

Classic sheet metal processing in new dimensions – punching, nibbling, forming

Since the fifties, as advances were made in sheet metal processing machines, the significance of the sheet metal as a material increased accordingly. Whereas punching machines were first used primarily for creating precision holes, they are used today for a multitude of manufacturing tasks in flexible processing. Their outstanding feature is that when used for punching, nibbling and forming, they can process quickly while retaining high precision.

The term punching describes a slitting process, in which a punching machine or press separates a sheet of metal by striking it. Initially, eccentric presses were employed for punching holes. Sheet contours were processed by stamping machines. By equipping these with nibbling tools, the nibbling machine was born.

Nibbling refers to separating a material bit by bit along any formed cutting line by punching several individual, overlapping holes.

Whereas an operator once moved the workpiece by hand, partial automation was later made possible thanks to the development of a machine with a coordinate guide and a template. A stylus connected to the coordinate guide of the nibble machine traced the contour of the template. This in turn moved the workpiece under the machine head to produce the component.

A major step towards combining punching and nibbling technology was taken with the introduction of a combination punching and nibbling punch machine. Adding a clutch to the nibbling punch enabled the machine to carry out individual strokes. Thus, it became possible to punch and nibble on the same machine.

The end of the sixties brought the introduction of NC technology to machine tool manufacturing and a precise continuous control system with NC axes. Instead of templates, punched tapes containing the necessary processing

information were used. The floppy disk finally superseded the punched tape as a data carrier. Moreover, tool changing and loading and unloading of the workpiece were automated.

The development of the electrohydraulic ram drive finally allowed a workpiece to be processed while taking the required punching power, stroke speed, and stroke position into account. Processes such as forming and tapping rounded off the processing possibilities of a complete metal sheet on a punching machine.

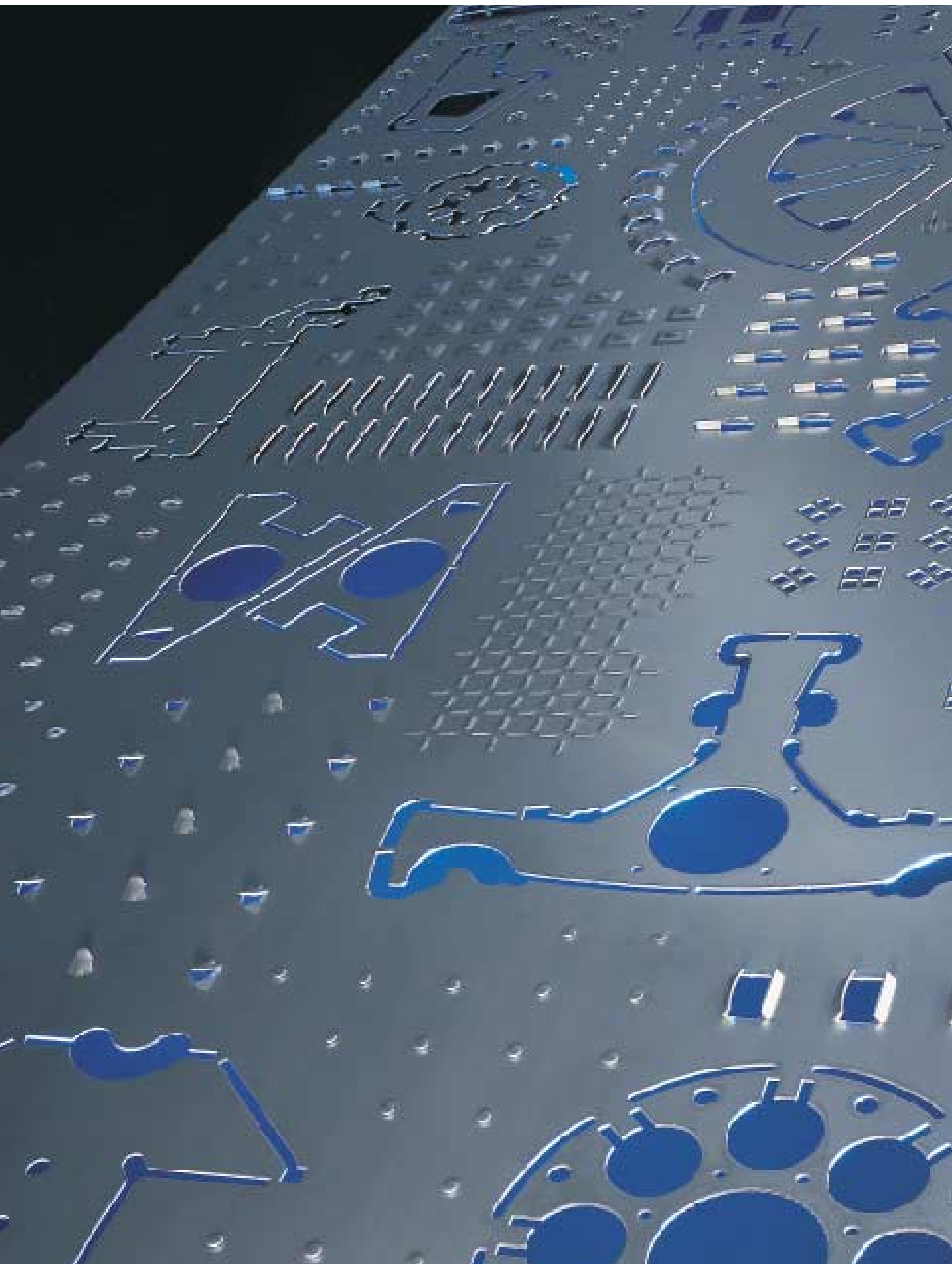
The rapid development of punching technology forms the foundation for today's high-tech machines with their wide range of possibilities and high processing speeds while maintaining the utmost precision and a favorable cost/performance ratio. Today we cannot imagine sheet metal processing without them.

Punching in terms of making holes or cutting out pieces is done by a process known as shearing. Shearing is the result of placing a sheet between an upper tool (punch) and a lower tool (die). The upper tool plunges into the shearing the sheet producing a punching slug which is pushed through the lower tool.

