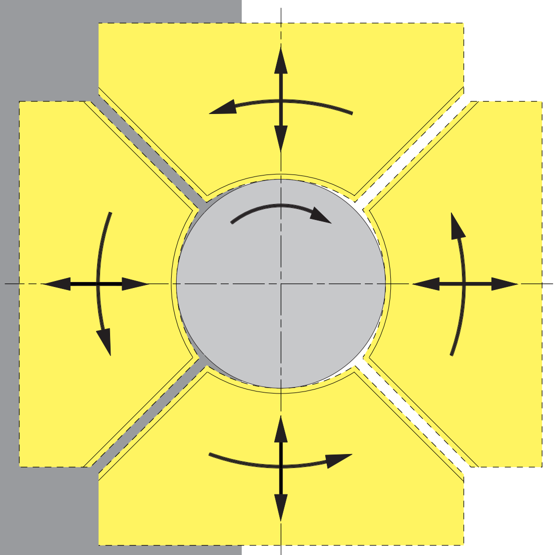
HMP

Rotary Swaging

What is Rotary Swaging?

Net-Shape-Forming

Rotary swaging is a process for precision forming of tubes, bars or wires. It belongs to the group of net-shape-forming processes, of which one of the characteristics is that the finished shape of the formed workpieces is obtained without, or with only a minimum amount of further final processing by machining.



Operation principle

The forming dies of the swaging machine are arranged concentric around the workpiece. The swaging dies perform high frequency radial movements with short strokes.
The stroke frequencies are ranging from 1,500 to 10,000 per minute depending on the machine size, with total stroke lengths of 0.2 to 5 mm. The radial movements of the dies are for most applications simultaneous. Usually one die set consists of four die segments. Depending on the application and on the size of the machine, alternatively sets of two, three, six or in special cases up to eight dies can be used.

To prevent the formation of longitudinal burrs at the gaps between the dies, there is a relative rotational movement between dies and the workpiece. The swaging dies rotate around the workpiece, or alternatively the workpiece rotates between the dies. For production of non-circular forms the dies and the workpiece are stationary without rotational movement.

Rotary swaging is an incremental forming process where the oscillating forming takes place in many small processing steps. One of the advantages of the incremental forming process compared to the continuous processes is the homogenous material forming. Rotary swaging achieves very high forming ratios in only one processing step as the deformability of the material is uniformly distributed over the cross-section.

Another advantage of the incremental forming process is the minimized friction. The time of contact between dies and workpiece is very short. During the contact there are only small relative movements. The transverse forces are compensated by the elasticity of the workpiece. Therefore rotary swaging does not require any surface treatment on the blank for lubrication, but it is sufficient to use oil in a closed cycle which mainly acts as a coolant and to clean the inside of the machine.

Net-shape production:

The achievable tolerances are extremely tight so that final machining is in most cases not required. This enables significant material savings and reduces the number of production stages, resulting in low piece prices.

Wide range of applications, significant weight savings:

Rotary swaging can produce a multitude of different external and internal forms. Weight savings of up to 30% - 50% can generally be achieved by rotary swaging versus conventional production methods.

High product quality:

The uninterrupted grain flow of the material together with the work-hardening resulting from the reduction increase the strength of the workpiece. The quality of swaged surfaces is at the level of ground surfaces.

High forming ratios, no restriction to materials:

Rotary swaging achieves high forming ratios without requiring hot forming. The favorable distribution of stresses during forming and the homogenous course of processing permit to form also brittle materials.

Cold and hot forming:

Rotary swaging forms materials in the cold, semi-hot and hot temperature range.

Environmental acceptability:

Unlike other forming processes, rotary swaging does not require any surface treatment on the blank. The oil, if required, is in a closed cycle.

Versatility:

Rotary swaging machines have short change-over times. The swaging dies and the machine setting are changed within a few minutes.

Short production times, high efficiency rates:

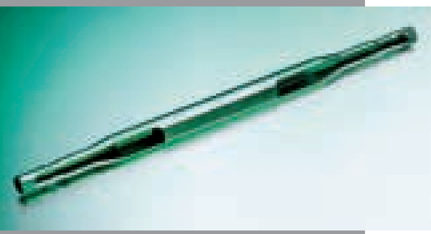
The construction of rotary swaging machines permits combination of several processing modules for efficient multi-station transfer lines so that net-shape parts can be produced with high outputs. The robust and easy to maintain construction ensures high efficiency rates.

Examples of Applications

Automotive Industry

Hollow Steering Column

Steering columns are nowadays commonly produced by rotary swaging worldwide. Starting from a cylindrical tube blank, the steering tubes are produced an single-station machines or on multi-station transfer lines with typical cycle times of about 10 to 16 seconds depending on the workpiece forms and sizes. Transfer lines including modules for the other processes produce completed net-shape parts.



Hollow Driveshaft:

Rotary swaging produces hollow driveshafts in Monobloc design. By reducing the wall thickness in the center section of the shaft it is possible to obtain a component with optimized weight. The starting materials are cylindrical tubes, which are processed on single-station machines or on multi-station transfer lines to net-shape components. The cycle times are typically about 15 to 20 seconds.

Optical Industry:

Temples

These parts are traditionally produced by rotary swaging. The process is either used for production of pre-formed parts for subsequent stamping of prismatic shapes without burrs, or as a net-shape forming process for production of temples with circular form.

Others:

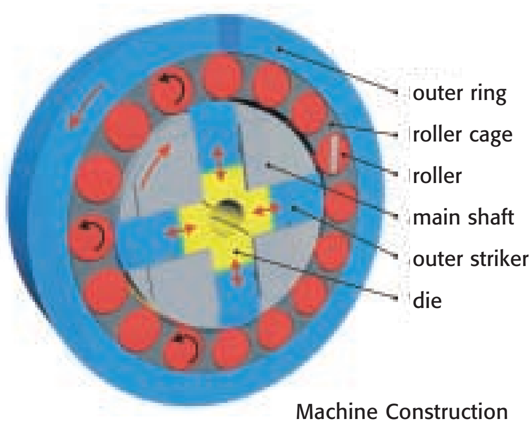
Fittings:

Rotary swaging produces fitting profiles an steel and aluminum tubes with highest quality. The process can create external forms with sharp corners at the transitions together with a constant inside diameter. Rotary swaging can be combined with an upsetting process for production of beads. Depending on the production volumes, the fittings are produced on single-station machines or on multi-station transfer lines, with cycle times of typically about 12 to 18 seconds.

Fastening technology

An example is fastening of parts for car seatbelt restraint systems. The homogenous forming creates an ideal positive locking, which is further increased by non-positive forces created by the residual stress after forming. The parts are produced on single-station swaging machines with special handling devices for the rope and for the external piece, with cycle times of typically about 12 to 20 seconds depending on size and form.

