"Constructive thinking" handbook

Tips, tricks and practical instructions for a smarter approach to handling sheet metal constructions as a means to improving manufacturability and lowering the cost price.

KEPSER
making metal matter

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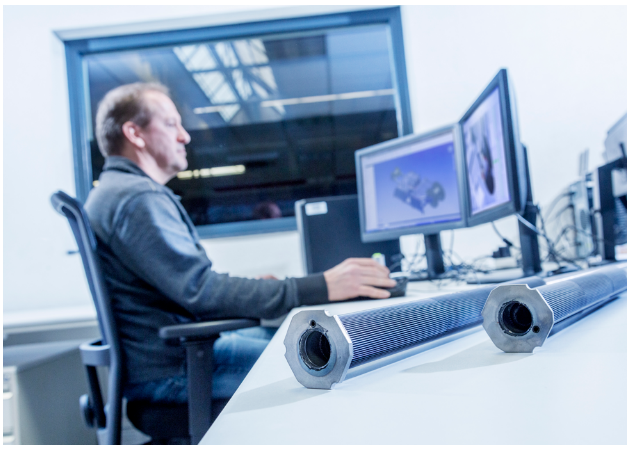
KEPSER

Introduction

"Constructive thinking". The title of this handbook perfectly expresses what we stand for. Finding cost-saving and creative solutions to technical problems is our speciality.



Kepser, nice to meet you. Since 1958, Kepser has grown into an all-round supplier to the metal industry. We supply highly demanding clients with customer-specific products in steel, stainless steel and aluminium. Prototypes, one-off pieces and small series of a repetitive nature. From semi-manufactured goods and sheet metal modules to complete end products.

In order to act as a full-value, flexible and reliable supplier, we pay a lot of attention to our equipment and machinery. In our production shops in Cuijk, we have marshalled a vast array of modern technology. What's more, our production shops are logically laid out on the basis of the material flow. Therefore, most products are processed in the same order as the equipment.
Technological developments in the field of sheet and profile machining are moving fast. Too fast to give you a complete overview of our machinery here. Which is why we refer you to our machinery list at www.kepser.nl for a complete and up-to-date overview of our processing options.

At Kepser, we invest not only in equipment, but also in software, cooperation, methods and – perhaps most importantly – people. And we can see this is working out well. Here are some examples of all four areas:

- Our CAD, CAM and ERP systems are connected both to each other and to our equipment.
- By cooperating well with our clients, we are able to manufacture 'smart' and increase the manufacturability of our products.
- An advanced production control system, which gives us instant insights into the production process, guarantees short processing times.
- Because our people have an enormous amount of knowledge, but are also enduring curious, about the newest production methods, we are able to constantly simplify and refine products and make them more affordable.

The next few pages take a look at how we work in broad terms. The chapters that follow contain an explanation of Kepser's various production processes as well as the necessary information and knowledge we have in these different areas. We want to use this to help you design your products in a way that makes them immediately ready for production. To discuss your design for complex parts and any questions you have about the manufacturability of your product, please don't hesitate to contact Kepser.

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How we work

From first contact to delivery of a product

Kepser strives for long-term relationships with satisfied customers. During an initial meeting, we discuss your personal requirements for the product, your organisation's approach to buying or outsourcing, and our company's approach to production. In this way, we know precisely in advance what we can, may or have to expect of one another.

To achieve good levels of performance, it is important for us to reach clear agreements on the following topics:

- How the drawings are exchanged
- Quantities and order frequency Quality
- Price Lead
- time
- Packaging
- Documents
- Delivery method Contact persons and their
- responsibilities Approach to the change
- management of products and/or drawings

How the drawings are exchanged
Digital delivery is preferred. Next, we store the drawings in a digital format. We agree in advance whether drawings are automatically sent together with an order or enquiry, or whether they will be made available on request. Kepser uses the convertible formats IGES, STEP, DXF and DWG and, for documents that must not be changed, TIFF or PDF. Manual sketches, drawings and models are converted in the CAD system by Kepser's engineering department. All product drawings are checked and, if necessary, made suitable for production. Determining the correct sheet metal result for Kepser is done with the aid of the 3D CAD model.

Quantities and order frequency
The organisation, production methods, tools and utilities of Kepser are of a standard you would expect from a modern supplier of sheet metal and profile work. Kepser has the universal tools and methods in house to be able to manufacture parts responsibly and for the right price, from one-offs to small series. The organisation is also partly geared to working in a repetitive manner. Among other factors, estimating the series size and number of orders is important when it comes to determining the production method and the associated price.

Quality
To arrive at the right price, it is important to know what the desired product quality is. The required tolerances, but also the finishing of the product, such as burr-free, broken edges, scratch-free, etc. And furthermore, any conservation or surface treatment, the welding method (weld lengths, heights and finishing), identification and other requirements.

Price
To handle the delivery correctly in financial terms, it is important to make agreements. These will mainly cover options such as fixed-price quotations, pricing based on post-calculation, quantity discounts, unit and setup costs. This also applies to the various payment terms and/or discounts and the validity of prices.

Lead time
A quotation will indicate the lead time and conditions in the event an order is placed. However, these can also be agreed on a mutual basis. Upon receipt of an order, we will confirm the delivery date in writing.

Unforeseen issues in the progress of production will be notified to you by the logistics department without delay.

Packaging
Unless specified otherwise, we will deliver the products carefully packaged on wooden pallets or in boxes, to prevent them from being damaged during transport. If you require any other types of packaging in addition to any packaging materials supplied by yourself, such as packaging in crates, then the cost of these will be charged separately.

Documents
The products are shipped together with a dispatch note (packing slip) indicating at least the order number, number of items, item number and drawing number. We may also print the project number or location number on it. If required, the products may also be given a sticker or label showing this information.

Delivery method
Unless explicitly agreed otherwise, all deliveries and prices are ex works. However, if we arrange transport at your express request, you will be charged the shipping costs, the costs of the courier or the special freight costs as a separate invoice item. When we tell you that your order is ready, you can inform our logistics staff about the actual shipping method you have selected for that order.

Contact persons and their responsibilities
Relationship manager: general contact person, who is technically and financially responsible for our relationship with you.
Engineer: responsible for the production method of your product, based on the received information and drawing. Logistics employee: responsible for the lead time, completeness and shipping method.

Approach to the change management of products and/or drawings
As our organisation is designed to handle repetitive work, it is important to know how items and drawings are amended generally. It is also important to know whether you have corrected any reported drawing errors or followed through with suggested improvements. The modification must also be made to the item and/or drawing coding by means of a letter or number. Our procedures are tailored to handle this.

Production preparation
Once the agreements have been made, we can prepare for the order using our 3D-CAD system HiCAD and then proceed to define the production method. In addition to the bills of material, the route of the products (processes such as laser cutting, edge finishing, etc.) and the times needed for this will be entered into the production control system ISAH. The CAM program WiCAM is used to control the laser cutting machines. This allows us to organise and track the products and processes from start to finish. For the first order and for repeat orders.

1 drawings

To avoid any uncertainties and production errors, Kepser works in accordance with NEN standards. These can be requested from the Royal Netherlands Standardisation Institute (Nederlands Normalisatieinstituut – www.nen.nl). In this handbook, we make reference to the relevant NEN standards where applicable, but also provide additional information or clarification where the standards, in our opinion, require this.

A technical drawing must be totally clear to the person working on the shop floor. In the case of drawings, it is therefore essential to indicate the correct dimensions and tolerances clearly and precisely. When it comes to production control, programming CNC machines and maintaining an overview of everything (especially when using the same parts in different products), mono drawings are preferred.

Exchanging the CAD package
HiCAD can import and export the following formats: DXF, DWG, STEP, MTA, VDAIS, VDAFS, CATIA, VRML, FEM. To generate CAM codes for CNC-controlled machines, both 2D formats and 3D models can be used.

General information

- Ensure that contours are closed.
- Do not use double contour lines, as the laser will cut these twice.
- When programming laser-cut products, note the place of insertion, if necessary by indicating where the insertion absolutely must NOT be located. This is because the insertion usually causes an unevenness on the product, which can pose an obstacle to the product's function or to subsequent processing. (Fig. 1.1)

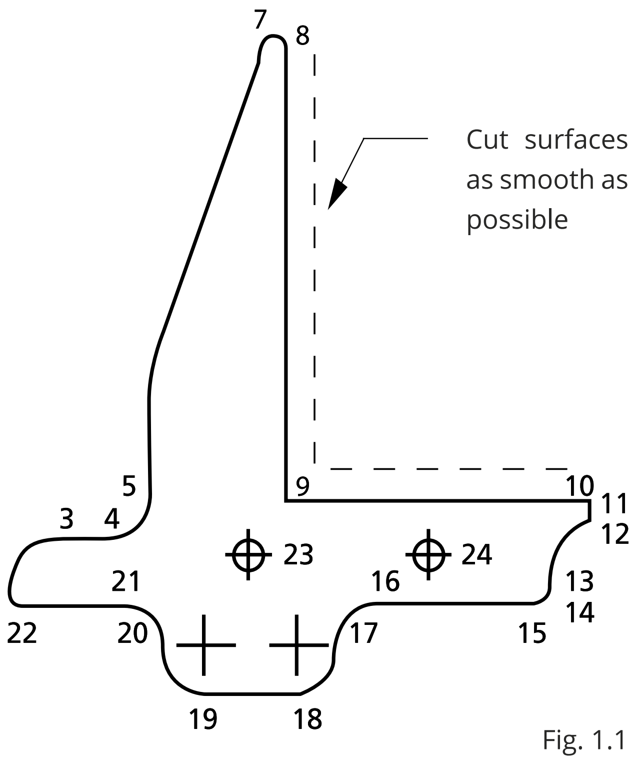

Fig. 1.1

- Drawings should preferably be provided at a scale of 1:1.
- Drawings should preferably be printed on A3 or A4.
- When producing the drawing, it must be known whether the product/sheet has a film coating
- Bear in mind that film is cut from above.
- Bear in mind that bulb plate is cut with the smooth side up.
- Indicate tapped holes with a 3/4 circle around the drilled hole.
- Draw size-tolerated holes and contours in the middle of the tolerance field.
- Use a functional size (in accordance with the description in chapter 3).
- Draw sufficient views.
- Use mono drawings.
- Note quantities in the bill of materials on a one off basis. This makes it easier to see from the bill of material how many parts are needed and avoids the need to look for a lower level. (Fig. 1.2)

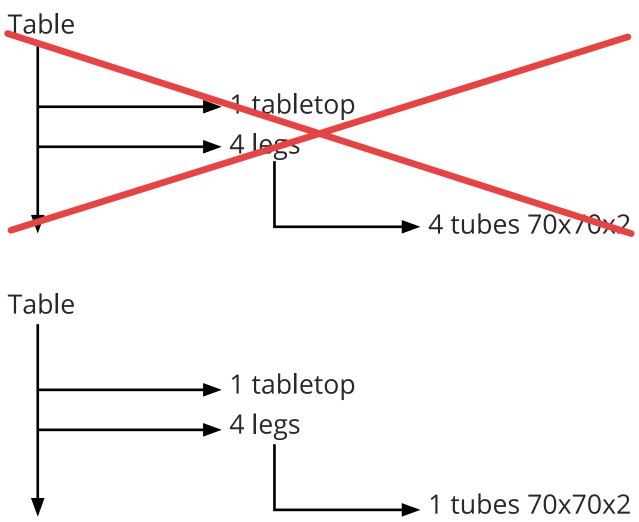

Fig. 1.2

The drawing

Title block
Inscription as per NEN 5308

- Ensure that drawings (files) are identifiable
- They must be given a drawing number, version number, date and description of the product or project.
- Preferably also note the nature of the change and the revision date alongside the revision number.
- Specify the reference drawing if the drawing is derived from another product (length variant, mirror image).
- Choose a meaningful product name (do not, e.g., name everything ‘sheet’).