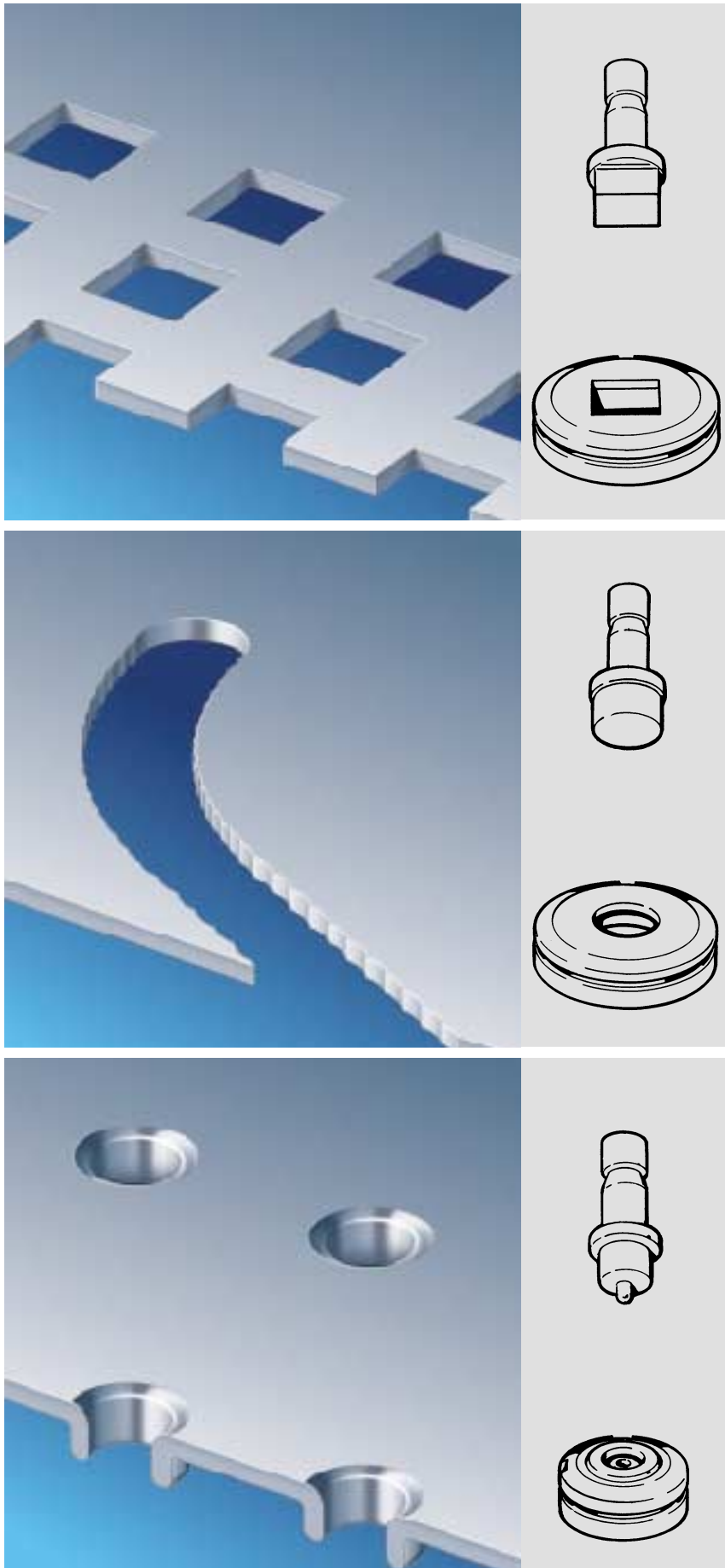
Punching encompasses the manufacture of an outer profile and apertures. When punching holes, the hole in the workpiece is identical to the geometric shape of the punch.

Aside from punching openings, a punching machine can also be used for





PUNCHING



Work processes: punching, nibbling, forming

other work processes. The most important of these are nibbling and creating formed areas.

Nibbling describes the step-by-step process of creating any kind of contour in sheet metal.

Forming is a manufacturing process in which a workpiece is shaped. Extrusions, beads, and louvers are examples of forming areas which, for instance, are required in the manufacture of electrical cabinets.

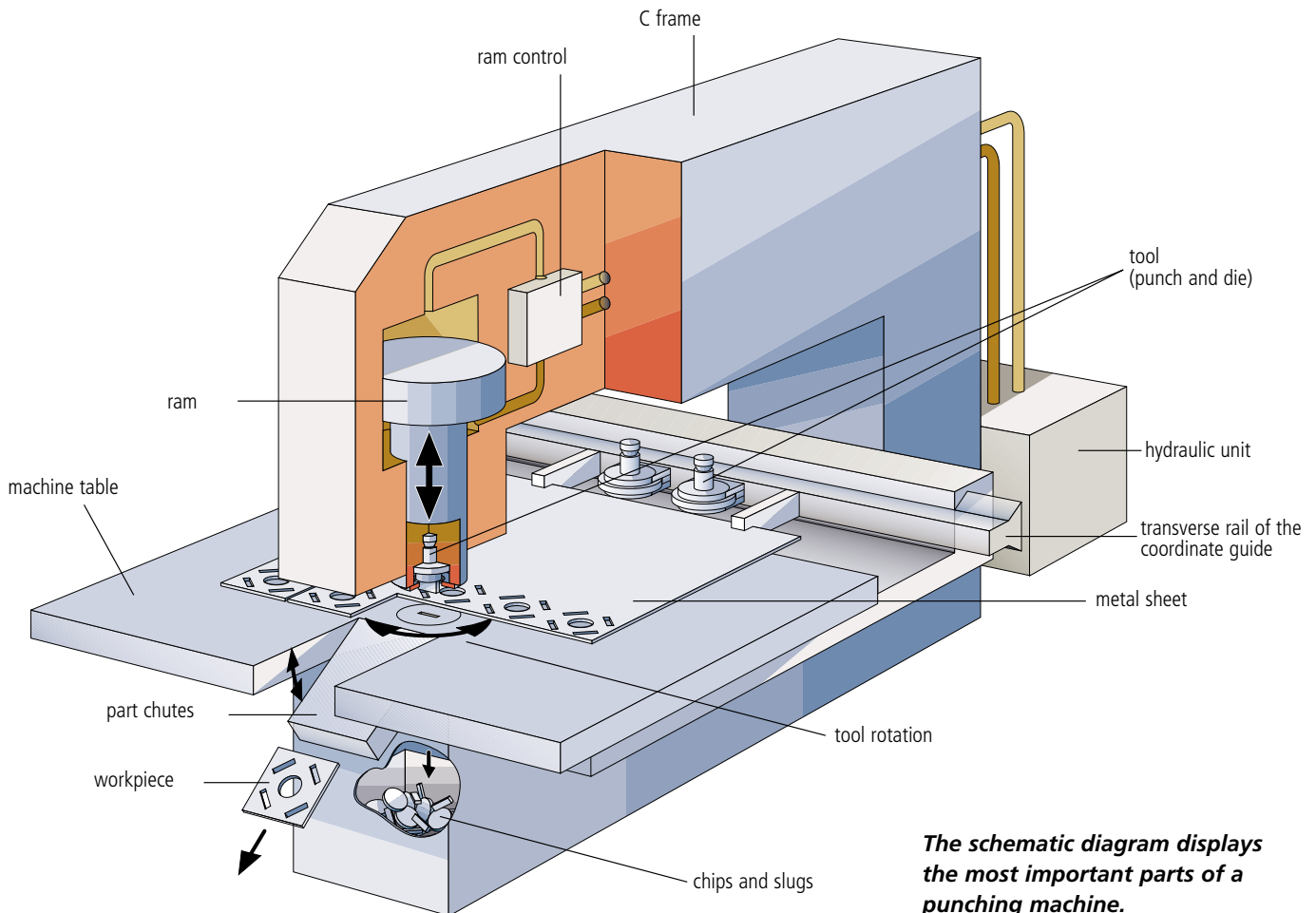
How a punching machine works

Before processing, the operator places the sheet into the clamps of the coordinate guide. A tool – punch, stripper, and die – are placed into the tool adapter. The sheet is positioned under the punching head by the program control: this is accomplished by quickly moving the coordinate guide and the machine table. The punch of the tool punches through the sheet, producing a hole with the same shape as the contour of the punch. The punch punches in rapid succession – up to 1000 strokes per minute – the programmed contours into the sheet.