Rotary swaging machines are high-speed displacement controlled machines. The stroke of the dies is with the HMP principle created by a cam control. The kinematics are generated in the core of the swaging machine, the so-called swaging head.

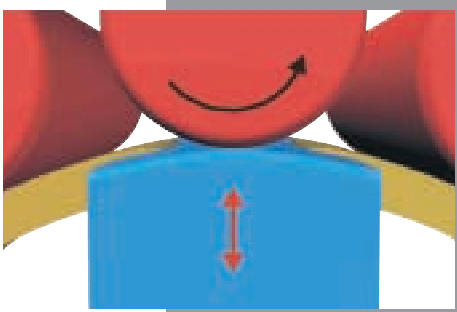


Machine Construction

Each time one set of rollers passes over on set of strikers one radial forming blow is executed. The radial movement of the strikers is transmitted to the dies and from there to the workpiece. When the outer strikers are located between the rollers they open radially outwards together with the dies by centrifugal force.
Advantages of HMP swaging heads are for example:

- The outer strikers have a trigonometric profile for smooth, gradually increasing contact when the rollers start passing over the strikers.
- The rollers are actively driven and rotate continuously without slip at all positions. This prevents rebounding hitting of the rollers against the strikers at the start of the contact.
- The machines are equipped with 16 pieces of rollers whenever the size of the swaging head provides sufficient space.

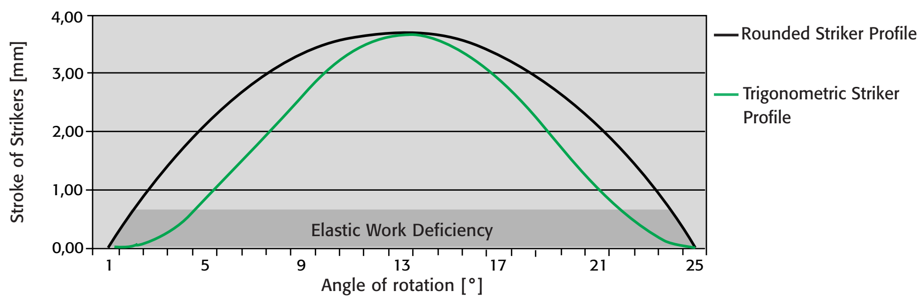
Characteristics:
Minimized wear on strikers: HMP outer strikers are long-life wear parts and do not require thermal treatment during the operation time. This keeps the service and maintenance cost low.
Low elastic work deficiency rate: The characteristic force-die stroke-relationship minimizes the elastic work deficiency and increases the efficiency. HMP rotary swaging machines operate with optimum energy utilization.
High stroke frequencies: This optimizes the forming process with regard to homogeneity and friction.



Internal Rotating System: *stationary outer ring - rotating main shaft*
The classical construction: robust and simple. When the dies are closed under the rollers they tend to twist the workpiece. These forces are compensated by slow rotation of the workpiece in the clamping jaws with controlled slip.

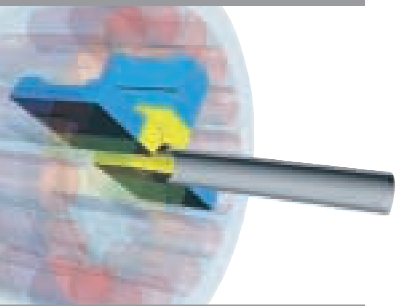
External Rotating System: *rotating outer ring - stationary main shaft*
When producing cylindrical workpieces, to prevent longitudinal burrs at the positions between the dies the workpiece must be rotationally driven. The main application of the external rotating system is the production of non-circular forms.

Double Rotating System: *outer ring and main shaft both rotate in opposite directions*
The stroke frequency of the dies is independent of the rotational speed of the main shaft. This system has special advantages for swaging of workpieces sensitive to torsion.

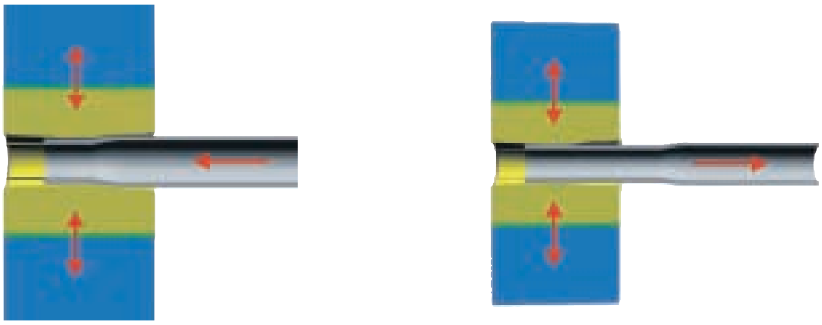


The Methods ...

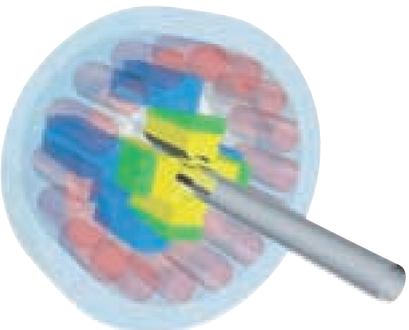
Infeed Swaging



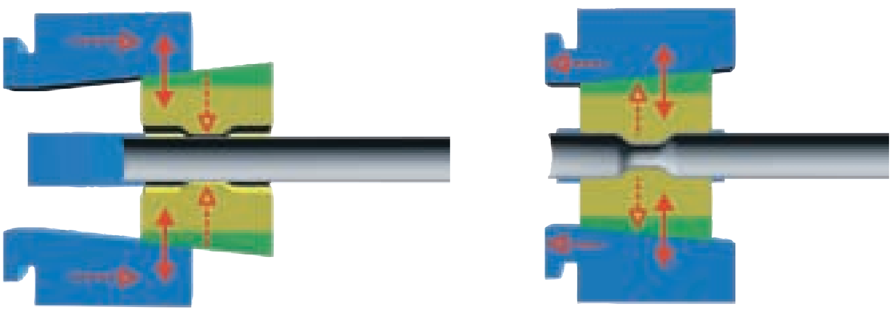
The workpiece is fed axially at a constant rate of speed through the oscillating dies. Most of the forming energy is concentrated in the tapered section of the dies. The cylindrical section of the dies is used for calibration of the reduced cross-section. The feed takes place when the dies are open at the positions where the rollers are in the free space between the strikers. The swaging head is equipped with calibration shims between the strikes and dies. There is no limit on the length of the reduced cylindrical diameter. The maximum achievable taper angle is about 10° per side.