Dimensioning
Dimension technical drawings in accordance with ISO 129.

Inscribing dimension lines
Technical drawings, general principles for showing

Text for dimensions
Technical product documentation text according to NEN-ISO 3098

Indicating dimensions

- Write the dimensions where they will be looked for when making the workpiece, i.e. in the projection that most clearly depicts the shape or the profile of the workpiece.
- If further calculations have to be made during production to determine certain dimensions, errors could creep in. Therefore, take the fabrication of the product into account during the dimensioning phase. Choose absolute dimensions for drilling and welding. (Fig. 1.3)

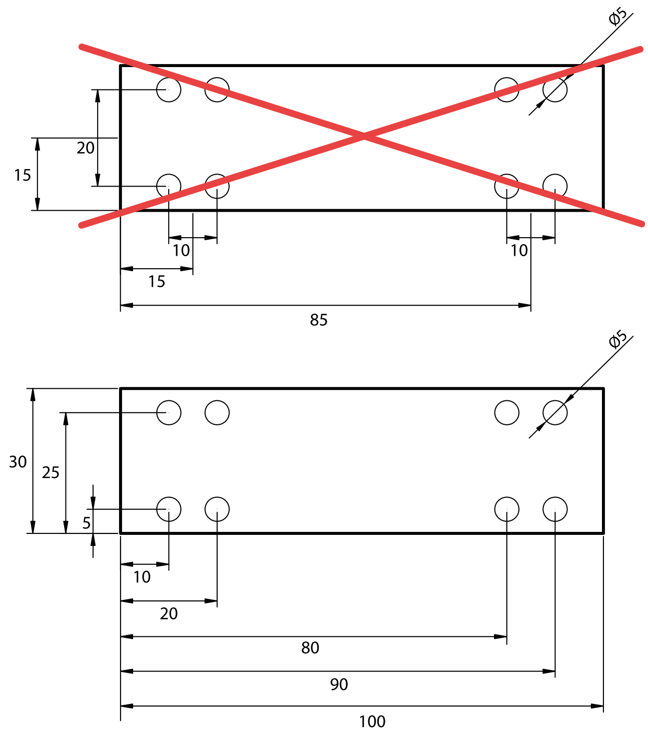

Fig. 1.3

- When setting chain sizes, opt for 'from bending line to bending line'. (Fig. 1.4)
- Specify the total length of a workpiece.
- Keep internal and external dimensions separate. Place the length dimensions that refer to the internal dimensions above the figure and the length dimensions that refer to the external dimensions below the figure.
- Do not specify the setting radius if it is not important. Generally, Ri=S may be used.
- Take a function approach to dimensioning: use tolerances on operations that are achievable and do not tolerate smaller than necessary for the purpose in question.

90 degrees upward

30 degrees upward

90 degrees downward

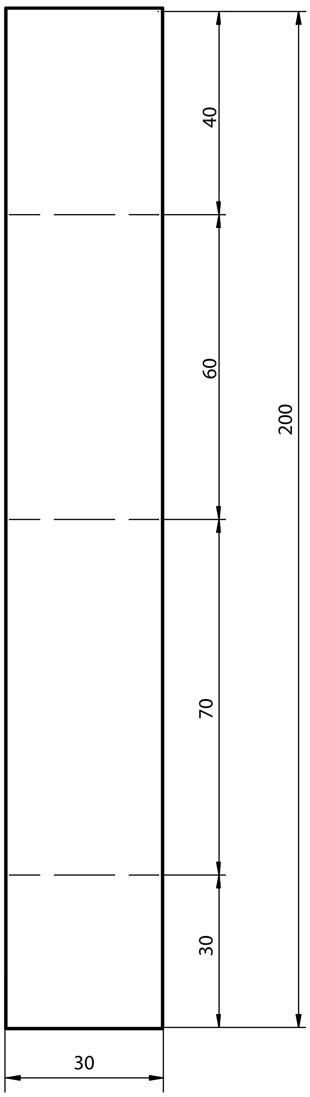

Fig. 1.4

Shape and position tolerances

Shape and position tolerances for technical drawings as per NENISO 1101.

Fits and dimensional tolerances

ISO system of fits, principles of tolerances, limit deviations and fits as per NEN-ISO 286. Preferred fits as per NEN 2807.

Be sure not to choose dimensional tolerances that are too tight, as this increases the production costs.

Roughness

Geometric product specification, indication of surface condition in technical product documentation as per NENENISO 1302.

Weld markings

Symbolic representation of welded and soldered joints on drawings as per NEN-ISO 2553.
Welding process as per NENENISO 4063. Quality level as per NENENISO 5817 and NENISO 10042. Welding position as per NENENISO 6947. Welding consumables as per NENENISO 544, ISO 2560 and ISO 3581.

2 material choice: sheet metal

The sheet metal materials most commonly used at Kepser are presented in the tables in this chapter. Other materials can be discussed. The sheets are held in stock in the standard dimensions of 2000 x 1000, 2500 x 1250 and 3000 x 1500 mm.
Larger sizes and intermediate sizes on request. The sheets are available in a range of designs (flat sheet, perforated sheet, bulb plate) and thicknesses. Various grades of the most common sheet thicknesses are always in stock.

In addition, Kepser has an extensive assortment of profiles in stock:

- Bar, L, U and flat-steel profiles in the grades S235JRG2 and S355JO.
- Round tubes (blank, cold-rolled or hot-rolled) in the grades ST 33, ST 35, ST 37 and ST 52 (welded and seamless).
- Rectangular and square tubes (blank, cold rolled or hot-rolled) in the grades ST372, ST 443 and ST 523.
- Other profiles (e.g. rails and open box) on request.

Steel

This handbook deals with the most common types of steel. For advice on your choice of sheet metal material, feel free to contact Kepser.

Hot-rolled steel

From a thickness of 3 mm, steel sheet is hot rolled and supplied in a pickled, oiled or blasted condition. Hot-rolled sheet metal is excellent for shaping purposes. This is because it does not have a rolling skin, which results in less tool wear and contamination.

Material number	Steel	Tensile strength N/mm²	Sheet thickness (mm)
1.0037	S235JR	340-470	3 to 10
1.0038	S235JR	340-470	12 and thicker
1.0570	S355J2G3	510-680	3 to 100

Kepser differentiates between normal steel sheets and laser quality sheets. The latter have more favourable cutting properties: better cleanness, meaning they do not contain any elements that could cause the formation of burrs, good flatness and a low internal stress level. Furthermore, they are significantly better to shape and galvanise and excellent for welding.

Material number	Steel	Tensile strength N/mm²	Sheet thickness (mm)
Manufacturer's spec.	RAEX 250 C	360-440	3 to 20
Manufacturer's spec.	DOMEX 250 YP	360-460	3 to 15
Manufacturer's spec.	RAEX 420 MC	490-620	3 to 20
Manufacturer's spec.	DOMEX 420 MC	490-620	3 to 12

Thermomechanically rolled steel

The thermomechanical rolling of steel creates a very fine-grained product with a strength and shaping properties that cannot be obtained through heat treatment alone. Furthermore, their weldability is excellent.

Material number	Steel	Tensile strength N/mm²	Sheet thickness (mm)
1.8974	S 700MC	750-950	3 to 10
1.8974	DOMEX 700 MC	750-950	2 to 10

Wear-resistant steel

Wear-resistant steel, like the name says, has a high resistance to wear. This resistance is obtained by hardening the material. Due to its composition, wear-resistant steel has a high carbon equivalent and a relatively low critical cooling speed. Given the risks that this can pose during welding, the welding of wear-resistant steel is not recommended (if possible). Moreover, machinability is generally poor due to the high resistance to wear.

Material number	Steel	Tensile strength N/mm²	Sheet thickness (mm)
1.5223	42MnV7	700-860	3 to 30

Heat-resistant steel (boilerplate)

For constructions that are have to withstand high temperatures for extended periods of time, heat-resistant steel is used. This type of material actually resists shaping.

Material number	Steel	Tensile strength N/mm²	Sheet thickness (mm)
1.5415	16 Mo3	440-590	2 to 16

Cold-rolled steel

Cold-rolled steel is manufactured from rolls of hot-rolled steel. First, the sheet is rolled out to smaller thicknesses. Next, the material is annealed and lightly milled. Sheets of cold-rolled steel have a good flatness and small thickness tolerances, and are available in thicknesses of up to 3 mm. Kepser opts for a quality variance of ½ DIN.

Material number	Steel	Tensile strength N/mm²	Sheet thickness (mm)
1.0330	DC01-A-m	270-410	0.35 to 3

Electrolytically galvanised steel (zincor)

Electrolytically galvanised steel sheets are less sensitive to rust due to their zinc layer. Usually, however, the zinc layer is thin, meaning that products should undergo further treatment to acquire definitive protection against rust. Normally, the layer thickness is 2.5 µm, but larger layer thicknesses of up to approx. 10 µm are also possible.

Material number	Steel	Tensile strength N/mm²	Sheet thickness (mm)
1.0330	DC01+ZE25/25-APC	270-410	0.5 to 3

Thermally galvanised steel (sendzimir)

In order to thermally galvanise steel sheets, they are first passed through a zinc bath and then treated with a chemical. The range of applications is diverse. The thickness of the zinc layer is 18 to 20 µm.

Material number	Steel	Tensile strength N/mm²	Sheet thickness(mm)
1.0226	DX51D+Z275/N-A-C	500	0.4 to 4

Weatherproof steel (manufacturer's name: CorTen)

Weatherproof steel has good resistance to corrosion. This is thanks to the well adhering, fairly passive and dense surface layer (oxide film). This layer forms under normal atmospheric conditions. The ability to process weatherproof types of steel is comparable to that of unalloyed types of steel.

Material number	Steel	Tensile strength N/mm²	Sheet thickness (mm)
1.8962	CorTen A	454	1 to 2.5 (cold-rolled)
1.8962	CorTen A	510-610	3 to 12 (hot-rolled)

Stainless steel

Stainless steel grades 304(L) and 316(L) up to and including a sheet thickness of 8 mm are supplied in a cold-rolled condition, with finishing quality Finish 2B. From 10 mm, the sheets are supplied in a hot-rolled condition, with finishing quality Finish 1D. The sheet can also be ordered with film, sanded, brushed or polished.