All the processing functions and positioning of the sheet metal are CNC controlled. The CNC control coordinates the drives to ensure that the individual motions and the exact assignment of the coordinate guide (tool positioning) and ram (punching stroke) are synchronized.

Several identical workpieces are often manufactured from a single metal sheet. In contrast to the classic procedure, by which a workpiece was initially cut to size and then processed, the sequence today has been reversed, particularly for large-scale manufacturing. The punching tool, once it has been loaded into the tool adapter, processes all identical elements of each part on the single metal sheet. The next tool is implemented and the process repeated. Only after the sheet has been completely processed does the machine cut out the individual workpieces with a punching tool. The individual parts are then removed from the work area via a part chute.

Machine concepts



The schematic diagram displays the most important parts of a punching machine.

Punching machines used in flexible sheet metal processing have a punching power of approx. 25 tons and, for the most part, employ standardized tools. Punching machines of this type are particularly suited for small and medium sized lots. This is due to their short setup times, quick tool changing times, easy to use tool and program administration, and finally automation components for removing and sorting pieces.

Machine frame

The machine frame of a punching machine absorbs the forces required for punching. It is either shaped as a C open at the front or as a closed O. The C frame allows you to easily access the work area and also to process oversize sheets by simply turning them.

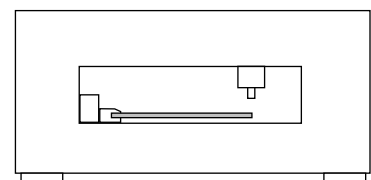
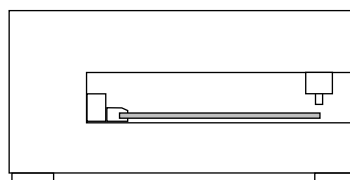
Ram drive

The up and down motion of the ram is produced either electrohydraulically with a hydraulic cylinder or electromechanically with an excentric drive.

In an excentric drive the excentric connection of the ram (connecting rod) to the rotating shaft causes the ram stroke. A flywheel is located on the shaft,

whose rotational energy is transferred to the punch by means of a quick-engaging clutch.

Oil under pressure moves the hydraulic cylinder or punching head. A hydraulic pump creates the required pressure (up to approx. 3380 PS) which is then directed into the cylinder. The result of this transfer of force is the generation of a punching stroke.



A machine frame has the shape of a C or an O.

Hydraulic punching head

A hydraulic punching head works in a way that has been optimized for power and energy. The required punching power level is selected automatically depending on the required punching power. Thin sheet metal only requires low oil pressure which results in less punching power. This in turn reduces the punching machine's energy requirements.

The hydraulic ram has its own NC-controlled axis which regulates the start and reversal points of the stroke movement of the ram according to the metal thickness. Unnecessary stroke lengths are thus eliminated, increasing the number of strokes and ensuring a perfect penetrating depth for the punch into the die. This leads to a significant increase of the tool life.

By regulating the ram speed precisely, a hydraulic punching head can reduce noise up to 80 %. The pressure increase in the punching head is measured and evaluated when the punch strikes the workpiece. A temporary reduction of the ram speed can lead to a more quiet punching of the workpiece.

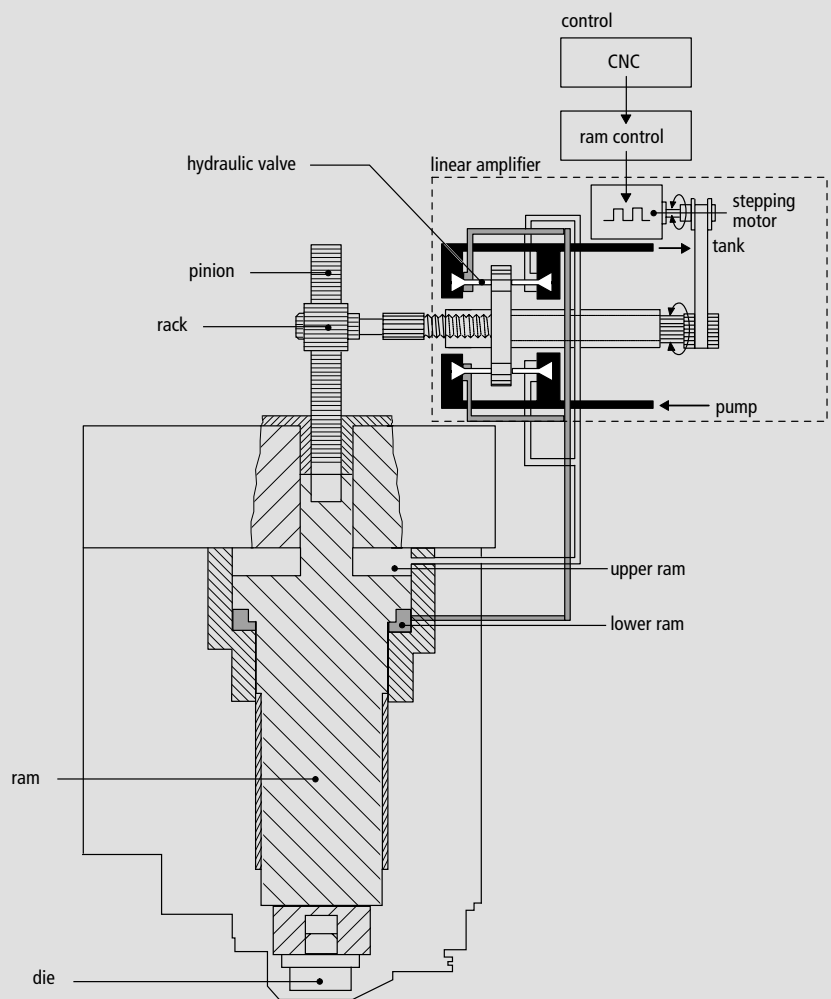
Tool adapter

In a punching machine we distinguish between a tool adapter in which a complete tool set is hydraulically tightened so that it cannot move and a turret which serves as a tool storage and guide.

