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CHINA MACHINE PRESS
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This book introduces the basic knowledge and new technology of metal forming in seven chapters. Chapter 1 is the introduction to the position of metal forming, its present situation and development. Chapters 2, 3 and 4 are the substance of metal forming, representing respectively the main processes, commonly used dies and machines, and covering the basic vocabulary in metal forming. Chapters 5, 6 and 7 introduce the advanced processes, dies, equipment and production systems of metal forming. The appendices include a glossary of metal forming.

This book can be used as a text book of the professional course for the undergraduate and postgraduate students of metal forming, or as a teaching material of special English reading. Moreover, it can also serve as a reference book for engineers and technicians of metal forming engaged in scientific research, management or foreign trade for learning metal forming technology and English.

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PREFACE

The requirement of modern industrial production and the development of computer science, microelectronics and laser technique are strongly motivating the progress of metal forming. Metal forming technology is developing toward partially replacing metal cutting and even directly making finished machine parts. New metal forming processes, dies and epuipment have been emerging constantly. Theories of simulation, optimization, expert system, neural network and adaptive control are being more and more widely employed in the field of metal forming. This book will introduce these newly developed metal forming techniques.

Partly finished with the support of Prof. T.Altan, this book is compiled by consulting related books, handbooks, technical reports, technical data of international conferences, international machine tool shows and the well-known companies at home and abroad and incorporating the author's researches. It contains relevant discussions of famous scholars in metal forming of the United States, Japan, United Kingdom, Germany, China, etc.

The book has seven chapters. Chapter 1 is the introduction to the position of metal forming, its present situation and development. Chapters 2, 3 and 4 are the substance of metal forming, representing respectively the main processes, commonly used dies and machines, and covering the basic vocabulary in metal forming. Chapters 5, 6 and 7 introduce the advanced processes, dies, equipment and production systems of metal forming, embodying most of the newly developed metal forming technology. The appendices include a glossary of metal forming.

This book can be used as a textbook of the professional course for the undergraduate and postgraduate students of metal forming, or as a teaching material of special English reading. Moreover, it can also serve as a reference book for engineers and technicians of metal forming engaged in scientific research, management or foreign trade for learning metal forming technology and English.

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Professor LI Peiwu
Professor YU Shijun
Jinan
September, 1994

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CHAPTER 1

INTRODUCTION

1.1 POSITION OF METAL FORMING IN MODERN INDUSTRY [1~3, 155]

Metal forming is one of the fundamental manufacturing processes. It plays an important part in metallurgy, machine-building, power, automobile, railroad, areospace, ship-building, weapon, chemical, electronics, instrument and meter making and light industries.

Metal forming is plastic working of materials. In metal forming, an initially simple part, a billet or a sheet blank, for example, is plastically deformed between tools (or dies) to obtain the desired final configuration. Thus, a simple part geometry is transformed into a complex one, since the tools "store"the desired geometry and impart pressure on the deforming material through the tool-material interface. Metal forming processes usually produce little or no scrap and generate the final part geometry in a very short time, usually in one or a few strokes of a press or hammer. As a result, metal forming offers potential savings in energy and material, especially in medium and large production quantities, where tool costs can be easily amortized. In addition, for a given weight, parts produced by metal forming exhibit better mechanical and metallurgical properties and reliability than do those manufactured by casting and machining.

As early as 1960's the industrialized countries in the world devoted much attention to the application of metal forming technology, since then there has been the trend toward the application of metal forming partially replacing metal cutting in manufacturing. At present, net shape manufacturing and near net shape manufacturing have become the focus of studies pursued by the metal forming circle.

In Germany, the United States, Great Britian, Japan and China, research institutions concentrating on the study of net shape manufacturing have been established and enormous funds and minds invested. Net shape manufacturing is vigorously developing throughout the world.

The percentage of the parts in use made by metal forming is increasing steadily. According to the count of the number of pieces, parts in use made by metal forming account for 85% in aircraft industry, 60% in electrical machinery, 70% in agricultural machinery and tractor-making, 80%~ 90% in electrical appliance, instrument and meter industry, 90%~ 95% in the production of standardized parts, 98% in the production of articles for daily use.