Material number	Stainless steel	Use/properties
1.4301	304	For general purposes. (C< 0.07%)
1.4306	304 L	The same, but often used for applications requiring a lot of welding (for avoiding intercrystalline corrosion). (C< 0.03%)
1.4401	316	For general purposes, but considerably better corrosion resistance. (C< 0.07%)
1.4404	316L	The same, but often used for applications requiring a lot of welding (for avoiding intercrystalline corrosion). (C< 0.03%)
1.4571	316Ti	Stabilised with titanium, a stronger material but less corrosion resistant.
1.4828	309	Mainly as heat-resistant stainless steel. (maximum 10000 °C, air)
1.4833	309s	The same, but low carbon content, thus less sensitive to dissipation and welding. (maximum 10000 °C, air)
1.4841	310	More heat-resistant and better corrosion resistance than 309. (maximum 11500 °C, air)
1.4845	310s	Silicon version with low carbon content, thus less sensitive to dissipation and welding. (maximum 1050 – 11000 °C, air)

If polished sheet metal is used, consider the grinding direction and how it affects the look of your product.

Aluminium

Kepser mainly uses aluminium of grades AL 99.5 and AlMg3. The corrosion resistance of aluminium is excellent under normal circumstances.

Also in stock: aluminium bulb plate AlMG3, 5 bulbs pickled.

Aluminium profiles, both open and closed, are mostly of grade 6060T6 (AlMgSi 0.5, material number 3.3206).

Material number	Aluminium	Use
30255	1050A H14/H24 (Al 99,5)	Can be machined, welded and shaped very well
33535	5754 H22 (AlMg3)	Can be cut, welded and shaped very well. Seawater resistant (preferred)

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3 design tips

- Do not use sheets that are thicker than necessary (owing to production time, costs and weight).
- Try to build a product as much as possible from uniform profile types and sheet thicknesses (owing to the setup and changeover time of the machine).
- Try to limit the number of welds in a product (due to contraction and the generation of internal stresses).
- Make use of stiffeners in set products where necessary.
- Wherever possible, weld in so-called low-stress areas (places where the loads are small).
- Use closed profiles as tubes and pipes in areas subject to torsion.
- Bear in mind that a sheet can withstand tension better than compression (buckling).
- Make the same parts usable for several functions (in order to limit stock and save time setting up machines).
- Use standard components. These are less expensive and more easily available.
- When coming up with a design, consider how the various components are positioned relative to one another.
- Use shaping techniques instead of welding (to save time and money on positioning, aligning, post-processing).
- Use shaping techniques instead of machining techniques.
- Use as many simple construction elements as possible, such as strip profile, set sheet, tubes, etc.
- Take the next step in the production process into consideration.
- Keep the assembly of parts simple. Bear in mind the attainable tolerances of the production process.
- Keep product tolerances as wide as possible (functional). This makes production easier and

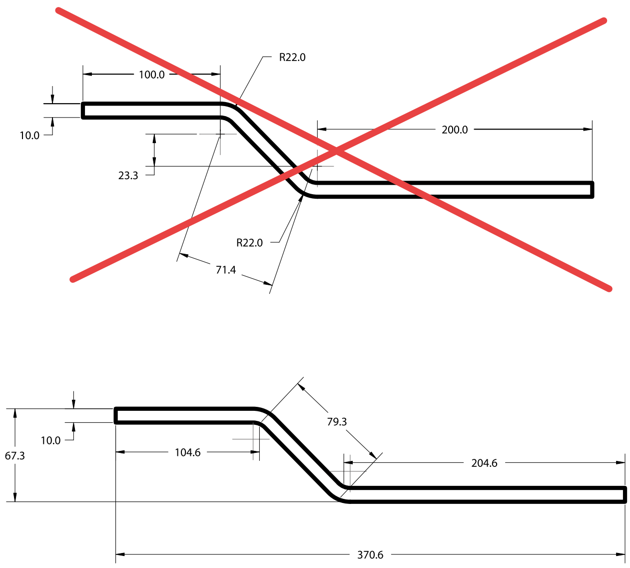

Fig. 3.1

- When inscribing the dimension required for production, ensure that this is directly applicable. (Fig. 3.1)
- Clearly indicate the finishing standard on the drawing (e.g. weld and finish sleek and smooth). Otherwise, only the basic machining operations will be carried out.
- Standardise frequently occurring design details or products like boxes, connections and seals.
- For composite products, make use of less expensive mono drawings.
- Sharp corners are often unwanted. So round them off with an external radius of 0.5 mm.

4 tabs

In order to weld two parts to each other correctly, these components have to be positioned relative to one another. Welding jigs are often used for this. However, they are fairly expensive and have to be made for each product, which takes time. Depending on how complex a product is, the related costs can quickly mount up. For one-offs and small series, the use of welding jigs is therefore often uninteresting, although we do recommend designing the construction in such a way that the parts position themselves.

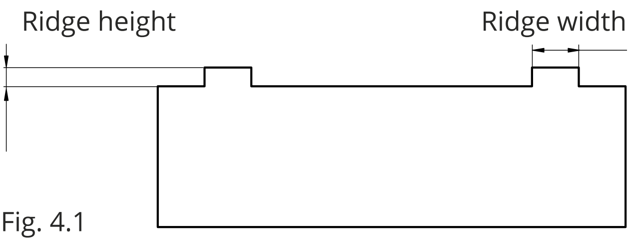

Fig. 4.1

Since the introduction of laser cutting, the use of tabs (Fig. 4.1) and slots has become a frequently used positioning technique. Using tabs allows production to go quicker and more accurately. Quicker because there is no longer any need to measure where a component has to be placed. More accurately because measuring errors are ruled out – there are no scribers or measuring tools that let you position parts as accurately as you can with laser-cut tabs. (Fig. 4.2)
There is a difference between tabs that are visible and those that are not. We also differentiate between tabs that are used solely for positioning and those that are also used to strengthen the joint.

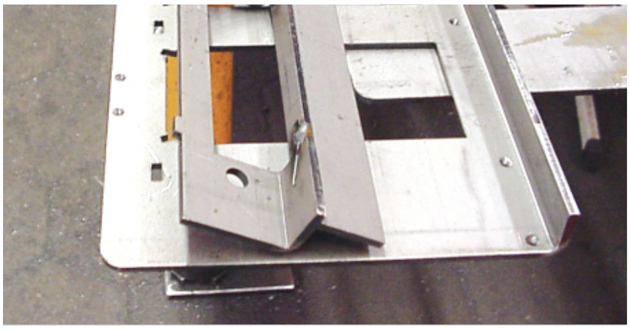

Fig. 4.2

The latter actually has consequences for the dimensions of the tab and the welding position. At Kepser, we prefer the use of positioning tabs.

Positioning tabs

- For accurate positioning, two tabs per contact surface are sufficient.
- Use three tabs per metre for large or less stiff products.
- Do not use more tabs than necessary.
- Tolerances should preferably be absorbed across the width of the tab slot. Any play in the length of the tab is thus no longer important (see example on the next page).
- Slot width = sheet thickness + 0.2.
- Slot length = length of tab + 0.2 (if lengthwise enclosure is required).
- Make the height of the tab lower than the sheet thickness, preferably 1 mm lower. In this way, the rear of the sheet is always flat.
- In principle, the length of the tab is not important, but keep it short. Preferably 10 mm.
- It is not necessary to also weld the tab.
- Provide strength not with the tab but with the weld length.
- Indicate the weld position with notches in those places where welding is not required.
- Keep the depth of the notch to between 10 and 15 mm. This does away with the need to provide length-related weld markings on the drawing (see the examples on the next page).
- Take account of machining tolerances when deciding where to position tabs.
- See where the most accurate measurement has to end up for the positions of the tabs (see the examples on the next page).
- For watertight joints, it is necessary to make tabs and slots fit properly and to weld them fully closed. In any case from the rear, possibly also from both sides.

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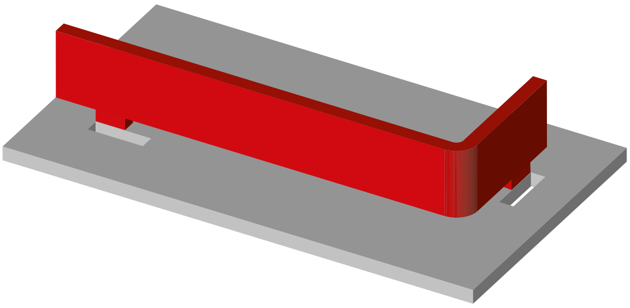
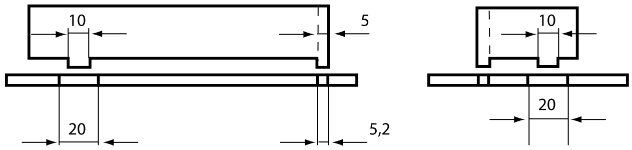
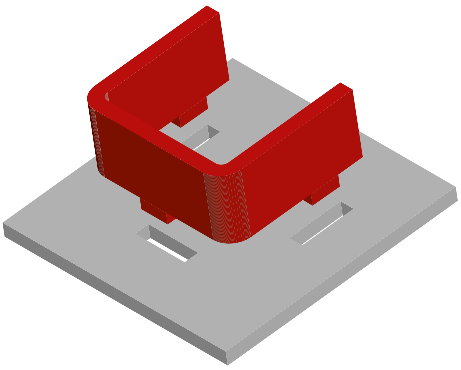
Some examples are provided below by way of clarification.

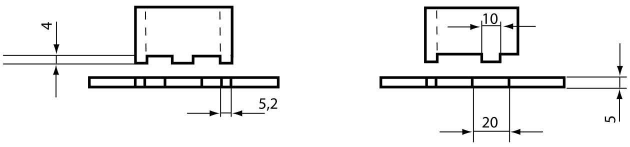


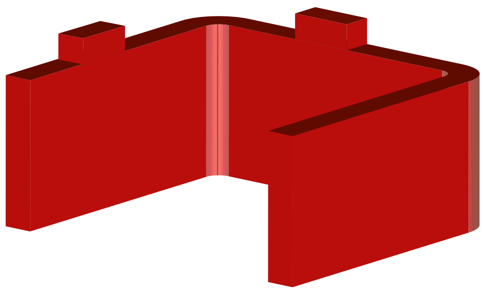
Example 1
- Tab length not important.
- Tab positioned through width of tab.
- X and Y position defined.
- Can be positioned well, despite small deviations during setting.
- Underside nice and flat.

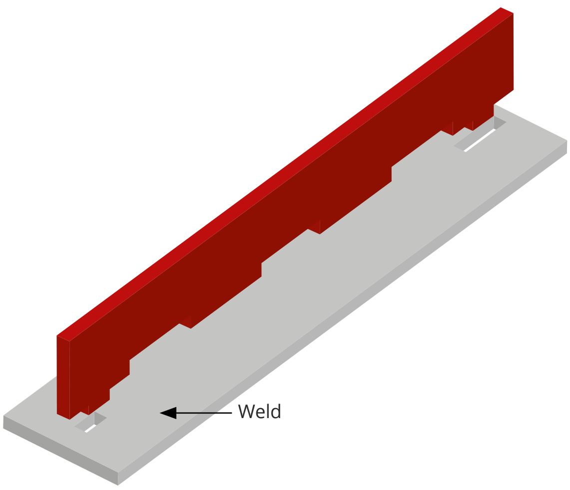




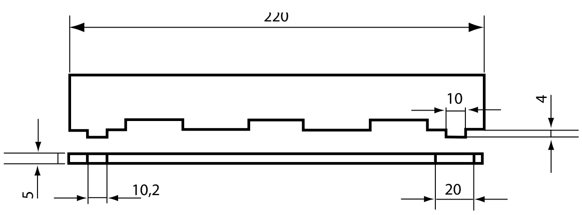
Example 2
- One lug too many used.
- This is not suitable if there is a small deviation during setting.
- Remove the tab from one leg.