With hydraulically tightened tools the ram as the upper tool adapter holds the punch with the stripper. The lower tool adapter holds the die. The upper and lower tool adapters have the same centerpoint. The long, hydraulic ram guide provides highly precise tool coordination and allows extreme eccentric loads on the tools (for example during nibbling and notching).

Tool rotation: The tool adapter can also be implemented as a rotational axis allowing all the tools to be rotated. The upper and lower tool adapters rotate synchronously and along the shortest route around the programmed rotational angle.

Principle of the hydraulic punching head



Schematic illustration of the hydraulic punching head

1. Setting the ram position

The control regulates the distance between the ram and the surface of the sheet metal. A stepping motor regulates this distance. In this initial position prior to the punching stroke the lower ram surface is under hydraulic pressure.

2. Executing the punching stroke

The punching stroke is initiated by an additional signal from the control. The hydraulic valve of the linear amplifier is opened and conducts a flow of oil onto the upper ram surface upon which the ram is pressed downwards. When the ram makes contact with the sheet, the hydraulic pressure on the upper ram surface automatically increases until the punch is executed. If a high degree of punching power is required, the hydraulic pressure on the lower ram surface is also cut off.

3. Return ram stroke

After the punch, the ram reaches its lowest position. The hydraulic valve is then closed by the mechanical rack and pinion. The ram is returned to its initial position by increasing the hydraulic pressure on the lower ram surface while decreasing the pressure on the upper ram surface at the same time.

This reduces the required number of tools, setup time, and the number of tool changes. Tools specifically designed for rotation such as multicut and curved tools allow contours to be processed very quickly with a minimum of roughness which otherwise would have to be performed by time-consuming nibbling. The versatile rotational axis can also be used as a drive for tapping tools and multitools.

In turret punching machines rotating the turret brings the tool necessary for processing under the punching station. The ram strikes the punch, drives it through the workpiece into the die and then moves back up. After the punching stroke, a spring pulls the punch back to the initial position.

Tool storage

The tool store contains the tools necessary for processing. Apart from internal tool magazines there are also external magazines which can automatically provide the punching machine with additional tools.

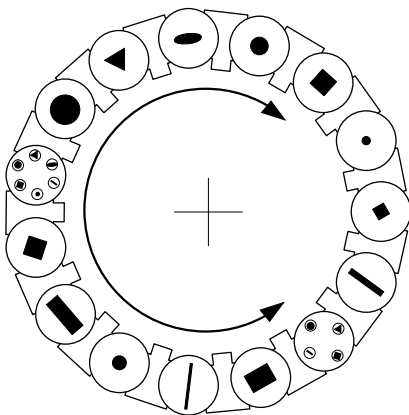
The tools are exchanged internally using a tool changer which is the mechanism serving to transport and load the desired tool into the tool adapter. The combination of tool changer and tool storage is realized by means of a linear magazine.



The rotating tool adapter allows all tools to be rotated.

The easily-accessible linear magazine is mounted along the transverse rail and takes full advantage of the available motion axes. This eliminates the need for a separate drive. The magazine is equipped with tool cassettes which already contain tools arranged in sets. A tool required for processing is inserted into the tool adapter by means of a programmed procedure of the coordinate guide. Aside from the tools, the clamps for workpiece are integrated into the linear magazine.

In turret punching machines the tools are normally arranged in a circle. The tools are set up manually. Punches, strippers and dies are attached individually in separate mounts. Rotating the turret brings the required tool into the defined punching position of the turret.



In turret punching machines the tools are arranged in a circle.



Complete tool sets are set up in the linear magazine.



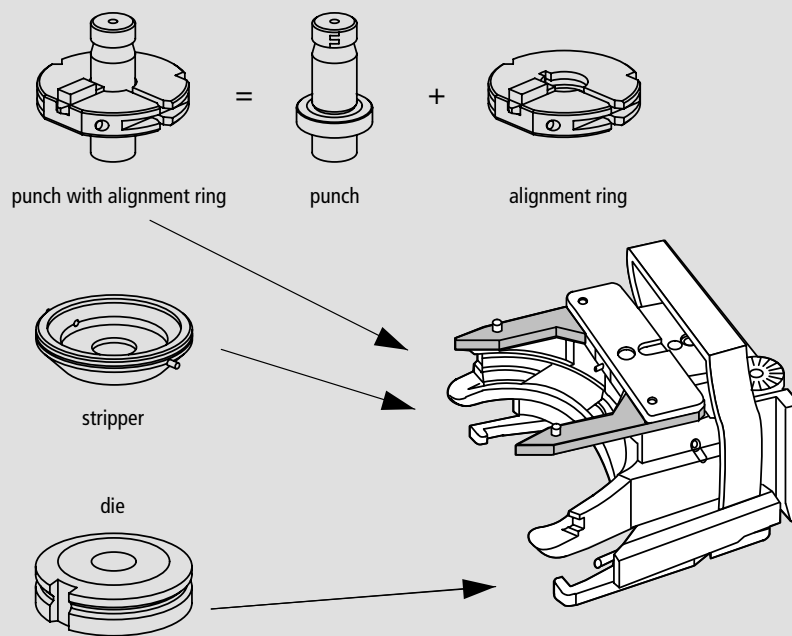
The external tool storage can supply the machine automatically with additional tools.

Workpiece clamping

Workpiece clamps hold the sheet metal and guide it as it is processed. They are hydraulically or pneumatically activated. The clamps can either be mounted to set positions or variably placed on the transverse rail.

The area of the sheet upon which the clamps are located remains unprocessed, because the clamps would otherwise collide with the punching head. If this collision area is also to be processed, you must reposition the sheet. The sheet is then clamped with a stripper, and the coordinate guide moves in a program-controlled manner with open clamps. Afterwards, the clamps clamp the sheet once again and processing continues. Repositioning is also necessary for pro-

Punching tools



A punching tool consists of a punch and die. An alignment ring and stripper complete the tool set. A tool cassette holds the tool set. This means that the complete tool set can be inserted into either the tool adapter or the tool storage in a single step.

Punch with alignment ring

The punch is manufactured from high-speed steel (HSS). For specific applications, punches with coated or oxidized surfaces can be used. The alignment ring is a clamping ring, which fastens the forming punch (e.g. rectangular tool) in the zero position. It transfers punching power from the ram to the punch.

Stripper/holding-down clamp

The stripper or holding-down clamp can perform three functions:
Stripping function: the stripper separates the sheet metal from the punch during the return stroke.

This prevents the metal from being pulled up

with the punch. During processing, the stripper is situated approx. 0.5 to 1 mm above the workpiece surface.

Holding-down function: The hydraulic control lowers the stripper onto the sheet before the punching stroke and holds it securely to prevent warping. This function is particularly important when processing thin sheet metal.