Plunge Swaging



In addition to the radial oscillations, the dies perform a larger radial closing and opening movement. Considerably steeper taper angles than are possible by infeed swaging can be produced. Plunge swaging also permits reductions between the workpiece ends. The forming energy is concentrated in the tapered and in the cylindrical areas. The plunging method generally requires more energy than infeed swaging and higher machine forces. The length of the forming area is limited to the length of the dies or to the forming energy which the machine can provide if pure plunge swaging is used. All plunge swaging machines may also be used as axial infeed swaging machines if the strikers and dies remain closed. Furthermore, plunge swaging machines can be used for a combined process of infeed and plunge swaging. The workpiece is loaded between the opened dies, the dies plunge in and then the workpiece is moved axially through the closed dies. This method enables to produce reductions between the workpiece ends without length restrictions.

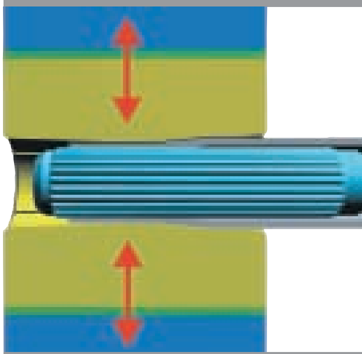


Rotary Swaging without Internal Tool (Mandrel)

The material flows in radial and in axial direction during forming.
The reduction creates an increase in the wall thickness and in the length of the workpiece. The wall thickness increase in case of a free radial flow of material can be calculated.

Swaging over a Mandrel

Internal profiles with close tolerances can be produced by use of a mandrel, which may be cylindrical, tapered or stepped. Swaging over a mandrel allows production of internal profiles like splines, non-circular forms, helical forms, etc.

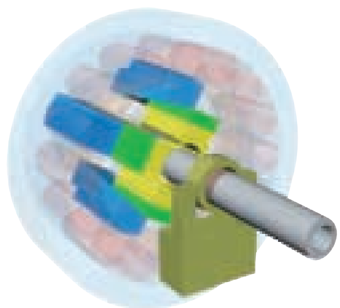


CNC Swaging

The radial die movements, feeder movements, mandrel, and counter-pusher movements are integrated into a numerical controls system which allows to produce a multitude of forms on the outside and the inside of the workpiece.

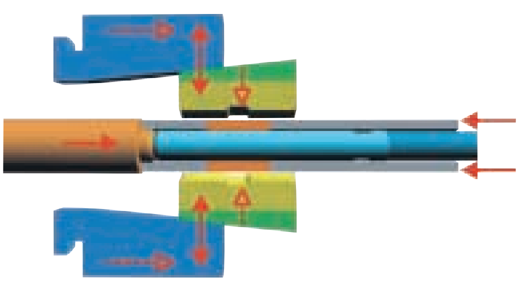
Hot Swaging

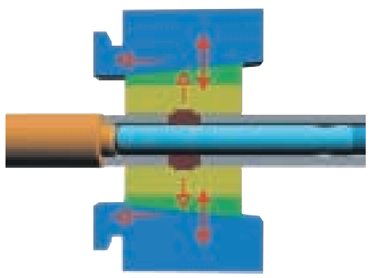
As a further parameter, increased forming temperature can be added to the process in order to decrease the yield stress. HMP has for many decades manufactured hot swaging machines for heavy forming applications.
The forming temperature is preferably selected in the semi-hot range below the limit of formation of scale. The heating process is carried out by the inductive method within the production cycle.



Upset Swaging

A section of the workpiece is heated in order to obtain a defined area with decreased yield stress. The standard rotary swaging process is combined with axial forces. This permits production of workpiece sections with increased cross-sectional area by increasing the wall thickness to the outside and / or to the inside.

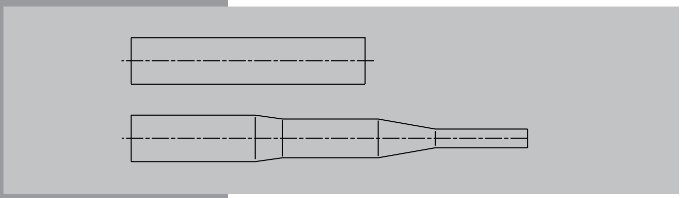




Workpiece Forms

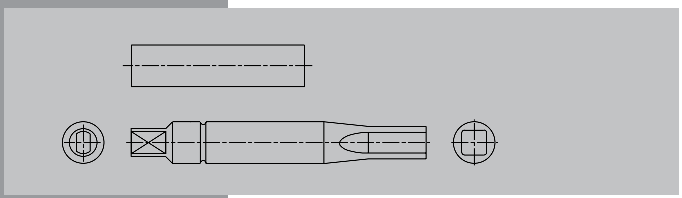
Examples of producible forms

1 Blank
2 Formed Workpiece



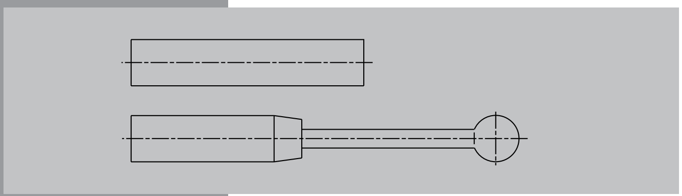
1
2

Bar produced by infeed swaging.



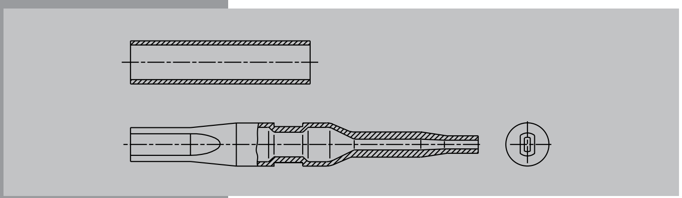
1
2

Bar with non-circular forms produced by plunge swaging.



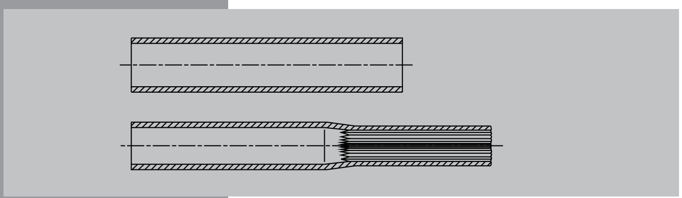
1
2

Bar produced by plunge swaging.



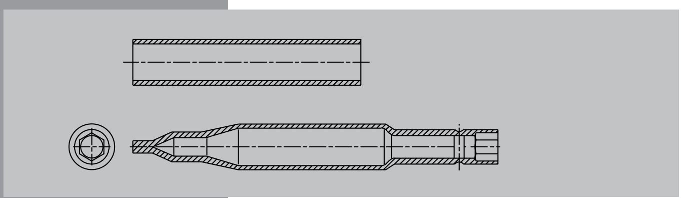
1
2

Tube produced by infeed and plunge swaging operations.