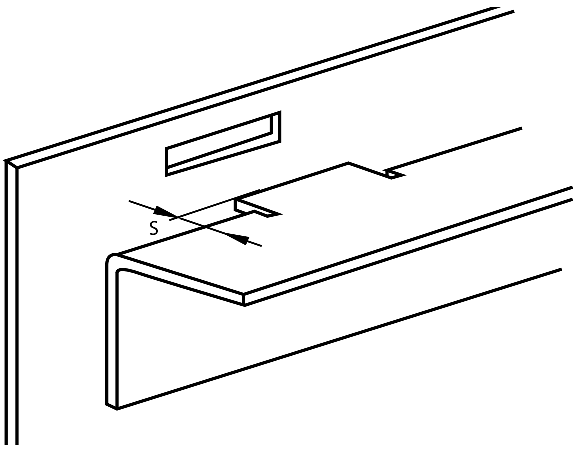


Example 3
- Tabs serve only for positioning.
- Only one tab suitable.
- Notches, other positions provided with fillet weld.
- Number of welded metres indicates the strength of the joint.



Tabs visible

- Bear in mind that visible tabs are always fully welded and then post-processed so that the tab become invisible. Tab-slot combinations for visible work are also designed to close tightly without play.
- The post-processing is different for steel and stainless steel. Steel is welded with MIG/MAG, stainless steel with TIG or tipTIG. In both cases: the more welding required, the more the product starts to contract. Therefore, only use the necessary number of tabs.
- In the case of steel, make the tab height lower than the sheet thickness. Any openings that arise are easy to weld shut using the MIG/MAG welding method.
- For stainless steel, opt for a small protrusion (0.5 mm). Then little to no filler material has to be used. In thicker sheets (from 3 mm), make the tab the same height as the depth of the hole. The joint is welded tight with filler material.
- On a curved sheet, allow the tabs to protrude after bending. In this way, the sheet can still be positioned using the tabs. (Fig. 4.3)
- Keep the tab height to a maximum of two times the sheet thickness. If it is longer than this, it will need trimming.
- Use at least one sheet thickness beyond the setting line as the cutting depth.



- The sheets to be fastened usually have to be placed as close as possible to each other. You should therefore ensure that the sheet with the tabs can rest on the sheet with the slots. If necessary, also remove the internal radius from the tab. (Fig. 4.4) In the case of thicker sheets (from 8 mm), a part of the slot's radius can be cut away in the corner to make it easier to fasten the tab.

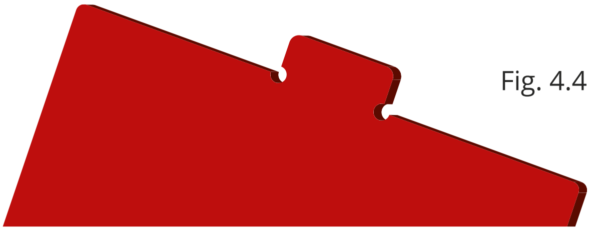


Fig. 4.4

- Makes the tabs in different places if left-hand and right-hand parts are almost identical. This prevents the parts from being incorrectly placed. (Fig. 4.5)

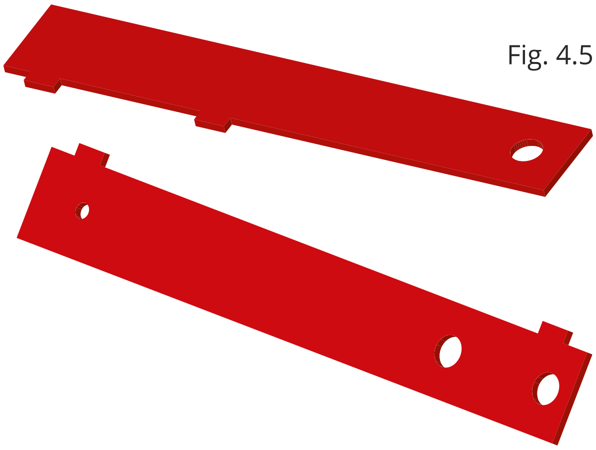


Fig. 4.5

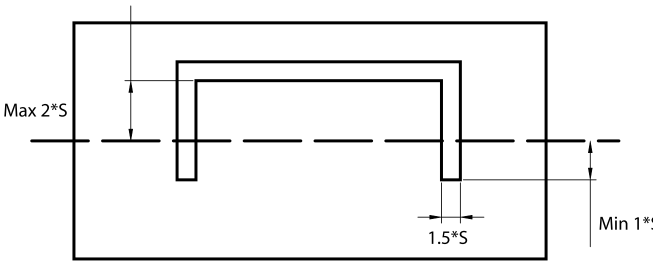


Fig.4.3

- The tab joint shown below is recommended for welding corner constructions. (Fig. 4.6)

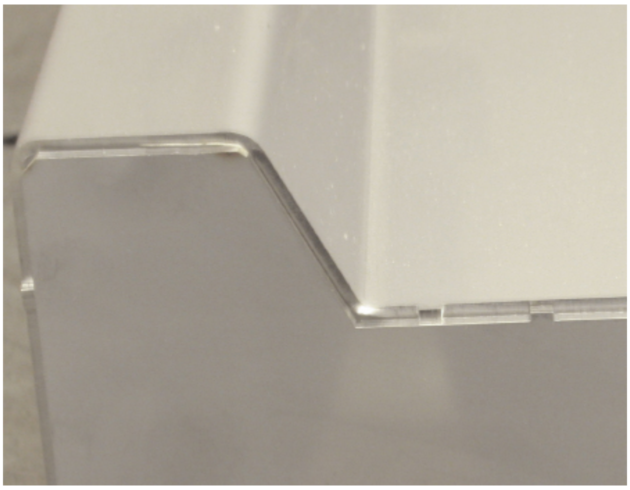


Fig. 4.6

- Always make the the tab length longer than the sheet thickness. This will produce right-angled tabs and holes, which prevents confusion during positioning.
- The use of tabs is not always possible or desirable. In this case, engraving as a way to indicate the position of the component to be joined is a possible alternative.
- This technique is also only possible on laser-cut sheet metal. (Fig. 4.7)

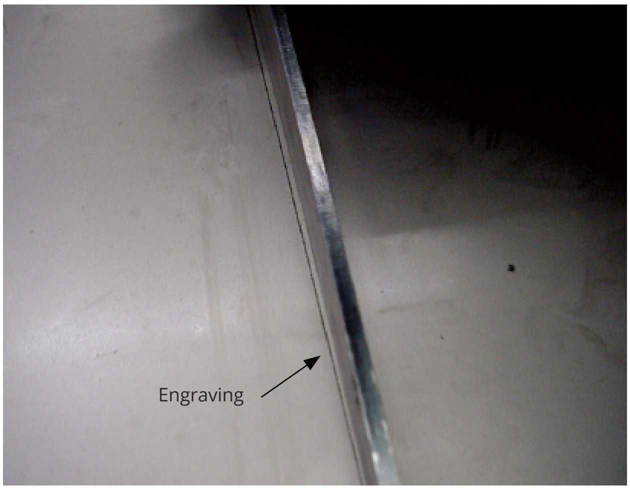


Fig. 4.7

5 shearing

Since the introduction of laser cutting, shearing and punching have increasingly fallen by the wayside. However, the shearing machine is still regularly used for smaller series (especially simple, often rectangular products). A shearing machine is actually much quicker to program and set up than a laser cutter. For this reason, you'll also find a few shearing tips in this handbook.

The achievable tolerances of shearing, also because of the wear of the blade, are dependent on the sheet thickness. The table below contains the tolerances per sheet thickness.

Sheet thickness S (mm)	Tolerances +/ (mm), cut length < 1000 mm
1	0.2
2	0.3
3	0.4
4	0.5
6	0.6
8	0.8

In-house production capacity	
Maximum shear width (mm)	3100
Maximum backstop (mm)	1000
Minimum backstop (mm)	3
Maximum material thickness steel (mm)	8
Maximum material thickness stainless steel (mm)	6

Narrow strips can quickly distort shearing. The degree of deviation depends on the shearing angle and the strip width. The greater the shearing angle and the smaller the strip, the greater the deviation. Possible deviations are the twisting of the strip, curving of the strip and sabre formation. (Fig. 5.1)

Steel bulb plate and mesh are not sheared. This is due to the damage caused to the blade by the uneven load.

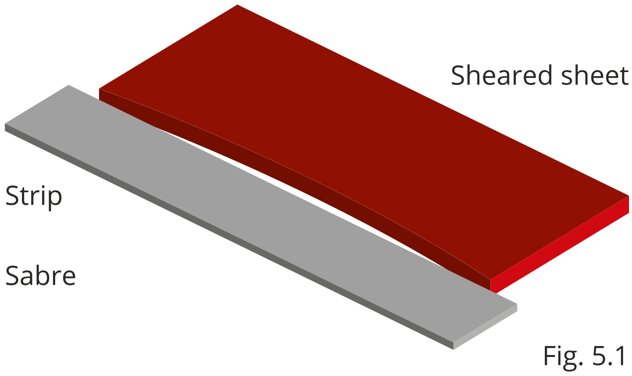


Fig. 5.1

Avoid perforated sections of sheet that have 'blind' selvedges all round; these are particularly labour intensive.

Corner notching
For notching the corners of sheet work, Kepser has a corner notcher (only at a fixed angle of 90 degrees).

Maximum sheet thicknesses:
- Steel 5 mm
- Stainless steel 3 mm

6 laser cutting

Laser cutting is thermal process in which a focused laser beam is used for strong localised heating of the material. Using a coaxial gas flow, the molten material is blown out of the cutting groove, which creates a nice, straight cut. The gas jet also ensures that the cut edges oxidise less.

The shape of the cut is created by the laser and gas jet moving relative to the sheet material. The is done with the aid of CNC control. The process is controlled with a CAD-CAM coupling. Kepser uses WiCAM for this.

Fig. 6.1

Among others, Kepser has a 5 kW CO2 laser from Trumpf (L3050). This machine has a 'flying optics' system, which means that the sheet remains stationary while the laser beam is moved over it assisted by mirrors and the cutting head (Fig. 6.1). Oxygen or nitrogen is used as a shield gas. The maximum sheet dimensions are 3000 x 1500 mm (for stainless steel with sheet thicknesses of up to and including 20 mm, for steel with sheet thicknesses of up to and including 25 mm).