Self-separating tools are used as an alternative to strippers and holding-down clamps.

Clamping the workpiece: to rework oversized sheets, the stripper lowers itself onto the sheet and clamps it down while the coordinate guide moves with opened clamps for reworking.

Die

Punch and die function as shearing tools which pass alongside each other in a scissor-like motion and cut the sheet. The resulting punching slug falls through the die and is usually extracted.

cessing sheet lengths greater than the working area.

Similarly, retractable clamps also allow a sheet to be processed completely, making the clamping strip unnecessary. If a clamp is positioned into the punching area, the clamp opens and moves automatically out of the collision area.

Coordinate guide

The metal sheet held by the clamps is positioned in the longitudinal and cross direction during processing by the coordinate guide. Rack and pinion systems or lead screws execute the motion and precision drives provide a positioning speed of over 4300 ipm at a positional range as small as 0.03 mm.



Retractable clamps

Machine table

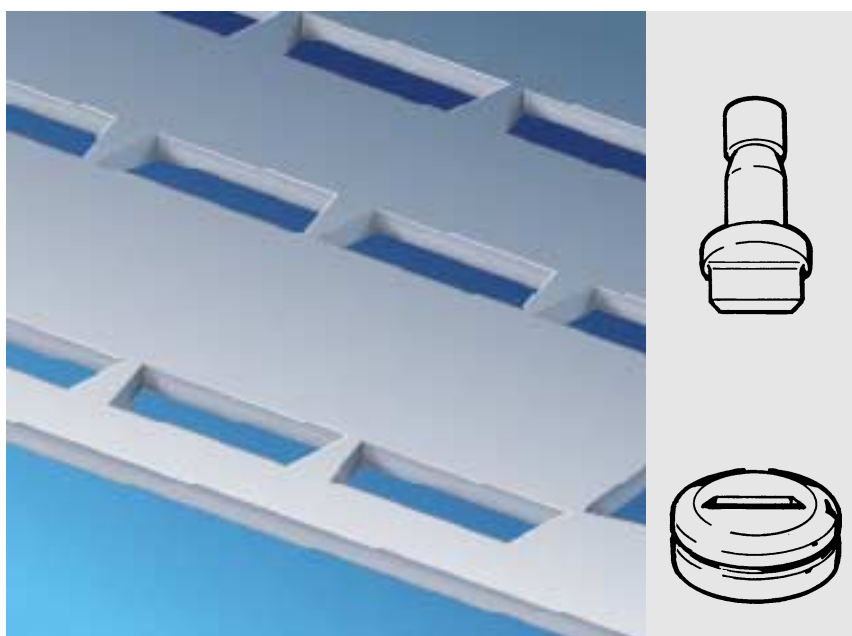
Machine tables support the sheet during processing. A complete support reduces vibrations when positioning. Furthermore, a table prevents the sheet metal from sagging, thereby adding to the high precision of the punches. Machine tables are rigid or can extend out in one direction.

Ball rollers or brushes which can be integrated in the table surface keep the effects of scratching to a minimum. They allow the sheet to glide more easily over the table.

Removing the parts

After processing with punching tools, the finished passes or scrap pieces are removed from the working area of the punching machine:

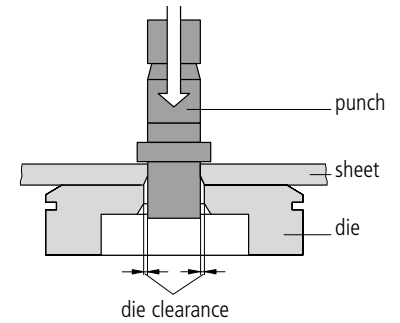
- Finished or scrap pieces of limited size are removed by movable chutes to the containers provided.
- Very large finished or scrap parts are removed by hand or by an automatic unloading system.
- Microjoint manufacturing: The parts are held by small webs and are pressed out by hand from the scrap skeleton.



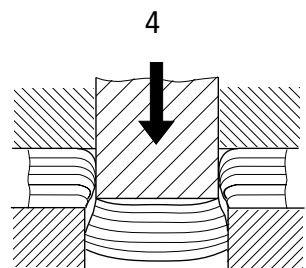
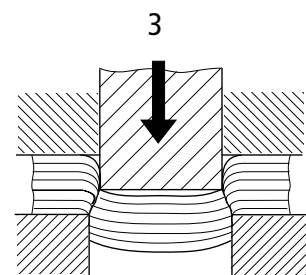
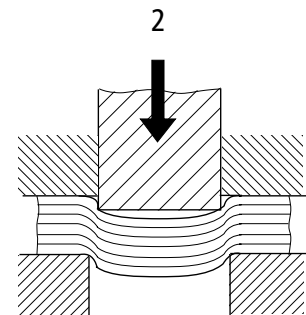
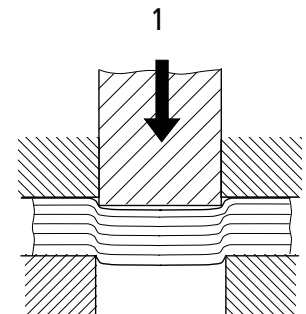
In microjoint manufacturing, small webs hold the parts in the grid.

- Small scrap pieces are usually punched into little pieces.
- Chips and punching slugs fall through the die – often with the help of a vacuum system – into a chip container or onto a conveyor belt.
- Processed parts and scrap skeletons can also be removed by supplementary unloading and sorting systems.

Tools



Die clearance width influences punching quality



The four phases of the punching process

Tools and workpiece

When punching, punching tools create holes and openings of any shape in the workpiece. The tool shapes used most often are: round, square, rectangular, and oblong tools. Depending on the contour shape, the outer contour of an individual part can be processed with punching tools in nibbling mode or with slitting tools. Slitting tools are narrow rectangular tools with a corner radius that in combination with the tool rotation can quickly cut out pieces.

The minimal dimensions for a punch can be calculated according to the following general rule: punch size (outer circle diameter) \approx sheet thickness. Smaller punch sizes pose the risk of breakage. To avoid breaking the punch, tools with a guided cutter can also be used.

The maximum size of a punch varies between 80 and 130 mm and is dependent on the following influencing variables:

- the maximum punching power available (machine type)
- the maximal geometrical size of the tool adapter or turret bore

- the sheet thickness
- the sheet's tensile strength

Nibbling usually requires smaller punches with a diameter of up to approx. 30 mm.

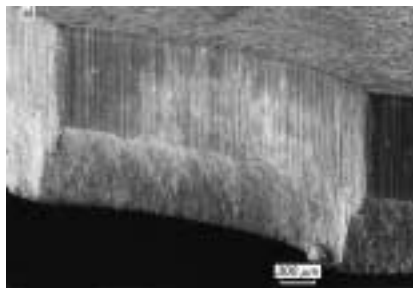
Tools and Processing quality

Die clearance and cut-fracture ratio: The technically required die clearance is the distance between the cutting edges of the punch and die. It influences punching quality.