1
2

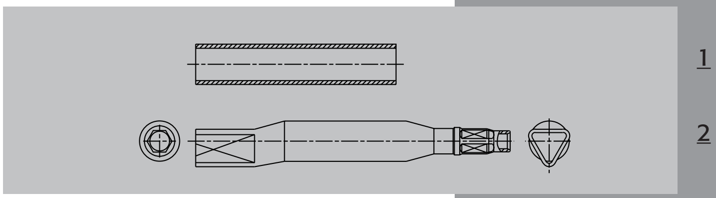
Tube produced by infeed swaging operation over a profiled mandrel in one operation.



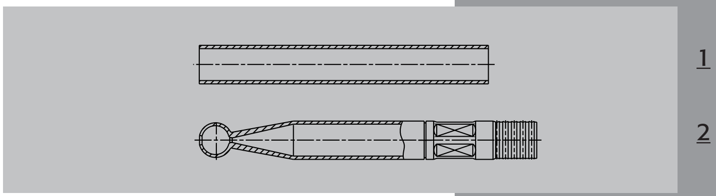
1
2

Tube produced by infeed and plunge swaging, right end formed over a mandrel.

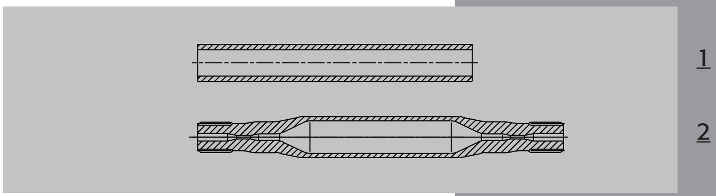
Tube with external triangular and hexagonal forms, produced by infeed and plunge swaging.



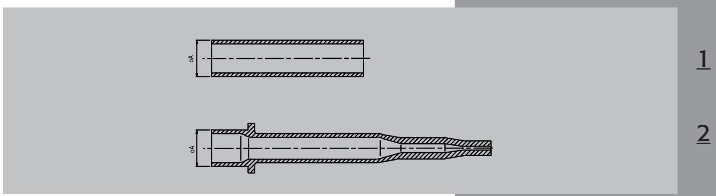
Tube produced by plunge swaging in several stages.



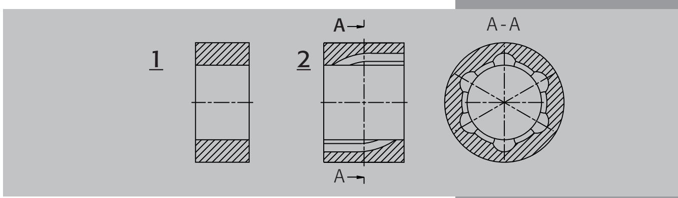
Tube with differing wall thickness produced by swaging over a mandrel, with external splines on both ends.



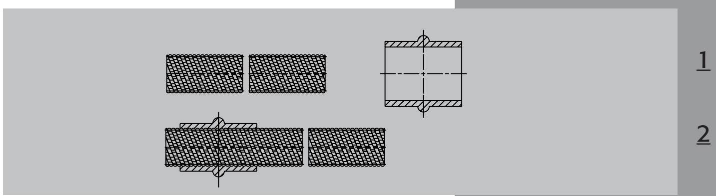
Example of a part produced by the HMP upset swaging method.



Example of a sophisticated internal profile produced by swaging over a mandrel in one operation.



Joint produced by plunge swaging.



Modular Machine Concept

Depending on the requirements of the application, rotary swaging can be combined with other processes. Transfer lines may be composed of several modular stations and units.

Swaging Unit:

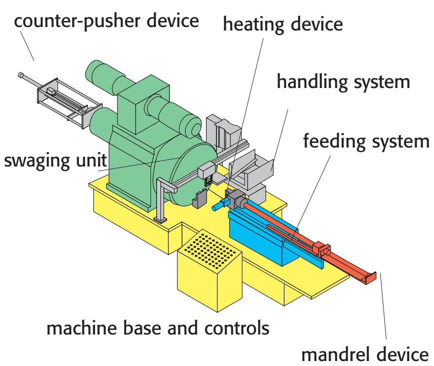
The swaging head is the actual work unit and the main part of the machine. Depending on the required forms and sizes of the specific application, it can be supplied in different types and sizes.

Feeding System:

Used for infeed of the workpiece into the work unit and subsequent return feed. The feeding system is an important part of the machine, which is designed, manufactured and assembled by our company. One of the characteristics of our feeding systems is the very high axial stiffness. A further important aspect are the process adapted clamping systems.

Machine Base:

The machine base is used to take up the different machine units. The base of HMP machines is not only a functional element, but has a special design with a short distance between base and workpiece. This creates a stiff C-frame arrangement of swaging head, feeding system and base, that allows on HMP machines high axial forces.



Mandrel Device:

The mandrel device is in most cases installed on the slide of the feeding system. The mandrel movements are usually hydraulic. If very precise mandrel positions are required, the device can alternatively be integrated into a CNC system with spindle drive.

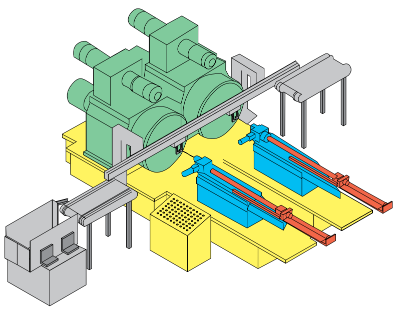
Counter-Pusher Device:

The device is installed at the rear of the swaging head. It is used to control the axial flow of the material, or alternatively also to take up a swaging mandrel.

Controls

The machines may be equipped with PLC or with CNC control systems.

Multi-Station Transfer Machine



Handling System:

The handling systems for HMP single-station and multi-station machines are developed by us and are adapted to the special requirements of the swaging process. The handling system takes the workpieces from the magazine or input conveyor, loads them into the clamping device of the feeding system and simultaneously unloads the finished workpieces at the machine exit.

HMP handling systems have essential advantages:

- *Accessibility:* The handling system can for setting and maintenance be pivoted away. This ensures optimum accessibility.
- *Robustness:* The handling system is located above the workpiece. This avoids unnecessary transversal movements, and prevents damages if components should fall down.

