fig. 11 shows the prototype stamping line of Mg alloy sheet developed by Aida Engineering Ltd. The free motion of slide is essential in this warm forming. Fig. 12 is a Mg PC case made by in this process.

Fig. 12 Mg PC case made by warm stamping
(Aida Engineering Ltd.)

4.4 High precision forming of fine product -Use of coining pressure

Fig. 13 is a dynamic pressure bearing, which has very precise and fine grooves with the designed depth of 10 μm on the surface. The workpiece is stainless steel with the thickness of 0.501 mm. The formed groove by the link motion of slide has not enough performance, in which the depth of a groove is 1 μm shorter than the required depth and scatters. This phenomenon is considered due to the elastic recovery of formed area. Then the groove forming by the coining mode of slide is conducted, in which the slide stays for a few seconds at the bottom dead. The stationary period at the bottom dead should be at least 1.0 second. The addition of coining pressure seems to

be very effective in order to obtain high precise product.

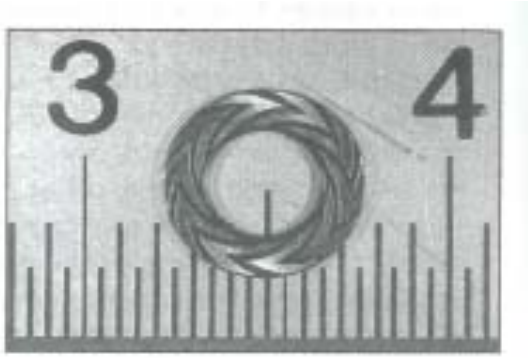


Fig. 13 Dynamic pressure bearing
(Miyoshi Industry)

5. FUTURE OF SERVO PRESS

Some examples of the application of servo press to forming processes are introduced. The servo press has a wide variety of benefits, however, it is not enough to utilize the ability of servo press. The application to the processing of hard formable sheet materials is not enough. The set of optimal design of slide motion still rely on the experience. The servo press itself has several disadvantages.

(1) Because of no flywheel, it is necessary to put a capacitor to store electrical energy, and to install a complex mechanism combined with link mechanism.

(2) Because of no clutch, the power cannot be blocked. The control mechanism to ensure safety should be taken in account.

(3) As the servo motor is expensive, the servo press is also more expensive.

Recently new technologies have been developed to advance further such as the development of servo motor with very low velocity, high torque and high response, and the closed-loop control during the full pressure in the processing. The use of servo press has just started, and there are still many issues to be solved and to be developed. The introduction of servo press to stamping shops has increased year by year. According the survey into manufacturers they expect many effective implementation of the servo press such as cost reduction, improvement of processing environment (vibration, noise), productivity increase, improvement of die life, and the expansion of forming technology for new customers and new industry. It is necessary to develop more useful and cheap servo machines and to investigate efficient and reasonable application technology of servo press.

In order to promote the industry-academia cooperative research activity of effective use of servo press, JSTP (The Japan Society for Technology of Plasticity) and JMSA (Japan Metal Stamping Association) established the joint committee of serve press application. The committee consists of manufactures of servo press, metal stamping, raw materials and tools, universities and institutions.

Japanese machinery manufactures have developed several types of servo presses according to the intended uses. The developed serve presses are universal types for multipurpose and single function types for specific use. The introduction of servo press to stamping shop has increased year by year. However, several questions still remain.

Are servo presses really useful ?

What purposes are servo presses suitable for ?

Are the functions of introduced servo press used efficiently ?

The aim of joint committee is the effective use and the development of servo press technology with industry-academia collaboration. The academic side is suitable for basic research, but is difficult to get information of problems in manufacturing shops. The industrial side has "know how", but is weak to clarify "know why". It is expected to carry out the basic research for practical application through the collaboration of two areas.

The joint committee selected research subjects from a wide range of issues to be solved concerning the application of serve press. The following subjects are the targets of committee.

1) Clarification of the characteristics of servo press, especially useful features.
2) Application of servo press to hard formable metals such as high strength steels, stainless steels, and aluminum alloys by the optimization of slide motion.
3) Fundamental study of deformation rate effect on material properties and rate-dependence of lubrication.
4) Practical effects in metal processing.
Improvement of die life, energy conservation, improvement of accuracy of products, increase in productivity, reduction of noise and vibration, etc.
5) Development of new processing method such as complex forming.
6) Application of servo press to forging.

Three working groups (WGs) have started their activities for cooperative experiments in the committee.

WG1 Step forming

Promotion of basic research toward the metal processing such as multi-stage forming utilizing the slide motion control of serve press.

WG2 Coining pressure effect

Servo press can stop the slide at the bottom dead position and ensure shape and dimensional accuracies of products. And it is expected to improve the rate of transcription of surface texture to formed workpiece. The deformation behaviors of workpiece and tool are examined.

WG3 Rate dependences of material properties

Tensile testing equipment is installed in the servo press as shown in Fig. 14. Material properties like stress- strain relationship, elongation, workhardening coefficient n value, plastic strain ratio r value are measured under various deformation rates and acceleration modes. Obtained data can be used to

optimize the slide motion and to be constitutive equation for simulation.

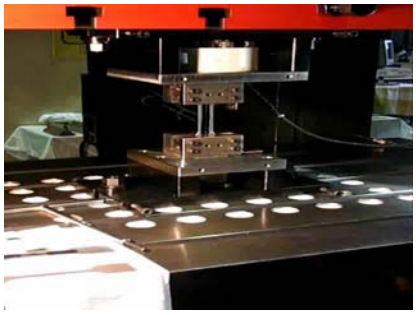


Fig. 14 Tensile testing equipment installed in servo press

6. ENDING REMARKS

The authors introduced the future issues of sheet metal forming. New products made by sheet metal forming for new industry and new users, environmental issues, and only-one specific techniques to win the international competition are required in the near future. The sheet metal forming is the processing supported by many fundamental and elemental technologies. One of them is the servo press application. It is a promising machine toward the future.

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