The punching process is divided into four phases:

- Phase 1: indenting the sheet
- Phase 2: cutting
- Phase 3: fracturing
- Phase 4: ejecting the punching slug

The choice of die and thus the die clearance affects the cut-fracture ratio (phases 2 and 3) when punching. A die clearance of $0.1 \times$ sheet thickness results in a cut-fracture ratio of $1/3$ to $2/3$. If the die clearance is smaller, the cut ratio increase to $2/3$.



punching with a 2/3 cut ratio

Punching with very smooth cutting surface: The larger the cut ratio, the more cylindrical the punching result which can be necessary for fittings with an extremely high supporting percentage. The largest possible cut ratio can be attained if you pre-punch with an approx. 1–2 mm small tool and a die clearance of 0.1 x sheet thickness. Afterwards, rework with the desired tool to form a scraping cut with a small die clearance. This method has also proven itself in reducing punching power for thick sheet processing with large tools.

Processing high-grade steel and aluminum: When processing high-grade steel and aluminum, cold welding and build-up edges may occur. These effects

can be reduced by in the following manner:

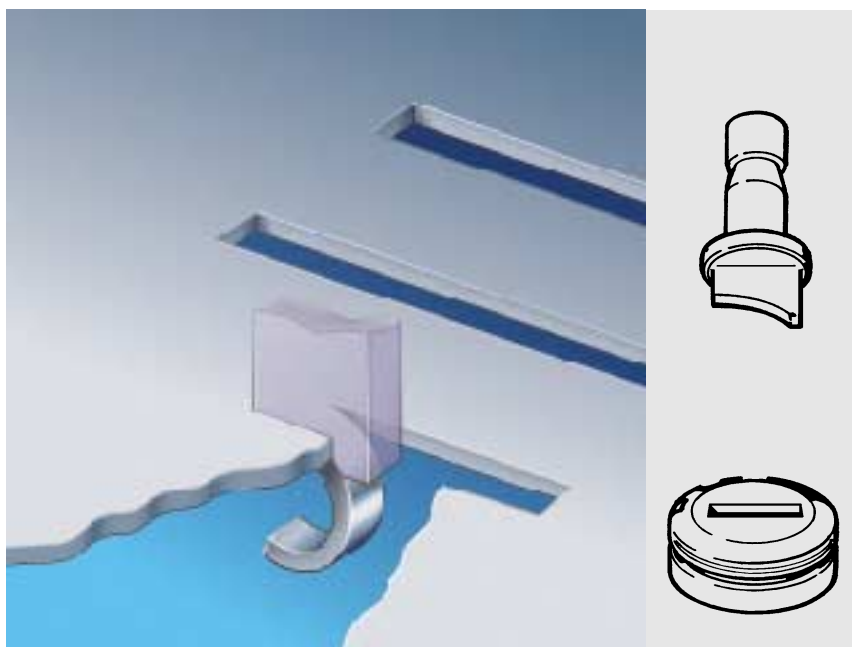
- by additionally lubricating the tool
- by using oxidized or surface-coated punches

Manufacturing very precise punches:

When punching with an active holding-down clamp, the stripper/holding-down clamp rests on the sheet during the punch. The sheet is then pressed against the underlying die, resulting in very precise punches of flat workpieces and a further improvement of cutting quality.

Roughness: If a contour, for example a circle, is nibbled with a round tool, the nibbled edge will have a roughness which correlates to the feed per stroke. Smaller strokes improve the quality of the nibbled edge. In other words, there is less roughness.

Visible edges – slots: Slotting is a two-sided shearing process in which an even cutting edge is produced free of build-ups. This process is particularly suited for visible edges. During the slotting process, the chip is rolled up into a spiral coil and finally separated by a deep-plunged stroke.



The slotting tool produces visible edges

Hand-held machines

Hand-held machines are used any time a workpiece must be processed directly on site. They can be used for three-dimensional workpieces with formed areas as well as for bulky constructions that are fragile to transport. Typical examples of hand-held machines are hand-held nibblers for producing cutting edges free of deformations in sheets up to 10 mm thickness. These can then be processed at a work speed of approx. 1.5 m/min. Hand-held shears which can slit and trim sheets up to 4 mm in thickness without producing chips can process at speeds of approx. 3 m/min. Hand-held machines are powered by electric or compressed air motors.



Hand-held nibbler



Low-scratch processing: In addition to machine-oriented measures designed for low-scratch processing, brushes embedded in the die are also available to improve the quality of the finished work-piece.

Left: The multiple tool considerably increases the number of available tools.

Right: Noise reduction by using punches with an angled cutting surface

Multiple tools

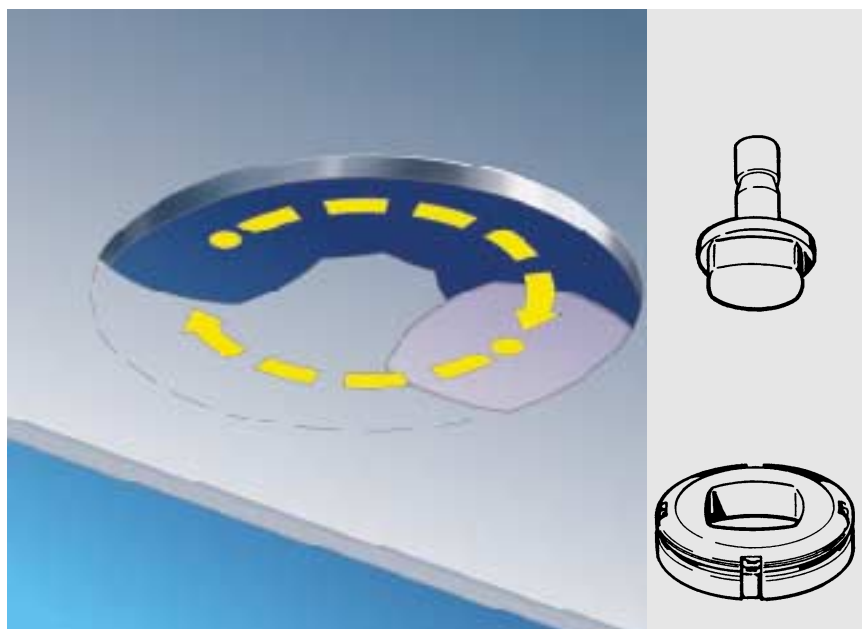
If the number of required tools exceeds tool storage capacity, or if processing time is to be shortened, multiple tools can be used.