By the application of cold extrusion, cold heading, precision die forging, special rolling,

fine blanking, spinning, multi-ram forging, multi-position pressing, high-speed pressing with progressive dies, powder forging, super plastic forming and laser processing, finished parts can be produced with high accuracy, low surface crudeness. The days have already gone when metal forming was considered as a process by which only semifinished products could be made. It is predicted by the International Manufacturing Technology Association that by the year 2000 metal forming combined with grinding technology will replace most of metal cutting.

The conventional process of getting semifinished products from die cavities and finished parts by subsequent machining can be changed by the Free Form Fabrication method, in which material, by laser beam scanning it from dot to dot, is stacked up into the desired parts.

Today Laser Stereolithography System based on the principle of Free Form Fabrication has come into practical use. This is the frontier of forming technology, and its development will cause a revolution in manufacturing.

1.2 PRESENT SITUATION OF METAL FORMING IN CHINA [3~10, 132, 155]

Metal forming is one of the oldest manufacturing methods in human history. It dates back to ancient China (about 2000~ 1000 B.C.), when many kinds of metals (including their alloys), such as copper, silver, gold, iron, lead, tin, zinc, etc. were plastically worked and different plastic working techniques, such as hot and cold forging, sheet metal working, spinning, foil-making, drawing, etc. were employed in the manufacture of armor, tools, handicrafts and so forth. Having undergone a long period of development, metal forming has now become a very important process—a pillar of modern manufacturing industry. Theories, materials, processes and equipment of metal forming have been advancing by leaps and bounds in our country, especially during almost the last fifty years.

1.2.1 Plasticity Theory in Metal Forming

The plasticity theory in metal forming is applied to investigating the mechanics of plastic deformation in metal forming processes. Such investigation allows the analysis and prediction of ① metal flow (velocities, strain rates and strains), ② temperatures and heat transfer, ③ local variation in material strength or flow stress, and ④ stresses, forming load, pressure and energy. Thus, the mechanics of deformation provides the means for determining how the metal flows, how the desired geometry can be obtained by plastic forming and what are the expected mechanical properties of the part produced by forming.

For analyzing metal forming problems, several approximate methods commonly used are mathematical analysis method, slab method, deformation work method, slip-line method, upper bound method and finite element method, which has now obtained the most extensive application.

In China, research work in metal forming covers the yield criteria, stress and strain-ana-

lysis, numerical simulation and their experimental researches, for instance, yield loci of superplastic material (Fig. 1-1), stress-strain type of typical plane stress processes, positions of metal forming processes on Mises cylinder, etc.

1.2.2 Materials in Plastic Working

The most commonly used material in metal forming is ferrous metal, i.e. carbon steel and alloy steel. Besides, non-ferrous metals, such as aluminum, copper, magnesium, titanium and their alloys are in use as well.

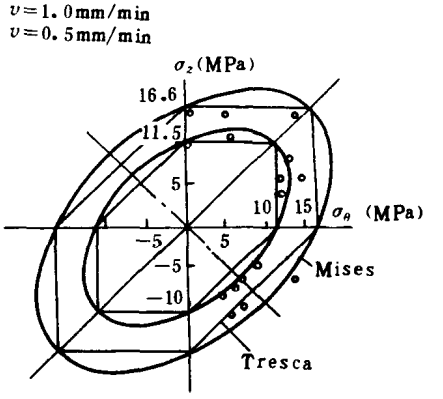

Fig.1-1 Yield loci of superplastic material [6]

In order to meet the increasing demands of different high-tech areas for the advanced materials, a new generation of advanced materials has been developed in our country, such as advanced structural ceramics, P/M superalloys, Al-Li alloys, intermetallic compounds, metal matrix composites, supperconductive materials and amorphous metals, etc. The general characteristics of these advanced materials from the point of view of processing are their low plastivity and poor workability. Thus some advanced technologies of plasticity have been developed, such as superplastic forming, isothermal forging, hot isostatic pressing, hydrostatic extrusion and explosive compaction, etc. The general characteristics of these advanced technologies of plasticity are their capability to improve the stress-strain state and the plasticity of materials.