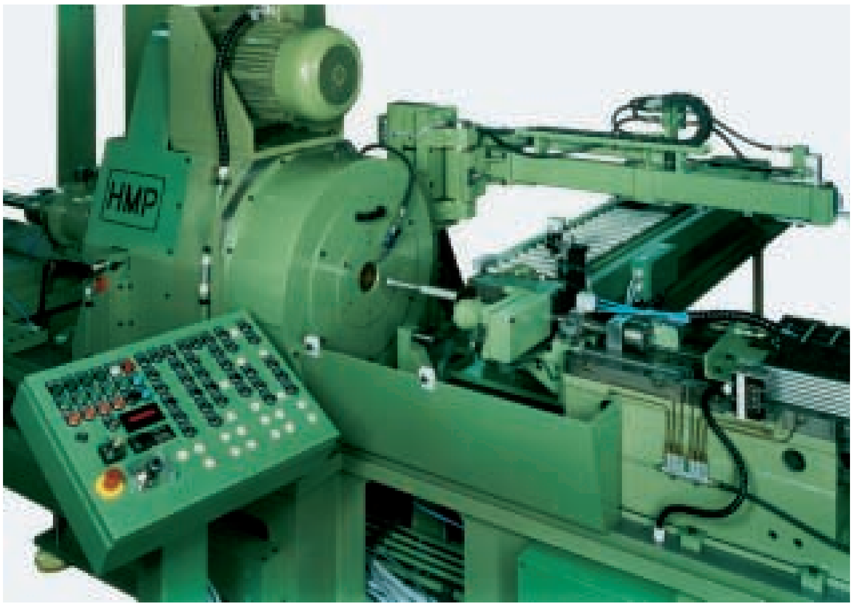
Model	System						Die Dimension width x height x length (mm)	Range of Application mm Bars	Range of Application (mm) Tubes
	Internal rotating	External rotating	Two-die machine	Three-die machine	Four-die machine	Plunging machine			
RA - 2	X		X				10 x 10 x 25	0,2 - 2,0	0,2 - 2,0
URA - 2		X	X				10 x 10 x 25	0,2 - 2,0	0,2 - 4,0
RB - 2	X		X				14 x 14 x 40	0,2 - 4,0	0,2 - 8,0
RB - 3	X			X			12 x 14 x 40	0,2 - 4,0	0,2 - 8,0
URB - 2		X	X				14 x 14 x 40	0,2 - 4,0	0,2 - 8,0
URB - 3		X		X			12 x 14 x 40	0,2 - 4,0	0,2 - 8,0
RB - 2 - DD	X		X			X	14 x 14 x 40	0,2 - 4,0	0,2 - 8,0
RB - 3 - DD	X			X		X	12 x 14 x 40	0,2 - 4,0	0,2 - 8,0
RE - 2	X		X				20 x 20 x 50	0,5 - 7,0	0,5 - 12,0
RE - 3	X			X			16 x 20 x 50	0,8 - 8,0	0,8 - 14,0
RE - 4	X				X		16 x 20 x 50	1,0 - 10,0	1,0 - 15,0
RE - 2 - DD	X		X			X	20 x 20 x 50	0,5 - 7,0	0,5 - 12,0
RE - 3 - DD	X			X		X	16 x 20 x 50	0,8 - 8,0	0,8 - 14,0
URE - 2 - DD		X	X			X	20 x 20 x 50	0,5 - 7,0	0,5 - 12,0
URE - 3 - DD		X		X		X	16 x 20 x 50	0,8 - 8,0	0,8 - 14,0
R2 - 2	X		X				25 x 25 x 60	0,5 - 9,0	0,5 - 15,0
R2 - 4	X				X		20 x 25 x 60	2,0 - 10,0	2,0 - 20,0
UR - 2 - 4		X			X		20 x 25 x 60	2,0 - 10,0	2,0 - 20,0
R2 - 2 - DD	X		X			X	25 x 25 x 60	2,0 - 9,0	2,0 - 15,0
R2 - 4 - DD	X				X	X	20 x 25 x 60	2,0 - 10,0	2,0 - 18,0
UR2 - 4 - DD		X			X	X	20 x 25 x 60	2,0 - 10,0	2,0 - 18,0
R3 - 2	X		X				32 x 32 x 70	2,0 - 16,0	2,0 - 25,0
R3 - 4	X				X		25 x 32 x 70	3,0 - 18,0	3,0 - 30,0
UR3 - 4		X			X		25 x 32 x 70	3,0 - 18,0	3,0 - 30,0
UR3 - 2 - DD		X	X			X	32 x 32 x 70	2,0 - 16,0	2,0 - 25,0
UR3 - 4 - DD		X			X	X	25 x 32 x 70	3,0 - 18,0	3,0 - 30,0
R4 - 2	X		X				40 x 40 x 100	4,0 - 20,0	4,0 - 30,0
R4 - 4	X				X		32 x 40 x 100	4,0 - 22,0	4,0 - 44,0
UR4 - 4		X			X		32 x 40 x 100	4,0 - 22,0	4,0 - 44,0
UR4 - 4 - DD		X			X	X	32 x 40 x 100	4,0 - 22,0	4,0 - 44,0
R5 - 4	X				X		50 x 55 x 120	5,0 - 30,0	5,0 - 60,0
UR5 - 4		X			X		50 x 55 x 120	5,0 - 30,0	5,0 - 60,0
UR5 - 4 - DD		X			X	X	50 x 55 x 120	5,0 - 30,0	5,0 - 60,0
R6 - 4	X				X		60 x 60 x 120	6,0 - 35,0	6,0 - 70,0
UR6 - 4		X			X		60 x 60 x 120	6,0 - 35,0	6,0 - 70,0
UR6 - 4 - DD		X			X	X	60 x 60 x 120	6,0 - 35,0	6,0 - 70,0
R7 - 4	X				X		70 x 70 x 150	7,0 - 45,0	7,0 - 80,0
UR7 - 4		X			X		70 x 70 x 150	7,0 - 45,0	7,0 - 80,0
UR7 - 4 - DD		X			X	X	70 x 70 x 150	7,0 - 45,0	7,0 - 80,0
R8 - 4	X				X		80 x 80 x 200	8,0 - 55,0	8,0 - 95,0
UR8 - 4		X			X		80 x 80 x 200	8,0 - 55,0	8,0 - 95,0
UR8 - 4 - DD		X			X	X	80 x 80 x 200	8,0 - 55,0	8,0 - 95,0
R10 - 4	X				X		100 x100 x 250	10,0 - 65,0	12,0 - 110,0
UR10 - 4		X			X		100 x100 x 250	10,0 - 65,0	12,0 - 110,0
UR10 - 4 - DD		X			X	X	100 x100 x 250	10,0 - 65,0	12,0 - 110,0
R12 - 4	X				X		120 x120 x 250	15,0 - 80,0	15,0 - 140,0
UR12 - 4		X			X		120 x120 x 250	15,0 - 80,0	15,0 - 140,0
UR12 - 4 - DD		X			X	X	120 x120 x 250	15,0 - 80,0	15,0 - 140,0
R14 - 4	X				X		140 x140 x 300	20,0 -100,0	20,0 - 160,0
UR14 - 4		X			X		140 x140 x 300	20,0 -100,0	20,0 - 160,0
UR14 - 4 - DD		X			X	X	140 x140 x 300	20,0 -100,0	20,0 - 160,0

Machine Examples

HMP machine concepts are developed in dialogue with our customers. The modular machine concept permits the machines to be equipped with precisely the correct units to exactly suit the requirements of our customers, with the quality standard of a serial machine. We realize production solutions which are developed in a process of simultaneous engineering together with the customer.