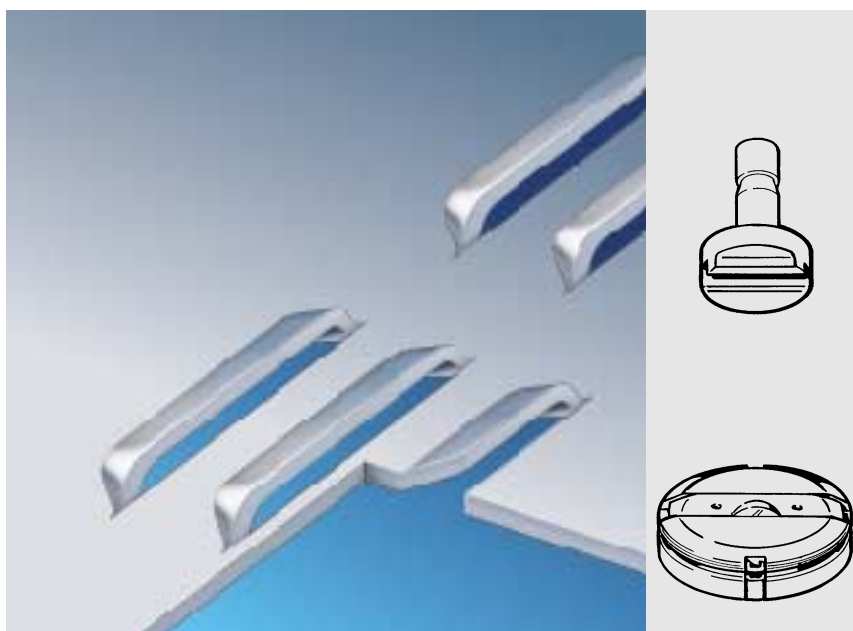
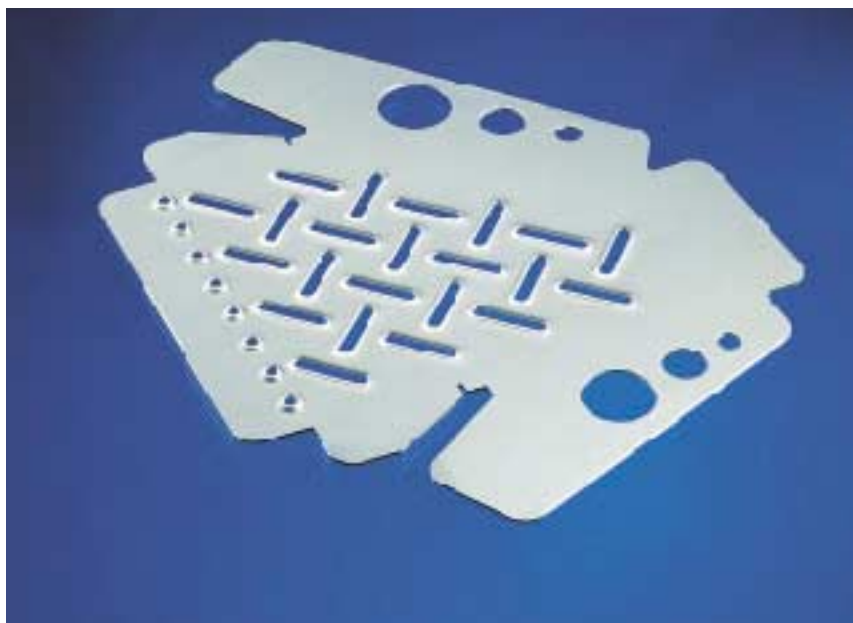
The multiple tool Multitool contains up to 12 tool stations of any form but limited size. It is set up in the tool adapter as any other punching tool. A program command causes the Multitool die to be activated in approx. 1.5 s and brought into any angular position by means of the rotational axis. Multitool considerably increases the number of tools in the tool storage.

Typical fields of application for Multitool are workpieces with many different round hole dimensions.

The Multi-Cut is a 4-sided tool developed for rotating with four convex shaped outer edges of various radii. It

At the bottom: The four-sided tool Multi-Cut as an alternative to nibbling





can produce circular openings of various radii without additional tool changes. Apart from a shorter processing time, an added advantage is that the cutting edge is less rough than a nibbled edge.

Tools and operational requirements

Tool life: In general, punching tools have a tool life of 400,000 to 600,000 strokes.

In order to attain such a tool life, care must be taken to ensure a stable tool guide, material-specific tool lubrication, a sharp cutting edge as well as the exact central position of the punch and die. The required sharpness of the cutting edge can be guaranteed only by re-grinding the cutting surface.

Tools with angled punch (noise reduction): Punches with an angled cutting surface require less punching power due to the lengthened power stroke when the punch penetrates the workpiece.

The lower punching power has the effect of reducing noise by approx. 50 % in comparison to a punch with a flat cutting surface of the same size. The maximum processable sheet thickness is, however, smaller.

Forming tools

As a supplement to punching and nibbling, a variety of formed areas with limited height can be created in the sheet using special tools. The most important formed areas are louver cuts, beads, extrusions and threaded forms.

Louver cutting: Louver tools make cuts in a single stroke and form them. The louver tool is used mainly for producing ventilation slits; for example, in manufacturing various chemical apparatuses,

Processing examples:

At the top: Case

In the middle: Footboard for a truck

At the bottom: A louver tool is often used to produce ventilation slits.