Take the Metal Matrix Composites for example. These materials offer a number of advantages over metals and alloys, mainly in high strength, high stiffness, excellent fatigue properties and improved tounghness, so that they can be widely used in all fields of high technology, especially in aerospace. The MMCs reinforced with monofilaments such as boron or silicon carbide are not able to undergo plastic deformation after fabrication. The MMCs reinforced with non-continuous fibers such as chopped fibers, whiskers and particles can undergo and need plastic deformation after fabrication to obtain final parts. Aluminum matrix, a particulate and whiskers reinforced composite, develops very fast in recent years because it is cheaper and can be fabricated easily by most of existing plastic working methods without significant modification. In fact, these MMCs have already found certain commercial application. The orientation of carbon fibers is shown in Fig.1-2.

The development of advanced materials requires new preparation and processing methods, and in turn a new preparation and processing method will promote and accelerate the development of advanced materials. Most of advanced materials are expensive, hard to deform, requiring new, unusual preparation and processing methods to keep and develop their excellent properties. That is the reason why superplastic forming, isothermal forging, explosive compaction, high temperature-high pressure processing technologies are getting popular

in development of advanced materials. Some of them, for example, superplastic forming, isothermal forging, hydrostatic extrusion have already found limited applications, but others are in the early stage of their development. Generally, these technologies are still under development and have a long way to go to practical application.

1.2.3 Metal Forming Processes

There have been many branches and categories of metal forming. So far, the processes employed or tested in China are: open-die forging, closed- die forging, radial forging, sheet drawing, blanking, bending, bulging, roll forging, orbital forging, spinning, drawing, cross rolling, powder metal forging, liquid metal forging, superplastic forming, etc.

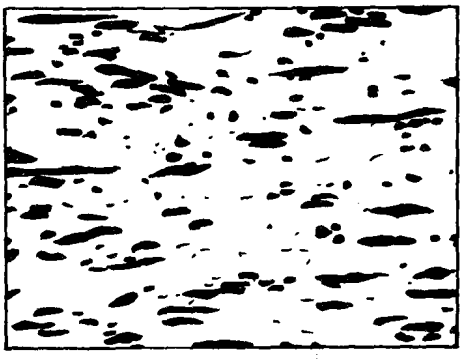

Fig.1-2 The orientation of carbon fibers [6]

In China, there are three 12 0000kN hydraulic open-die forging presses, which make it possible to forge steel ingots weighing up to 260 tons. They are also capable of producing heavy forgings for the equipment in power stations as large as 600 000kW, and 2m-in-diameter rolls of rolling mill. A lot of advanced processes such as JTS-, WHF-, FM- and KD-method have been applied to the presses. The hydraulic bulging method, developed in the 1970's, has been successfully used to produce retaining rings for generators of 300 000kW.

In China, there is one hydraulic press of 30 0000kN for the hot closed die forging, one hydraulic press of 120 000kN for the multi-ram forging, one horizontal extrusion press of 125 000kN, two mechanical presses of 120 000kN for the hot closed die forging, and many screw presses used for this purpose. Besides, there are 200 odd sets of horizontal forging machines, over 600 steam-air closed die foging hammers. Production of closed die forgings on hammers is being replaced by that on mechanical and screw presses. As far as the gear production is concerned, the straight bevel gears used in automobiles and tractors have been precisely forged in batches for years and this precise forging methiod has begun to be used to produce spiral bevel gears (Fig. 1-3). In addition, the precisely forged sychromesh gear rings have also been put into mass production.

The isothermal forging is one of the important measures to produce net shape or near net shape parts. We have successfully forged the parts with thin webs and / or high ribs 1.1 meters in lengeh. The isothermal forging method has been applied to hobbing cavities in the die blocks not only of zinc alloys but also of die steels.

Roll forging method is not only used for preforming billet before finish-forging steps, but also for direct production of final forgings such as front beams in trucks and blades in steam engines. Cross wedge rolling method has been widely used to produce stepped axle type parts in autos, tractors, motorcycles, bicycles, generators, dissel engines, textile machines, etc. Rotary forging method has found wide applicitions in producing differential axle type forgings for

autos and tractors.

Sheet forming is a conventional manufacturing method most widely used, yet it has undergone great changes, and many new processes of sheet forming have been developed. A breakthrough has been made in the technology of stainless steel drawing, car body skin pannel forming, etc. Hydraulic forming, rubber pad forming and explosive forming have been applied in production as well, for example, hydraulic forming of pulleys and bellows, rubber pad forming of five-way connections of the bicycle frame, explosive forming of hollow blades, etc.