Some advantages of laser cutting

- Straight, burr-free cut. (Fig. 6.2) High cutting speeds.
- Narrow cutting gap.
- Cuts with a smooth surface (the thinner, the smoother).
- Free contours.
- Accurate.
- Fast switching to another product.
- Contactless machining.
- Hardly any thermal influencing of the product.

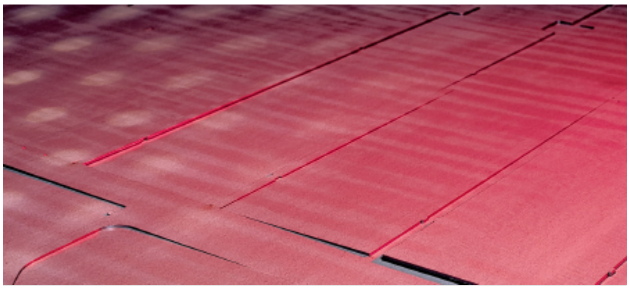


Fig. 6.2

The quality of the product to be cut also depends on the condition in which the input material is supplied. Rusty, sand-blasted, shot-blasted and painted sheets have a negative impact on the result, while pickled and oiled parts have a favourable impact. *See also chapter 2 Sheet material.* Sheets are automatically laid in place by the liftmaster. (Fig. 6.3)

Fig. 6.3

Depending on the type of material, sheet thickness and post-processing, either nitrogen or oxygen is selected as the cutting gas. In the case of steel that is cut with oxygen, a layer of oxide is produced on the cutting edge. If powder coating is required, this layer is unwanted, so nitrogen is the designated gas. Stainless steel is always cut using nitrogen.

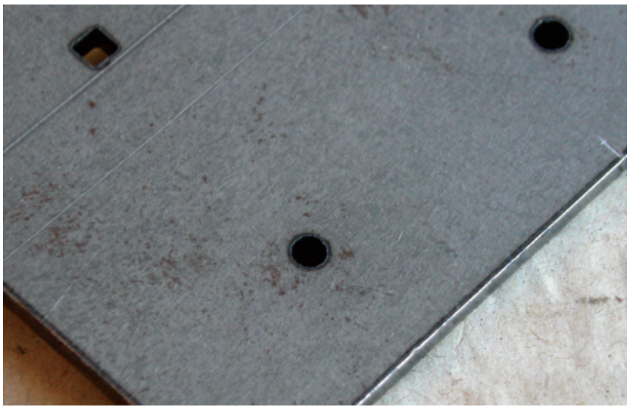


Fig. 6.4

Minimum hole diameters

The contour type to be chosen depends on the dimensions of the hole as well as the cutting speed and the achievability of the quality. (Fig. 6.4) The table below shows the minimum cutting diameters of holes.

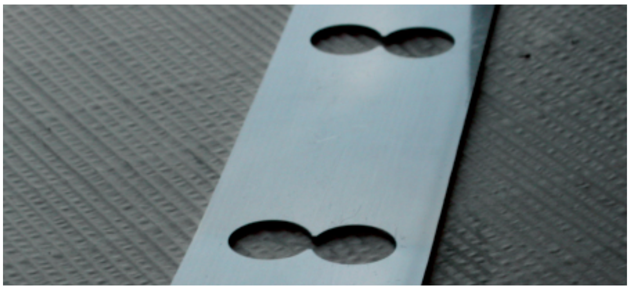


Fig. 6.6

There is no minimum distance between holes. It is possible to allow holes to overlap. (Fig. 6.6)

It is not possible to program a recurring blind edge for perforated sheet. This is due to the perforation pattern. Because special consideration has to be given to nesting and cutting, aligning becomes too expensive.

Minimum hole diameters for laser cutting: Trumpf L3050, 5 kW														
Sheet thickness (mm)	1	1.5	2	2.5	3	4	5	6	8	10	12	15	20	25
Steel (mm)	1	1.7	1	1.3	1.5	2	2.5	2.4	3.2	4	4.8	8	12	40
Stainless steel (mm)	1	1.5	1	1.3	1.5	2	2.5	3	4	5	7.5	9	18	

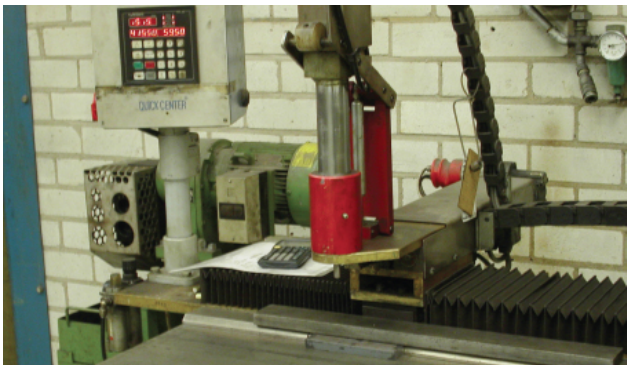


Fig. 6.5

There are holes whose diameter has to be smaller than shown above. The position of the hole can be indicated by engraving it. Of course, this only makes sense for round products. Rectangular products are laid on the automatic centre punch (Fig. 6.5) to position the holes. In this case, there is no need to engrave a centre point.

Cutting diameter of the laser beam

To cut a narrow opening, the laser does not make a peripheral contour, but a single track. The width of the cut opening depends on the diameter of the laser beam. This varies per sheet thickness and type of cut. To give an impression of the sizes, the largest and smallest diameters, and the cutting gap that depends on them, are shown below.

Material	Smallest diameter	Largest diameter
Steel	0.15 at 1 mm sheet thickness	0.7 at 25 mm sheet thickness
Stainless steel	0.2 at 1 mm sheet thickness	0.3 at 15 mm sheet thickness

Because the diameter of the laser beam is variable, a correction factor can be set. This makes it possible, in the case of internal and external contours, to let not the centre but the edge of the laser beam follow the intended line.

In the case of a single cut, the centre of the beam follows the drawn line. (Fig. 6.7)

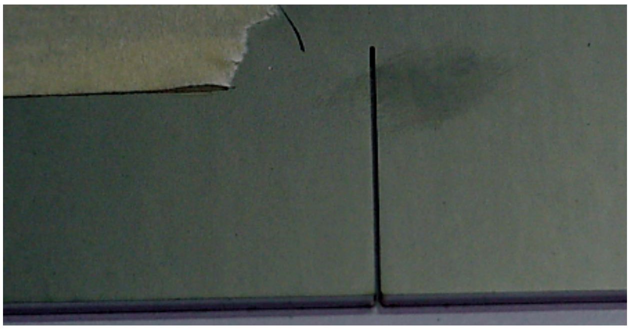


Fig. 6.7

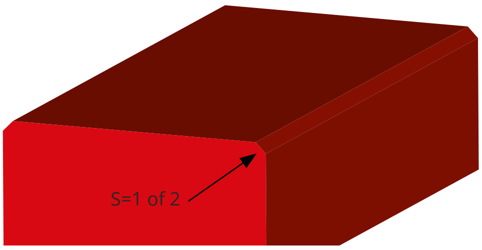
Accuracy
The Trumpf laser guarantees a positioning accuracy of +/ 0.1 mm.

Because the bundle diverges (dilates) as it burns into the material, the cutting edge of a laser cut product is not exactly square.

Finishing
Laser-cut products are supplied burr-free as standard.

- Bear in mind that laser-cut products have sharp edges.
- Do you want to have the edges broken? Then mention this on the drawing. (Fig. 6.8)

Fig. 6.8



Laser cutting

- When drawing holes, think beyond just round ones. A hexagonal hole, for example, prevents the blind rivet nut from spinning. (Fig. 6.9)

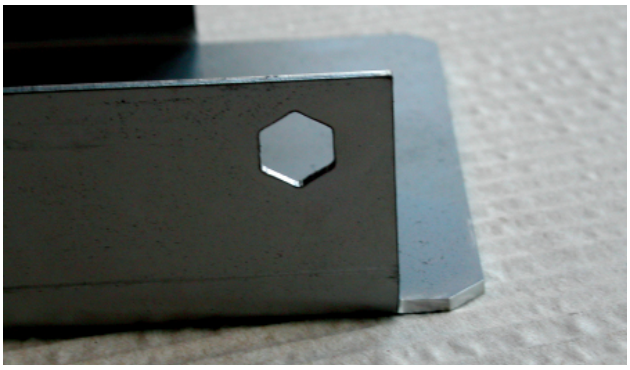


Fig. 6.9

- For the laser, the shape of the hole makes little difference. See chapter 11 for more information about deviated holes.

- The use of so-called Microjoint joints (in which a product remains connected to the residual material by a small part that is not be cut) offers the following advantages:
  - The possibility to fix small parts.
  - Preventing products from 'falling through'.
  - The possibility to fix to the table long, narrow parts that can distort due to the application of heat.
  - The possibility to lift products off the table in a single movement.

  Although a Microjoint joint causes a small burr on the contour, no post-processing is generally required.
- Indicate texts that have to be engraved in yellow in the drawing program. (Fig. 6.10)

Fig. 6.10

- Drawing closed contours. The laser cuts the open contours before the closed contours.
- The laser automatically rounds off sharp corners. Inform the laser programmer if this is not required. The size of the radius is between 0.5 and 3 mm depending on the material thickness, contour type, type of gas and type of material. (Fig. 6.11)

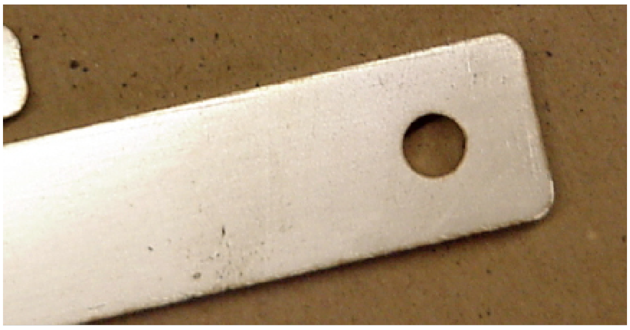


Fig. 6.11

- The same products are often used for several applications. For example, a switch cabinet in which different components can be placed. Depending on the components in the switch cabinet, a number of openings are required. In this case, push out sheet metal parts by hand. The laser leaves little tabs that hold the slug inside the hole. The slug can be pushed out by hand. (Fig. 6.13)

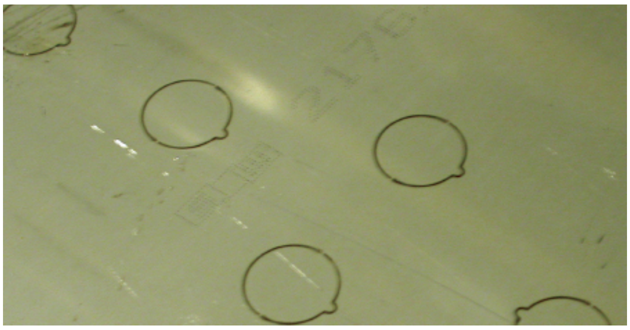


Fig. 6.13

- The thickness of a bulb plate is made up of the sheet thickness plus the height of the bulb. This total thickness is used for programming bulb plate. Also draw the product with this sheet thickness. The bulb points down during cutting. Take this into account during construction.
- Engraving sheet metal parts can simplify subsequent machining. Consider engraving setting lines for products that are difficult to edge. (Fig. 6.12)