PUNCHING

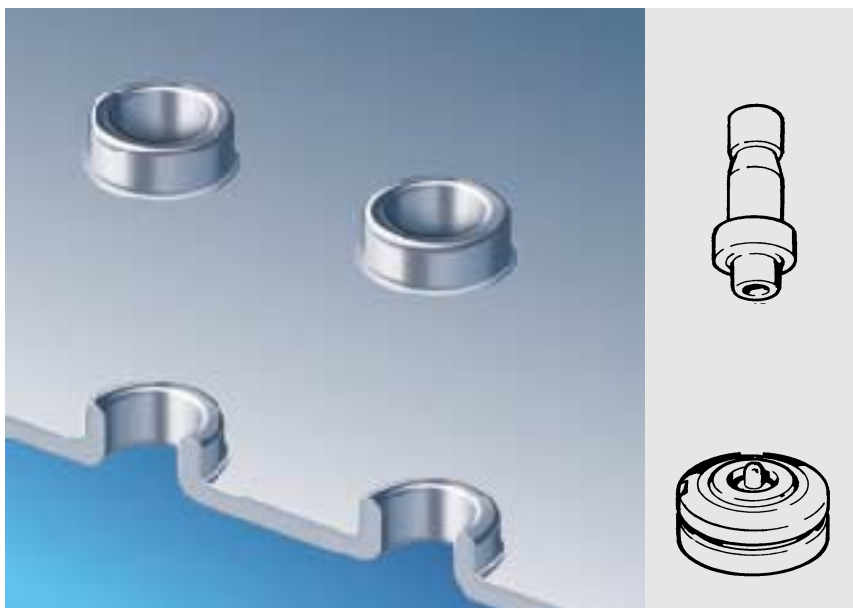
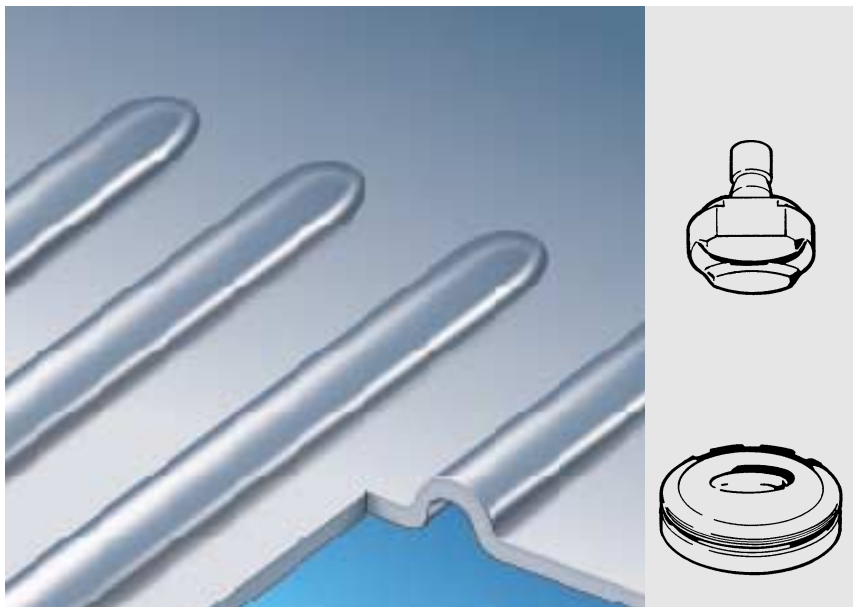
in ventilation and air conditioning technology as well as in electrical cabinets.

Beading: Beading refers to the process of embossing hollow, ring-like formed areas in a nibbling operation. Beads are produced to reinforce metal sheets. The quality of their surfaces is determined by the feed selected. The following general rule applies: maximum bead height = 2 x sheet thickness.

Extrusions: Extrusions are formed areas produced in a single stroke with a drawing punch and a drawing die. Holes are normally pre-punched prior to the forming process.

Extrusions are used, for example, for cable bushings in electrical cabinets. Threads are also frequently formed in them as a means for attaching sheets.

Tapping: Tapping refers to the creation of threads in prepared punch holes or extrusions which are used in electrical cabinets. Since the material is displaced and not cut, this process does not produce any chips. Displacement causes a strain hardening of the material which contributes to the stability of the thread. Threads from M2.5 to M8 are possible.



At the top: Beads reinforce the sheet metal.

In the middle: Extrusions

At the bottom: A tapping tool creates threads without chips.

Machine costs

The following items contribute to machine costs which accrue by the hour:

Calculation basis for fixed costs:

- initial cost
- depreciation period
- interest rate
- required space (cost of floor space)
- scheduled time of use

Calculation basis for variable costs:

- electrical energy consumption of the entire installation (electricity costs)
approximate value: 5–10 kW
- tool costs
- cost of replacing worn-out and defective parts
- scheduled time of use

Machine hourly rate: The total costs are calculated by adding the fixed costs to the variable costs. For the most part, these are determined according to the extent to which the machines are utilized.

Fixed costs

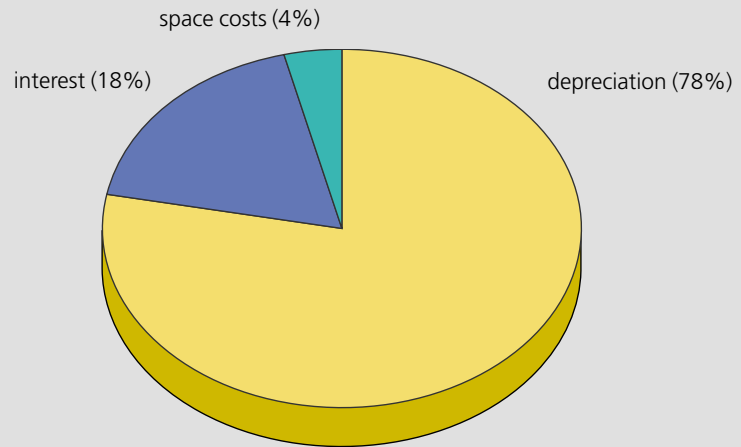
Calculation of fixed costs:

calculated depreciation = initial cost / (depreciation period x machine time)

calculated interest = (initial cost / 2) x interest rate / machine time

space costs = required space x cost of floor space / machine time

The infrastructure costs in the Federal Republic of Germany provide the basis for these calculations



Variable costs

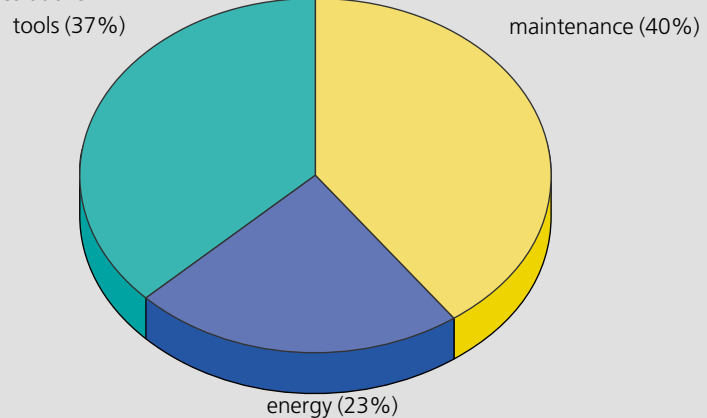
Calculation of variable costs:

Energy costs = electrical energy / h x electricity costs

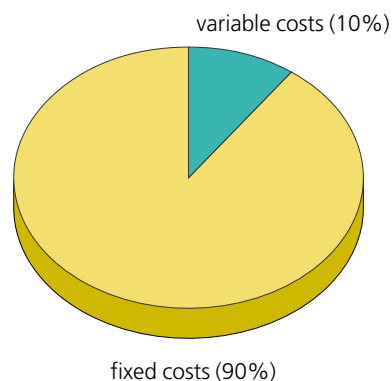
cost of replacement and wearing parts

scheduled time of use

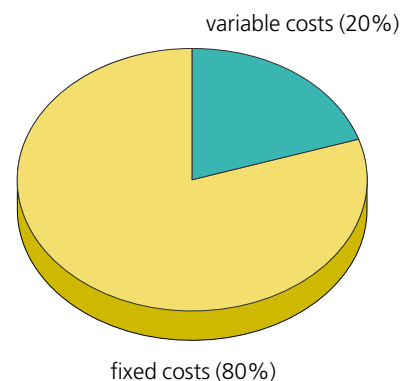
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One-shift operation



Two-shift operation



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