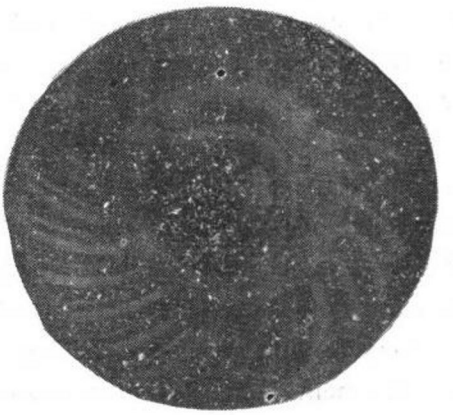

Fig.1-3 A precisely forged spiral bevel gear [6]

Some good results have been achieved in the study and spread of fine blanking technology. Since 1964, over 20 factories have introduced from abroad more than 30 special-purpose fine blanking machines mostly used to produce instruments and meters, electrical switches and appilances, watches, cameras, duplicators, teleprinters and electronic elements and devices. At present, the materials for fine blanking are up to 10mm in thickness. The largest part by fine blanking is a chain wheel for Yamaha motorcycle. In the light of our country's condition, Beijing Research Institute of Mechanical and Electrical Technology has developed hydraulic precision forming die sets applied to common presses, opening up a new way for spreading precision forming techniques.

Since the beginning of 1980's in our country great advances have been made in spinning techniques, including conventional spinning and power spinning. We have mastered the spinning technique with a direct copy as well as numerical control. In addition, the viscoplastic pneumatic bulging has been successfully employed in sheet forming. By dieless bulging the 200m3 liquified gas tank and the 8m-in-diameter spherical water tower have been built.

1.2.4 Metal Forming Machines

Having a history of over thirty years, metalforming machine industry in China has grown up with complete product varieties on a large scale. The varieties of products commercially available were up to 610 in 1990's. The metalforming machine tools with heavy duty, high speed, high precision, numerically controlled and those for special purpose make up about 8 percent in annual output value. Newly developed metalforming machines are characterized by advanced technology. Some of them have been reaching the modern world level of the similar products in developed countries.

1. Open-die forging equipment

There are nearly 100 hydraulic forging presses in China, of which 8 sets are above 60MN in capacity, and 3 sets—120~ 125MN (12000~ 12500tf). Fig.1-4 shows a 120MN open-die

forging hydraulic press installed in the Shanghai Heavy Machine Works. In our country, there are more than 1100 hammers, of which 96% are pneumatic hammers, among them 8200 hammers are 400kg or less in capacity, and 1300 sets are 1t to 5t in capacity.

The majority of the above-mentioned hydraulic forging presses are driven by pumps and accumulators with emulsion water, and their control systems are more or less out of date. These presses have no modern forging thickness control and press-manipulator integration. Many forging shops are lacking in auxiliary equipment, such as tool magazine, tool cross transfer attachment, top tool changing and rotating system, transfer cars with rotating top, scale removal, etc. In these workshops forgings are produced with larger tolerance and allowance. The workers' labor intensity is high with low productivity. Therefore, modernization of existing forging presses is an urgent need.

As for forging hammers, they are low in efficiency with great noise and vibration and serious pollution of the environment. So forging shops with hammers are also facing reconstruction and modernization.

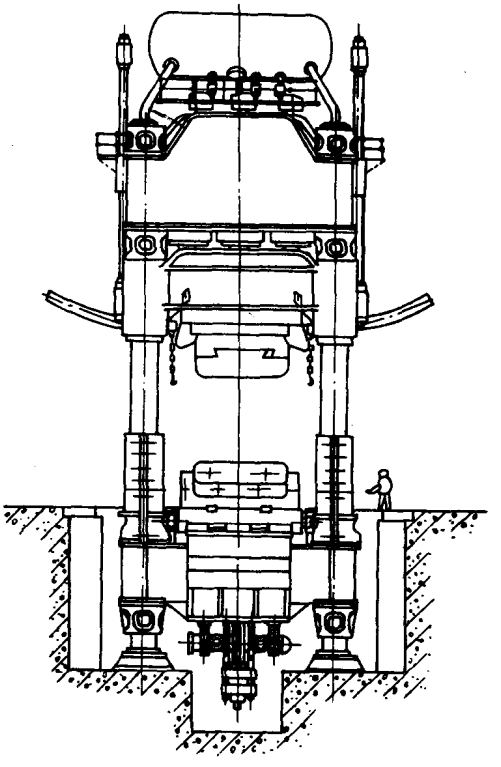

Fig.1-4 A 120 MN open-die forging hydraulic press [154]

Recently a 8000kN integrated CNC control hydraulic open-die forging press has been developed. Many practical plans have been put forward to absorb shocks from the foundation bases of hammers. To decrease the noise level in forging and stamping shops is another task we are confronted with. In this aspect, some preliminary results have been gained.