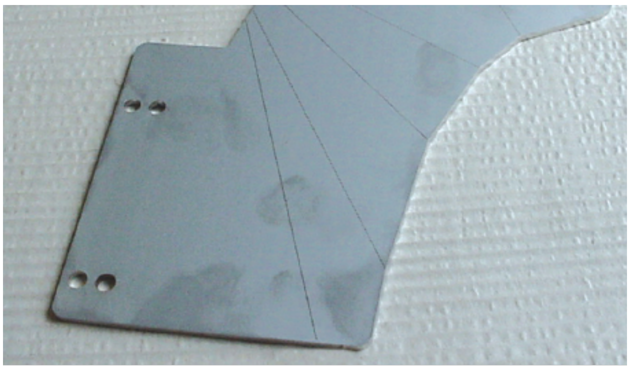


Fig. 6.12

- Build up a round shape from circular arcs instead of short line segments.
- For set products, use the top of the laser-cut surface as the viewing side. This is due to the more attractive cut on the top and less scratching due to the way the sheets are placed. In the case of film, this happens automatically because film is cut from above.
- Sometimes the run-up to an internal contour can be an obstacle, e.g. for pushing through a pipe. In that case, consider a run-up notch. (Fig. 6.14)

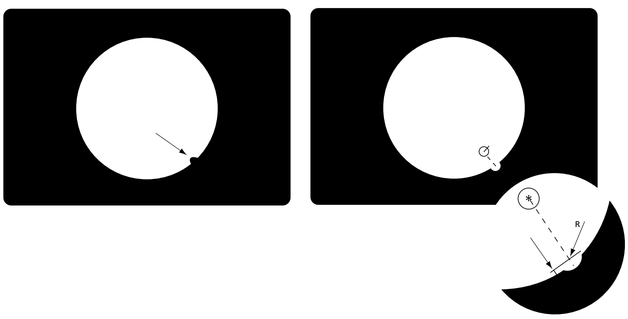


Fig. 6.14

6.a laser-cutting profiles

The principle behind the laser-cutting process for profiles is the same as the explanation given in chapter 6. Laser cutting. The same gases are used for this.

Fig. 6.a.1

The process is controlled with the aid of a CNC control. The process is controlled with a CAD-CAM coupling, for which we use FX-Tube. This is a system for tube and profile machining that converts imported solids of 2D CAD data into complex programs. This system also has a 3D simulation mode (Fig. 6.A.2) for interactive fault detection, among other things.

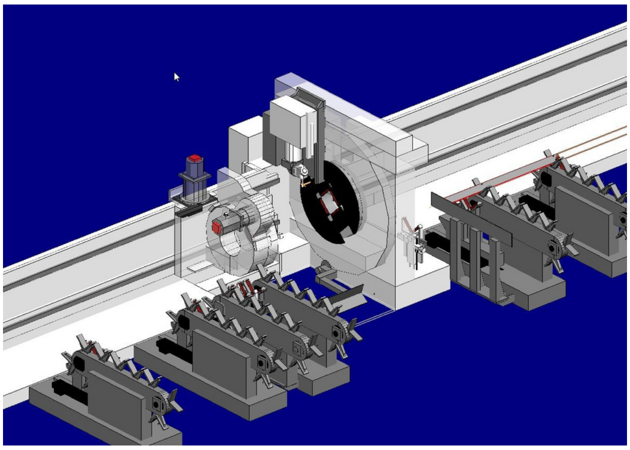


Fig. 6.a.2

Some advantages of the laser cutting of tubes and profiles.

- Time-saving in the preliminary stage. Designers and engineers can, on the basis of their design, take the many possibilities of tube laser cutting into account.
- Time-saving after processing. By applying positioning tabs, dimensioning become virtually unnecessary in the welding department. No welding jigs are needed either.
- Very short machining time.
- Very accurate cutting down to 0.1 mm; this depends on the dimensions of the product.
- 3D laser cutting. The possibility of setting the cutting head below 45 degrees and then rotating it makes it possible to cut entirely in 3D. (Fig. 6.a.3)

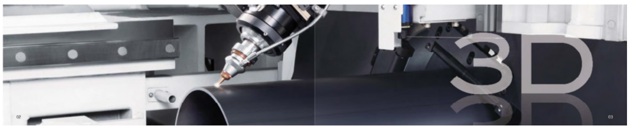


Fig. 6.a.3

- Hardly any thermal impact on the product. There is less distortion than occurs with sawing, drilling, milling and punching.
- A seamless connection is to be created from round to square profiles, for example.
- Unprecedented high degree of design freedom.

General information.

A tube laser machine consists of a clamping device, laser cutting head and a feed and removal magazine. The clamping device itself consists of 4 parts: 3 loose chucks (of which the 2 outermost have a mandrel) and a fixed chuck. The loose chucks can move along the X-axis for, among other things, feeding and removing the product. These can also rotate on what is called the C-axis.

For the laser head, this is another story: here, we have to deal with the Z-axis: laser head up and down, the Y-axis: moving perpendicularly across the product, the A-axis: for rotating around the Z-axis, and the B-axis: for rotating in the longitudinal direction of the product. (Fig. 6.a.4)

The laser head is the base point of the machine. It has the possibility to move around and along the aforementioned axes in order to be able to apply the most divergent contours. To allow the tube to move, we use the clamping device. (Fig. 6.a.5) The loose chucks with mandrel can be compared with a four-jaw chuck of a rotary lathe. They clamp the material to be machined firmly in place and can also rotate. The laser cutting head contains a support called the fixed chuck (Fig. 6.A.6), which has 4 rollers for smooth longitudinal movement of the product. This support sits as close as possible to the laser head so as not to experience any loads caused by possible bending of the material.

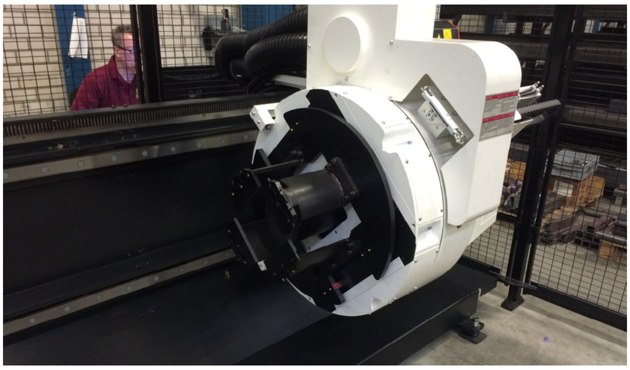


Fig. 6.a.5

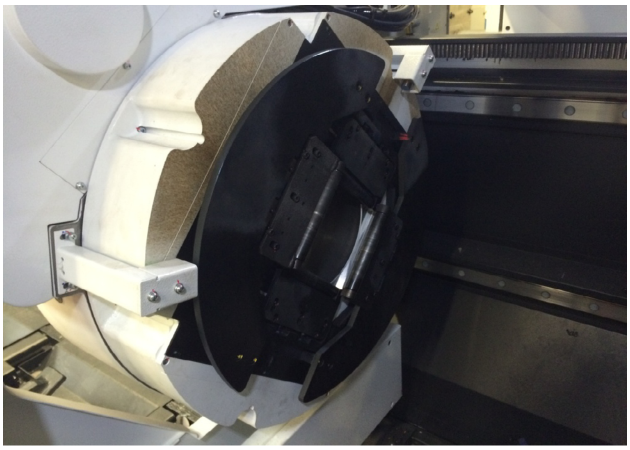


Fig. 6.a.6

If the loose chuck with mandrel is moved all the way back, a new tube or profile can be clamped in place. This has already been laid in the correct position by the magazine, so that this is able to grip the clamping device properly. Next, the material is pushed up to the laser head by the fixed chuck. After scanning, the position is determined and cutting can commence. Once the product is ready, it will drop, regardless of its length, into a bin or be placed in the finished products magazine by the loose chuck with support.

We can machine the following dimensions and profiles.

- Maximum dimensions of round tube: Ø 220 mm,
- maximum dimensions of profile: 200 x 100 mm and 160 x 160 mm (ø diagonal of diameter 220).
- Maximum profile length: 8000 mm.
- Maximum wall thickness: steel 15 mm / stainless steel 8 mm / aluminium 5 mm.
- Maximum product weight: 330 kg.
- Maximum product length is trade length / 320 mm. This is the machining loss.
- Fig. 6.a.7 shows a number of profiles we can process. Exotic variants can also be machined; however, the supplied drawing must agree exactly with the material.

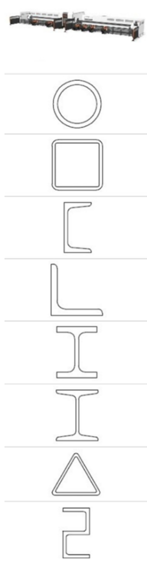


Fig. 6.a.7

Information to be provided.
We can import .DXF, .DWG, .STEP and .IGES files and a number of other formats. It is very important for the drawing to agree fully with the material to be cut. An example is the internal and external radius of tubular profile or angle bar. The supplied files are also critical for determining the final product. The customer is therefore personally responsible for supplying correct files. In some cases, we are prepared to make a drawing of the supplied design ourselves and write a program for it. It is clearly important that all dimensions are known.

- Cutting with oxygen takes longer, but avoids the formation of a layer of oxide on the cut edges.
- Depending on the wall thickness of the material, 3D cutting is possible. If the material is cut at an angle, the total distance through the material is greater, which lengthens the cutting time. In the case of 2.5D cutting, considerable amounts of time can be saved because the cutting is perpendicular to the material.
- It is possible to engrave text, e.g. the item number of a product. Positioning lines are also frequently set. This saves time in the welding department because you hardly have to do any measuring, if at all.
- When designing a machine, skid or frame, it is a good idea to choose material with the most similar wall thickness possible. This saves time when retooling the machine.
- The rule of thumb is that holes and cut-outs should not be smaller than the wall thickness of the material. However, if this is desired then you could opt to pierce centre holes, which saves time having to re-measure them when drilling.
- The cutting speed for large contours is many times faster than for smaller contours; choosing large contours where possible saves cutting time.
- On the feed edge, the clamping device of the machine is equipped with an extraction system. This extracts most of the swarf. Especially in the case of stainless steel, these hot particles want to adhere firmly to the inside of the profile. There are ways to process the material beforehand to avoid this or to clean it after machining.
- When cutting aluminium, the cut edges on the inside will often be rough. In this case, post-processing is often necessary.
- With open profiles, such as corner or C-profiles, it is important that the drawing contains the internal and external radii and that these also correspond to reality.

To be able to guarantee the best quality, we take account in-house of the factors that our customers are unable to influence. Small dimensional differences in profiles are normal in the base material and can prevent small deviations. But to keep this to a minimum, we work with material from the same batch wherever possible.