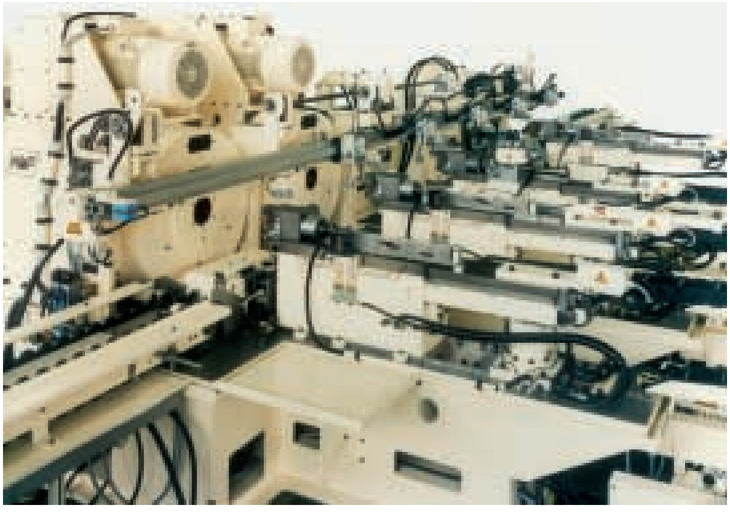
Single-Station Machines:

HMP single-station machines combine highest versatility with short production times. The machines have short change-over times and excellent accessibility.



Multi-Station Machines:

HMP transfer lines are worldwide used for production of serial components with high volumes, especially in the automotive industry. The machines are characterized by short production times, high efficiency rates, and low maintenance cost.



Rotary swaging is a process with many potentials, which is at its full economic efficiency if it is used at the highest possible value added level.

Tolerances

External: Depending on the size of the formed workpiece, the achievable tolerances are ranging from +/-0.02 mm to +/-0.1 mm. This corresponds to a quality of IT 8 - 10.

Internal: Swaging over a mandrel achieves tolerances of +/-0.01 to +/-0.02 mm, and qualities of IT 6 - 8. The achievable tolerances are also a function of the quality of the blank.

Roundness: Depending on the length of the workpiece, there are a tolerances of +/-0.005 to +/-0.1 mm achievable.

Concentricity: The quality of the blank has a major influence on the achievable accuracy. Swaging can generally improve the concentricity by about 50%.

Surfaces:

The quality of swaged surfaces is similar to that of ground surfaces.

Tool-Life:

The lifetimes of swaging dies are very much dependent upon the specific forming application so that general statements are not useful. It is our target to achieve a die life of minimum 50,000 pieces. In many cases there is a die life of up to 1,000,000 pieces achieved. For sophisticated forming applications we develop for our customers an economical tooling concept and try to achieve minimized tooling cost. We manufacture and supply swaging dies.

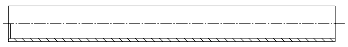
The lifetimes of the other components of HMP machines are within the typical ranges. This especially refers to the main internal machine components operating under high forces, such as strikers and rollers.

Space Requirement:

The required space depends on the size of the machine and ranges from few square-meters to 100 m^2 for big transfer lines. It is essential that HMP machines do not require any special floor foundations, but only a floor with plane surface and sufficient weight carrying capacity.

Utilities:

The electrical power requirements depend on the size of the machine. Additionally most of the machines require air supply for the pneumatic system. All other utilities have closed cycle systems.

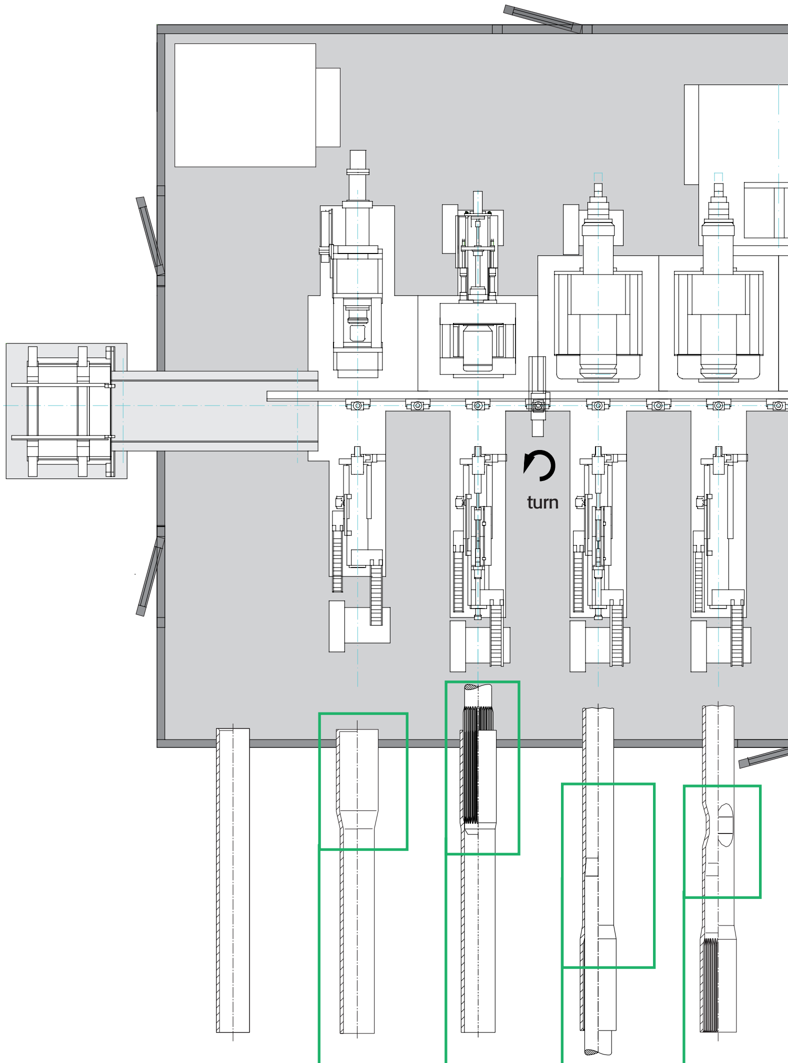
From 

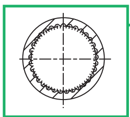
Complete Production on a Transfer Line

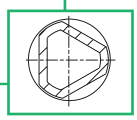
Example of a typical machine layout with sequence drawing, customarily supplied with a quotation. Prior to the quotation we often have intensive discussions with our customers where a full understanding of the functional requirements of the workpiece and of the exact needs for the production process is established.