2. Closed-die forging equipment

Closed-die forging equipment make up a low proportion of metal forming machines. Most of them are closed-die forging hammers. In addition, there are more than 80 mechanical closed-die forging presses, over 30 large screw presses (>16MN), some forging machines, and a few counter-blow hammers, etc.

Among metal forming machines manufactured in China, several are at high level. For example, the 300MN(30 000tf) closed-die forging hydraulic press is the largest die-forging press in Asia. It is eight columns, eight cylinders type, and the working pressure of emulsion water is $450 \times 10^5 / 320 \times 10^5 / \times 160 \times 10^5$Pa, working area of slide table is 10m × 3.3m. It has worked for more than 23 years and produced a lot of almuminum alloy die-forgings for

airplanes. The 125MN(12500tf)hydraulic extrusion press for non-ferrous alloy extrusion is another large press designed and manufactured in China. Besides, a 100MN(10000tf)2 direction die-forging press, a 80MN(8000tf) locomotive wheel die-forging press and a 1MJ counter-blow hammer have also been manufactured in Chinese heavy machinery works.

In recent years, some advanced new products have been put on the market, such as the 1MJ hydraulic high speed hammer, on which a large titanium alloy turbine disk of airplane has been successfully forged. A new 8000kN(800tf)hydraulic extrusion press for non-ferrous alloy controlled by proportional pressure valve and a new 16MN(1600tf) hydraulic extrusion press controlled by proportional direction valve have been produced.

The following are some other achievements of Chinese researchers in closed-die forging hydraulic presses: ① the new synchro balance system of 300MN(30000tf) hydraulic die-forging press, with control accuracy up to 0.042mm / m, the highest in the world as compared with other die-forging presses, ② optimization of main cylinder of 80MN(8000tf) hot die-forging press, the working life of which is 2.6 times that of the original, ③ theory and application of prestressed wire-wound frame and container for metal forming (several dozens of presses with such prestressed frame have been designed and manufactured in China), ④ New type of hydraulic drive elements such as different types of valves, etc.

Screw presses are widely used in precision forging in our country. Among them, the friction press, being simple in construction, low-cost, and easy to service and operate, finds favor with precision forging plants, especially the enterprises of villages and towns. According to statistics, in the automobile and tractor industry, the closed-die forgings made on friction presses amount to 25%(by weight) of the total closed-die forgings, the number of friction presses accounts for 52% of the total number of closed-die forging machines. In the gear-making industry the number of friction presses accounts for 65% of the total number of closed-die forging machines, and this percentage tends to increase. In our country already exist specialized forging plants or workshops for precision forming of gears in which all the forging equipment is made up of friction presses or combined units with friction presses serving as the major machines. Now we are able to design and produce heavy-duty friction presses. In 1979, a friction press with nominal force of 25000kN was built in Qingdao Metalforming Machine Plant.

In theoretical study of screw presses, our scholars have made new contributions. Metal forming plants, colleges and universities and scientific research institutions have achieved remarkeble results in the joint development of new-type screw presses. We designed and turned out hydraulic screw presses of hydro-cylinder type, counter-screw type, hydro-motor type and double-screw type, as well as arc stator and ring stator screw presses with direct electric drive. Recently, we have succeeded in the development of J55 series clutch-type screw presses, thus entering into the rank of the major countries producing screw presses. The J55-1600 type clutch screw press with nominal force of 16000kN produced by Qingdao Metalforming Machine Plant is shown in Fig.1-5.

3. Mechanical presses in sheet metal forming

The output of mechanical presses shares over 50 percent in gross production of metalforming machine tools. Among them, the openside ones have the highest output and wide application. Although the inclinable-table presses are still dominating in quantity, those new machines with fixed tables have been of consideration by manufacturers and users.