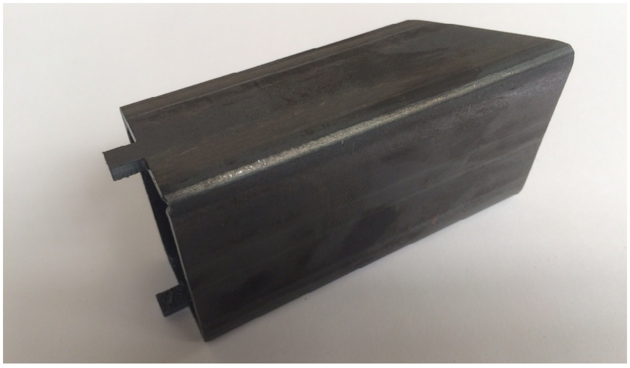


Fig. example: positioning tabs


Fig. example: trimming

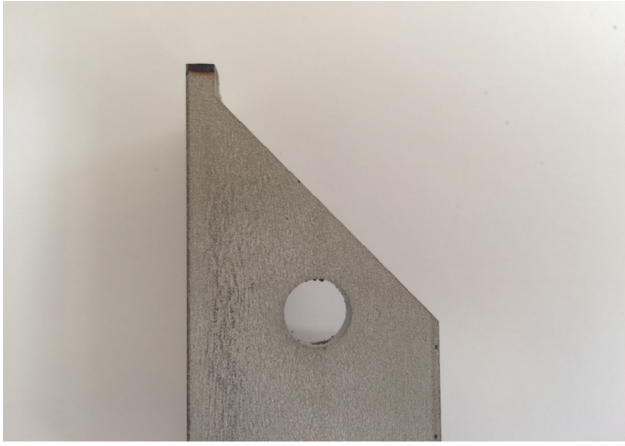


Fig. example: mitre cut lip

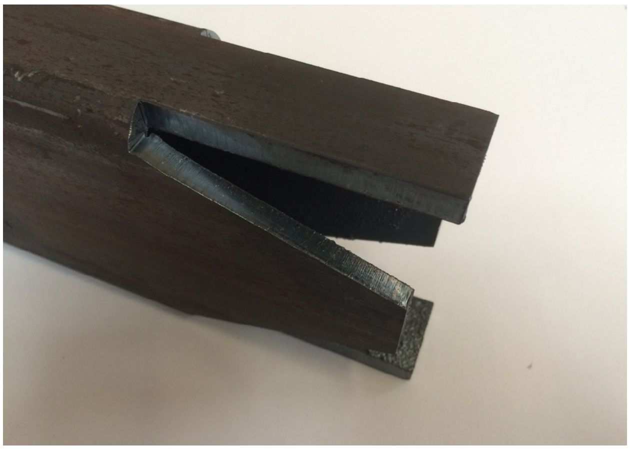


Fig. example: miscellaneous


Fig. example: miscellaneous1

7 drilling

Tapping

The table below contains the drilling diameters for the various screw threads. This table is based on the used standard forms.

Metric thread			Gas thread	
	Minimum sheet thickness	Bore diameter (mm)		Bore diameter (mm)
M2	0.8	1.6	G 1/8	8.7
M2.3	0.8	1.9	G ¼	11.75
M2.6	0.9	2.15	G 3/8	15.25
M3	1.0	2.5	G ½	19
M4	1.4	3.3	G 5/8	21
M5	1.6	4.2	G ¾	24.5
M6	2.0	5	G 7/8	28.25
M7	2.0	6	G 1	30.5
M8	2.4	6.8	G 1 1/8	35.5
M9	2.4	7.8	G 1 1/4	39.5
M10	3.0	8.5	G 1 3/8	41.5
M12	3.0	10.5	G 1 ½	45
M14	4.0	12	G 1 5/8	48.5
M16	4.0	14	G 1 ¾	51
M18	5.0	15.5	G 2	57
M20	5.0	17.5		
M22	5.0	19.5		
M24	6.0	21		

For metric thread, the following rules apply: Bore

- diameter = thread type pitch.
- The minimum sheet thickness for tapping is twice the pitch.

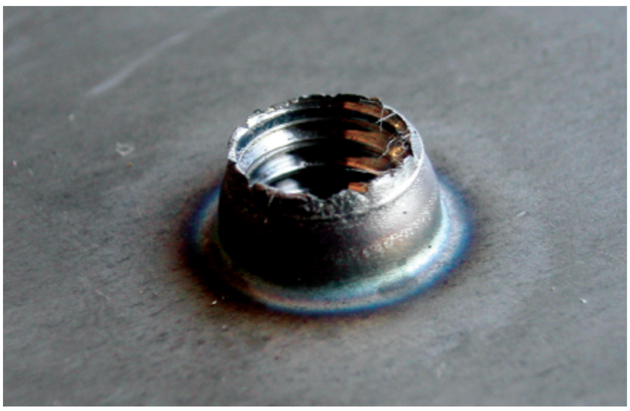
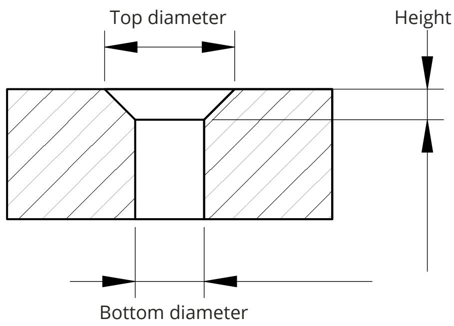


Fig. 7.1

Galvanising (Fig. 7.2)



Screw thread	Dimensions				
		Head (angle 90 degrees)			
		Saw cut		Hexagon	
	Bottom diameter	Top diameter	Height	Top diameter	Height
M 3	3.3	6.3	1.5	6.72	1.71
M 4	4.4	9.4	2.5	8.96	2.28
M 5	5.5	10.4	2.5	11.2	2.85
M 6	6.6	12.6	3.0	13.44	3.42
M 8	8.5	17.3	4.4	17.92	4.69
M 10	10.6	20.0	4.7	22.4	5.89
M 12	13.5			26.88	6.69
M 16	17.5			33.6	8.05
M 20	22.0			40.32	9.16

Friction drilling and tapping

If the wall thickness of a rectangular tube is insufficient for thread tapping then the friction drilling and tapping technique is used. Friction drilling consists of two actions. The drilling of a hole in the sheet and, at the same time, the forming of a bushing. (Fig. 7.1) After drilling, the bushing makes it possible to tap a thread length that is many times larger than the sheet thickness. These machining processes are carried out using a high-speed drill fitted with a special tap.

Screw thread	Wall thick-ness	
	Minimum	Maximum
M 5	1.5	1.75
M 6	1.5	4.0
M 8	1.5	4.0
M 10	2.0	4.0
M 12	2.5	4.0
M 16	2.5	4.0

Application requirements

- Distance between the holes: 2.5 x hole diameter
- Distance from hole to edge of the sheet: 0.5 x hole diameter + 5 mm.
- Distance from hole to edge of setting: wall thickness + 5 mm + 0.5 x hole diameter + radius of setting.
- Distance from hole to centre of weld: 0.5 x hole diameter + 9 mm.

Do not position holes in pipes and tubes in the middle. The force introduced during machining will depress the profile.

When it comes to forming the bushing, friction drilling is not suitable for machining in flat sheet metal.

Recessed cylindrical head

A multi-step drill (Fig. 7.3) can make a recessed hole for a cylindrical head (pot hole) in a single drilling action. (Fig. 7.4)

Also in stock:

- 26 x 13 (pre-drilling necessary, size 13 not a bore but a cylinder)
- 13.5 x 8.4
- 22 x 8.5 (pre-drilling necessary, size 8.5 not a bore but a cylinder)

Fig. 7.3

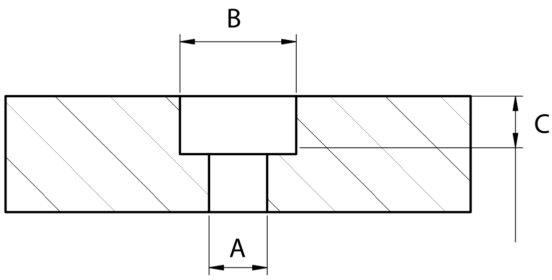
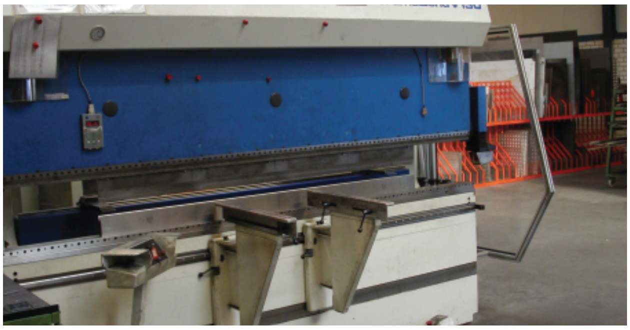


Fig. 7.4

Screw thread	Dimensions			
	Thread shaft A (mm)	Headshaft B (mm)	Height of head (mm)	Depth head part minimum C (mm)
M 5	6	11	5	5.5
M 6	6.6	11	6	6.5
M 8	9.0	15	8	8.5
M 10	11.0	18	10	10.5
M 12	13.5	20	12	12.5
M 16	17.5	26	16	16.5

8 bending



Transforming a flat sheet into a three-dimensional product is often done through bending. Bending is a highly complex technique because of the many factors that influence the final result: type of material, material thickness, rolling direction, thermal influences, tool wear, groove width, upper blade, shortening values, setting angles, internal radius, influence of holes, etc. This chapter looks at the most important aspects of bending.

Free bending

Kepser uses so-called free bending, (Fig. 8.1) because it is the most flexible way to bend an angle. By moving the top die downwards, the sheet is pushed into the bottom die and bent. This angle this produces depends not on the tool,but on the pressing depth and the sheet thickness.

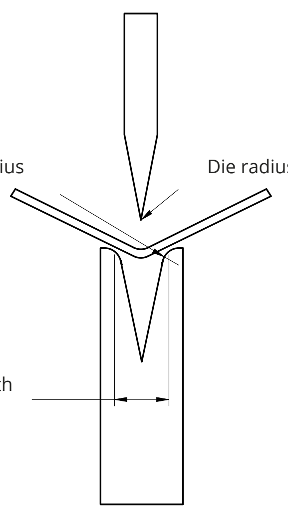


Fig. 8.1

As both the upper blades and the bottom dies consist of separate pieces, an arrangement can be created for the optimal setting of each product. For the setting of stainless steel, tape is used to prevent the material being damaged. (Fig. 8.2)

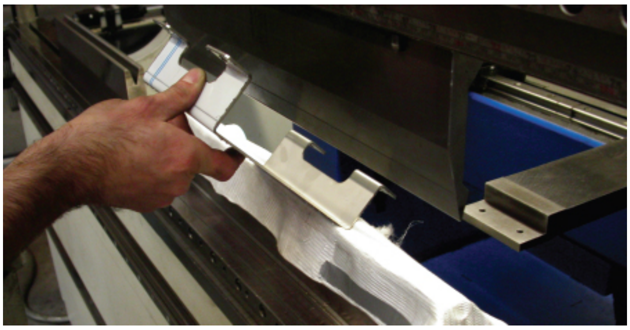


Fig. 8.2

Kepser has four bending presses, all equipped with a graphic visualisation of the bending process on the screen and angle control by means of the so-called ACB system (more information on the ACB system later in this chapter).
The programs used on the Trumpf presses are interchangeable, subject to the product's dimensions being allowed on another press. The maximum length of the product to be set is 4080 mm (information on the dimensions per bending press later in this chapter).