The shown transfer line consists of 9 work stations combining different forming and machining processes. The machine is equipped with a magazine-hopper, an input conveyor for transport of the tubular blanks into the machine, and with an exit conveyor for removal of the finished workpieces. The noise and safety enclosure covers the complete machine. This enclosure reduces the noise level to max. 80 dB(A), and also acts a safety device. If one of the doors of the enclosure is opened during automatic operation the machine will automatically be immediately stopped. The supply units for the hydraulic system and for the coolant system with their required pumps and filters are in the shown case located inside of the enclosure.

The different machine stations are connected by a linear transfer system transporting the workpieces from the input conveyor into the feeding system of the first station, and simultaneously from station to station.







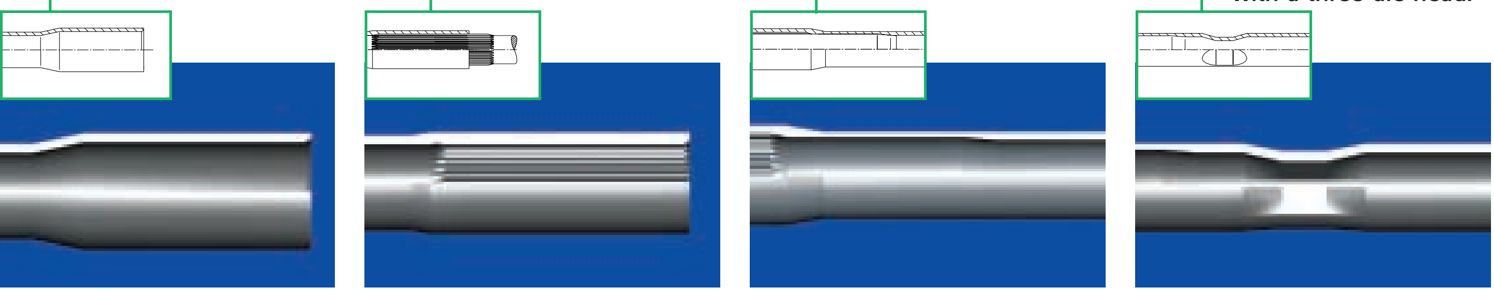
1 Expanding: Production of the pre-diameter for the internal spline on a hydraulic axial forming machine.

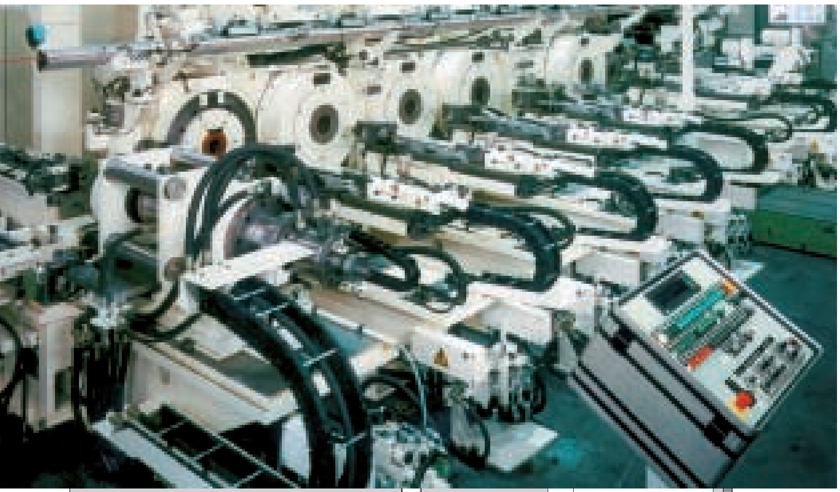
2 Infeed swaging: Production of the internal spline by swaging over a profiled mandrel.

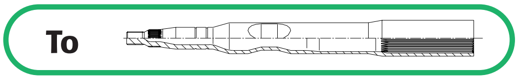
Workpiece rotated 180°

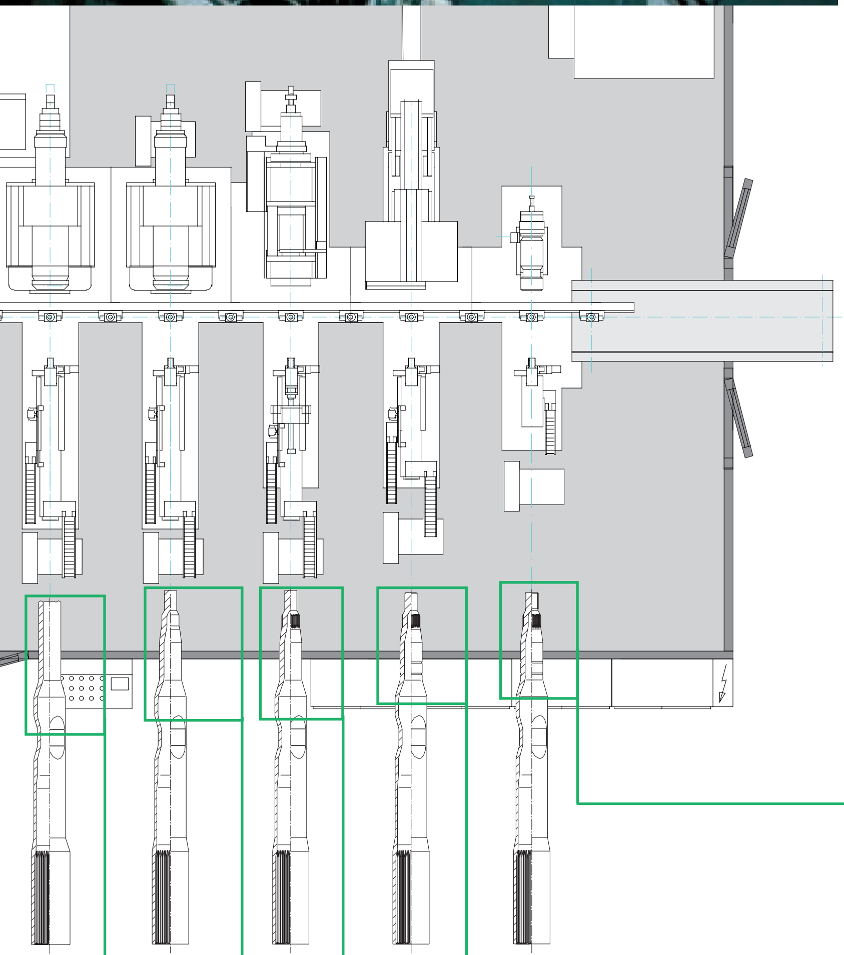
3 Infeed swaging: Reduction of the outside diameter with simultaneous reduction of the wall thickness in the center section.