During the period of the " Seventh Five- Year Plan" , the large capacity sheet stamping press developed rapidly to meet the needs of automobile and electrical industries. Quite a lot of new products with advanced technology were developed to replace imported equipment. For instance, a four point double action drawing press of model J47- 1250 / 2000 has been developed by Jinan No.2 Machine Tool Works. The press has the nominal capacity of the inner ram 12500kN, the outer 7500kN, table dimension 4600mm × 2500mm. It is the biggest in size double action press in China. All the advanced technology and successful experiences relating to large capacity presses at home and abroad are adopted in the machine. The successful trial production of the machine means a well forward with design and manufacture of large capacity sheet stamping presses. 22 large capacity presses with 6 varieties have been installed in four press lines in Shanghai Audi Automobile Co. and Guangzhou Pegnaut Automobile Co.

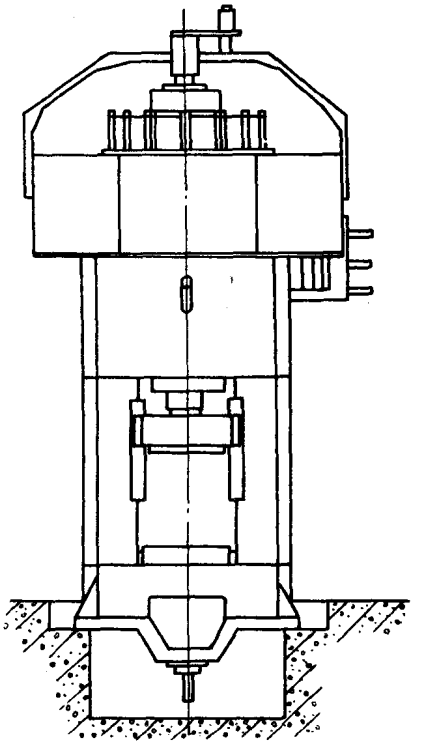

Fig.1-5 J55-1600 type clutch screw press

Several sheet stamping presses with different structures have been developed in Shanghai Press Machine Tool Works by adopting outstanding technology from abroad, for example, the straight side single action press Model JS31-800 with nominal capacity 8000kN. Qiqihar No.2 Machine Tool Works has produced EIS type 12500kN single point press, E2S type 4000kN double point press and E2D type 5000 × 3000kN two point double action press and other machines through introducing the technology from Komatsu Co. Ltd. Japan.

High-speed precision press is one of the most important machines for precision blanking in electronic, electric and instrumental industries. This kind of equipment used to be imported from abroad. In order to change the situation, Jinan Foundry and Metalforming Machine Research Institute has developed a new kind of 600kN high speed precision press model DS-048. The factory in Qiqihar, by introducing techniques from Schuler Co. Germany, has also produced SA80, SA125 and SA200 high speed precision presses. Their nominal capacities

are 800, 1250 and 2000kN respectively. They are characterized by high speed, with the maximum speed being 900 strokes per minute. The height of enclosure of the machine is adjustable. Shanghai No.2 Metalforming Machine Tool Works and Haulik+Roos Co. Germany, has jointly developed a new high speed precision press. The machine of model RVD32-540 has nominal capacity 320kN, 100～500 strokes per minute. The machine of Model RVD63-800 has nominal capacity 630kN, 80～500 strokes per minute.

4. Shearing and bending machines

The structure and / or the parts made of steel plate have the advantages of high rigidity and less weight. They are applied most extensively. For meeting the needs of industry in shearing and braking, manufacturers have developed various machines.

Shanghai Punching and Shearing Machine Works has developed QC12Y hydraulic swing type plate shear. Its upper cutter holder is supported by an eccentric sleeve and acted by two hydraulic cylinders and a nitrogen cylinder to carry out shearing action. The eccentric sleeve can be adjusted to change the distance between upper and lower cutters. Its frame is a welded steel construction. There are both front and back stop dogs in the machine. The back one is mounted on the upper cutter holder. It is mechanically adjustable and can swing up and down with the upper cutter holder. The micro adjustment is done by a hand-wheel. The machine is compact, less in weight, high in rigidity, and easy in adjustment. It has developed into a complete product series with minimum sheet shearing thickness of 4mm, and maximum up to 16mm, Huangshi Metalforming Machine Tool Works produces MVN and MVCS hydraulic plate shears with shearing thickness 4～25mm by introducing the techniques from LVD Co. Belgium. Its upper cutter moves up and down periodcally, and the length of stroke can be adjusted steplessly. A quick adjusting device is used to adjust the distance between cutters. The manufacturer also produces PPN and PPNMZ series of hydraulic press brake machine with nominal capacity of 650～5000kN, which is also introduced from LVD Co. The mechanical and hydraulic feed-back synchronous system is adopted for high accuracy and strong resistance to sideloading. Shanghai Punching and Shearing Machine Works has developed WC67Y hydraulic press brake with nominal capacity of 400～2500kN. A mechanical sychronizer is used for ram slide synchronization. The stop dogs, which can be adjusted by an electric motor and fine adjusted manually through buttons, are used for accurate positioning at the end of slide stroke.

Changzhi Metalforming Machine Tool Works has developed W11XPC horizontal three-roll plate bending machine and W12PC four-roll plate bending machine. They are all hydraulic driven. Both upper and lower rolls are active and driven by hydraulic motors. The upper rolls and lower rolls of the machines can move separately or simultaneously. The displacement is controlled by a microcomputer with digital readout. They have high synchro-accuracy. The inclining and resetting of the inclinable bearing, as well as loading alignment are all driven by hydraulic cylinders. To preroll and then roll cylindrical-, arc-, and cone-shaped products, the plates need to be placed on the tables only once, no reversing is necessary.

5. Hydraulic presses for general application

Hydraulic presses are applied less than mechanical ones. In recent years, domestic manufacturers are working hard to improve up their design. Quite a lot of new hydraulic presses have been developed with advanced hydraulic drive system and electric control system. For instance, a YT28-630 / 1030 type double action sheet stamping hydraulic press has been made by Tianjin Metalforming Machine Tool Works. Its capacity of inner ram slide is 6300kN, and the blank hold pressure of outer ram is 4000kN. The table dimension of the machine is 3200mm × 2200mm. The active stroke speed of slide during drawing is 20～55mm / s, and the speed of idle downward stroke is 300mm / s, much higher than that of the old ones. The frame is a rigid combined construction. The inner and outer ram slides are guided independently, resulting in better running accuracy. The table is movable so that the mould can be changed quickly. The inserted valve bank and variable delivery pump are employed in hydraulic system to reduce hydraulic shock and improve reliability as well as to prolong service life. The programmable controller is used in electric control system with a multiple failure alarm indicator.

High speed hydraulic presses have found wide application in the developed countries, but they have not been fully developed in China yet. Hefei Metalforming Machine Toll Works produces three series of high speed presses by introducing outstanding technology from Lauffer Co. Germany. One of them is the highspeed hydraulic drawing press model EZU63, with nominal capacity 630kN, maximum stroke of ram slide 630mm, operation speed 22.8mm / s, idle down stroke speed 380mm / s. The C-type frame is for easy operation. There is a build-in hydraulic die cushion, too. Blank hold pressure can be varied with different strokes, which is suited for deep drawing and bending operation. An optical curtain protection device is for safety in operation. This machine is characterized by high accuracy, high speed, and high productivity.

A YH240-10 precision, straightening hydraulic press has been jointly developed by Hefei Metalforming Machine Tool Works and Hefei Institute of Technology, with nominal capacity of 100kN, which is specially for straightening operation of shafts, tubes, and strip materials. The displacement of slide is measured by optical grating and servo-controlled with digital readout. The accuracy of measurement is up to 0.05mm. The stroke limit can be preset by a dial to avoid overstraightening. The machine is built to replace the manual straightening operation so as to reduce finishing stock, operation time and to increase productivity.

6. Numerically controlled metalforming machine tools

(1) NC press Jinan Foundry And Metalforming Machine Resarch Institute has developed a J92K-25 type NC punch turret press with nominal capacity 250kN, 24 punch positions, maximum sheet dimension 1000mm × 2000mm, max. sheet thickness 6mm. The travelling speeds along both x and y axes are 40m / min. The positioning accuracy between two adjacent holes is ± 0.15mm. The machine has 3 axes NC control, with 2 axes operating simultaneously. The program can be input either by tape or by keyboard, with CRT display