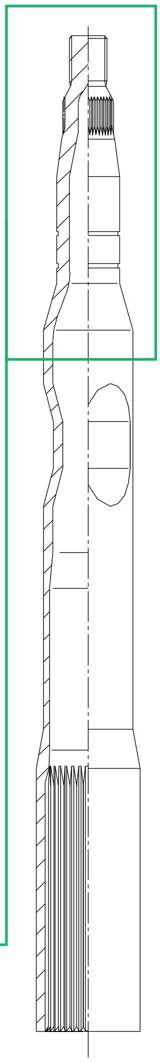
4 Plunge swaging: Production of the triangular form. The machine is an external rotating machine with stationary main shaft and equipped with a three-die head.



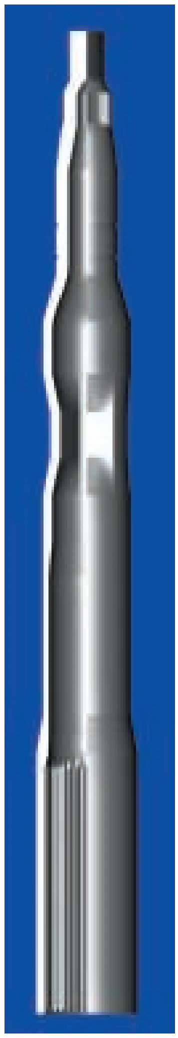






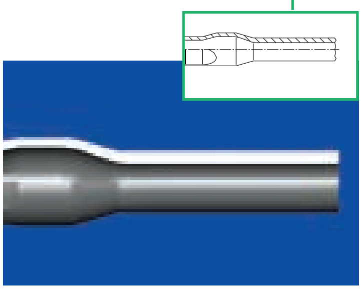


9 Thread rolling: Production of the external thread with special forming tools.

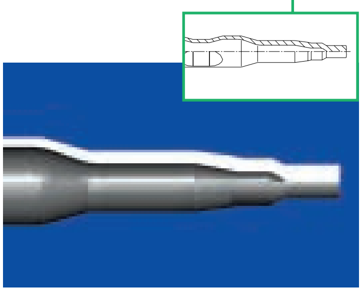


Upon request, washing equipment can be integrated into the transfer line so that the parts leave the machine completely free from the oil used for cooling and lubrication of the production processes.

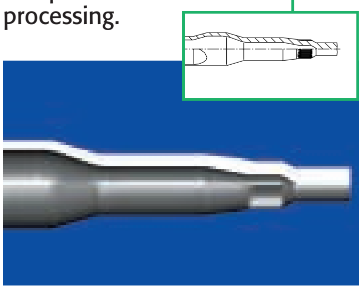
5 Infeed swaging: Pre-forming of the workpiece end.



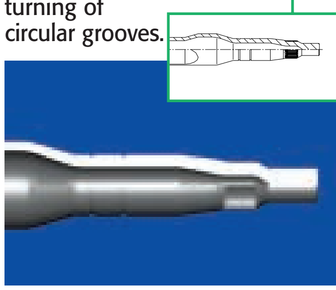
6 Plunge swaging: Finish swaging of the forms on the workpiece end.



7 Spline forming: Production of the external spline on a hydraulic axial forming machine. The high spline quality allows direct assembly of the component without further processing.



8 Turning: The material must be allowed to flow freely in one axial direction during the forming process. The excess material is removed by an end facing process, which is carried out together with simultaneous end chamfering and turning of circular grooves.

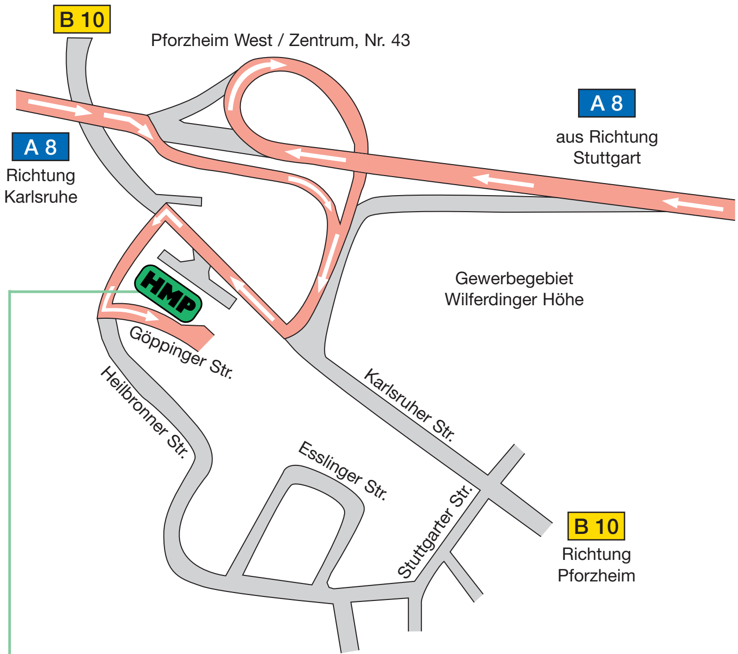


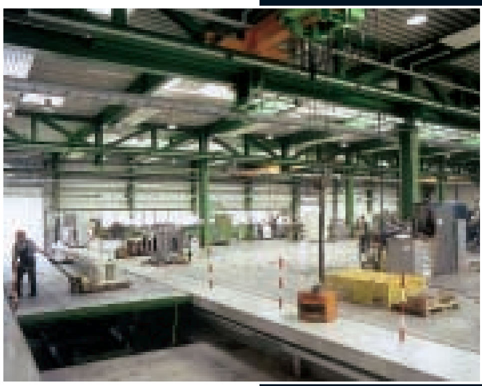
Your Way To Us

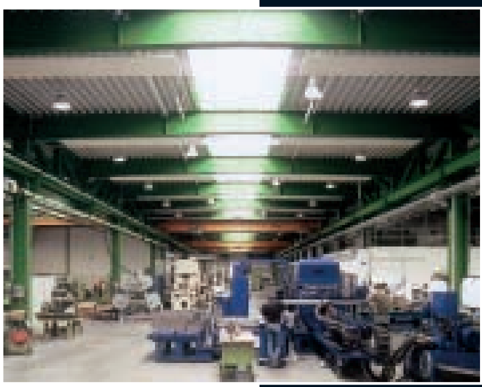
By car: Take highway A 8, exit Pforzheim West/Zentrum, exit No. 43. Turn right at the first traffic light, turn next left (not into parking lot) after 200 meters, and then again next left. Parking is possible directly in front of the building.

By plane: The nearest airport is Stuttgart, from there take highway A 8 to Pforzheim. From Frankfurt (Main) Airport take highway A 5 (direction Basel), at junction Karlsruhe change to highway A 8 to Pforzheim.

By train: Pforzheim main station, from there approximately 10 minutes by taxi.







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