Ratio of groove width to sheet thickness

An important aspect of bending is the ratio of groove width to sheet thickness and the associated internal product radius.
As a rule, we use the ratio: groove width = 8 x sheet thickness. However, it is possible to bend a larger or smaller groove. Different combinations have to be examined individually.

The following applies to the associated radius:

- Standard groove (8 x s) Ri = 1.2 x s
- Smaller groove Ri = s
- Larger groove Ri = 1.5 x s

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- Do not specify the radius on the drawing if it is not important.
- Draw the radius in accordance with the rules on the previous page. Kepser mainly uses universal tools, which means that machining has to be done using a fixed radius. At Kepser, the radius is adjusted to obtain good sheet results for production.
- Make a specific note of the radius if its accuracy is very important. This can then be pushed into a product with the help of a circular shaft. A special upper tool often has to be made for this.

Bending force

The bending force is calculated with the following formula: F = C*Rm*B*S2/V.

F = bending force.
C = correction factor, Trumpf reckons this to be 1.33. Rm = tensile strength.
B = width of product. S = sheet thickness.
V = groove width.

The maximum bending force is 400 kN/m edge length.

Accuracy of angle

During setting, an angle accuracy of +/ 0.5 degrees can be guaranteed.

Accuracy of the ACB system

After a sheet has been bent to a certain angle, it always rebounds. To compensate for this rebound, the sheet is bent slightly further than the required angle. However, the exact size of the rebound is difficult to estimate; it can even be different each time the same materials are pressed.
To avoid this, the bench presses of Kepser have an ACB (Automatically Controlled Bending) system. (Fig. 8.3) This system automatically calculates how much a sheet has to be overpressed to achieve the setting the angle, the upper blade lifts slightly, after which the rebound is measured. (Fig. 8.4)

Fig. 8.3

Using this measurement, the upper blade is pushed into the angle again and the system automatically corrects the product to the desired angle. The ACB system guarantees an accuracy of 0.3 degrees.

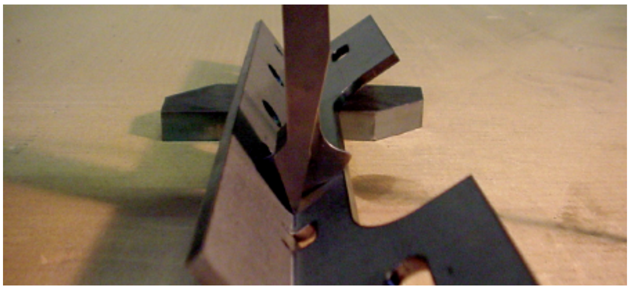


Fig. 8.4

Accuracy of leg length

desired angle. After Deviations in product length that are caused by the laser cutting are increased by the bending. At Kepser, deviations are always kept smaller than 0.2 mm per setting. For deviations in several settings, see Fig. 8.5.

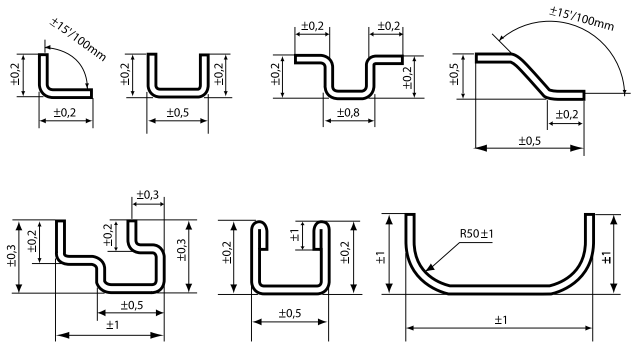


Fig. 8.5

Large notch

It is often necessary or desirable to to take a piece out of a sheet before bending it. Any distortion of the bend in the angle can be partially absorbed if the hole is still easy to weld shut. Welding actually causes the material to contract and the set parts can still pull slightly towards each other, which makes the perpendicularity better than flat after setting.

In this case, use round holes with a diameter of 1.5 x sheet thickness (regardless of the sheet thickness and type of material). (Fig. 8.6)

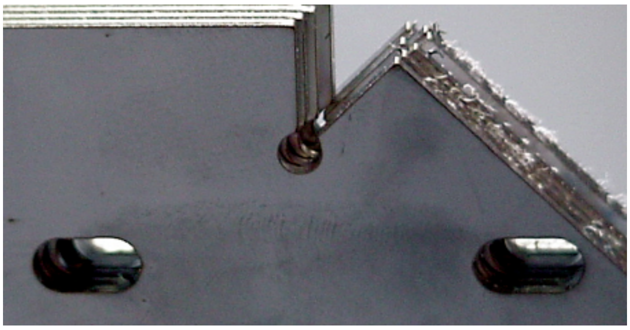


Fig. 8.6

Minimum dimension from hole to bending line

To determine the distance from the hole to the bending line, different formulae are used for different hole shapes. We differentiate between round holes, square holes and slotted holes. (Fig. 8.7+ 8.8)

Xmin = minimum distance to the bottom of the hole s = sheet thickness
d = hole diameter
Ri = internal radius
b = hole width (slotted holes and square holes)

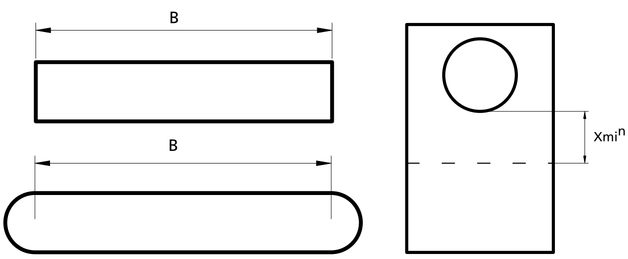


Fig. 8.7

Distance X_{min}

- Round holes $X_{min} = Ri + 2 \times s$
- Square holes $X_{min} = Ri + 3.3 \times s$ $b \leq 25$
  and slotted holes $X_{min} = Ri + 3.5 \times s$ $25 < b < 50$
  $X_{min} = Ri + 4 \times s$ $b \geq 50$

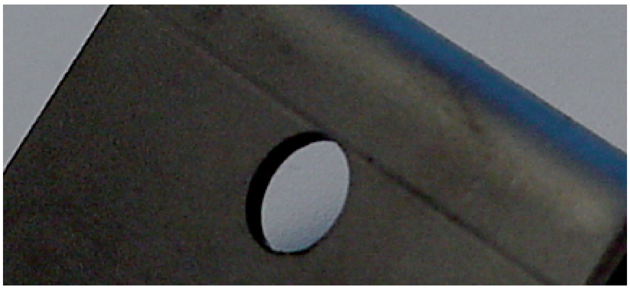


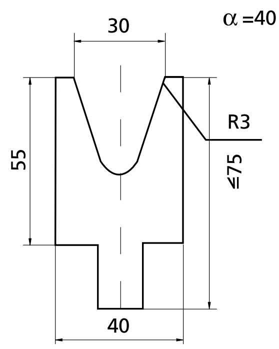
Fig. 8.8

Note: it is important to apply the correct radius when using these formulae.

- Round holes (8 x s) Ri = 1.2 x s
- Square holes Ri = s
- and slotted holes Ri = 1.5 x s

Kepser uses groove 20 as the ideal groove width for 3 mm (24 is not available).

Bottom tool				
Type	Groove width	Standard sheet thickness	Total width	Radius side of groove
OZU-351	8	1	16	2.5
OZU-352	12	1.5	20	3
OZU-353	16	2	30	3.5
OZU-363	20	3	35	4
OZU-031	30	4	40	3
OZU-032	40	5 + 6	50	4
OZU-016	60	8 + 10	80	5
OZU-081	10 Straight groove, flattening	1 + 1,5 + 2	50	



- Strictly apply the formulae on the previous page only if distortion of the hole is absolutely not permitted.
- If any distortion is admissible, use the formulae to obtain the critical dimensions and then make the dimensions a little larger where possible (due to fluctuations in the material).

Sometimes, holes have to be closer to the bending line than is possible according to the above formulae. A trick that can be used here involves making an incision on the bending line. (Fig. 8.10) This trick works not only for holes, but also for other shapes that lie close to the corner. However, the following questions have to be answered first:
- Could the hole distort?
- Will the opening created by the incision remain open after bending?

Welding shut actually requires additional processing, which means extra costs, and the product may end up being distorted. The largest possible opening, ideally over the entire bending zone, is the preference here.

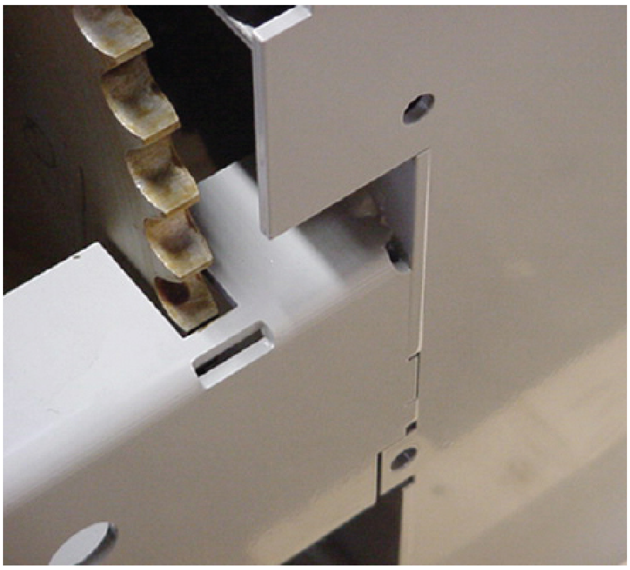


Fig. 8.10

- Use the following rules if the opening has to be as small as possible:
  - Length of opening = minimum length of hole.
  - Width of opening = minimum length of the shortening in the inside corner (depending on the sheet thickness and setting groove). This shortening is to be calculated with the CAD package.

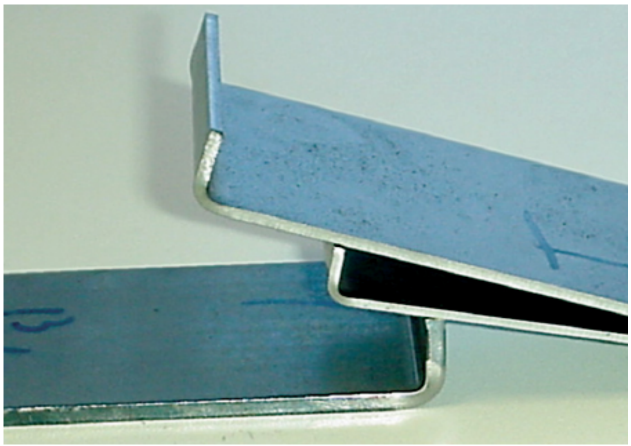


Fig. 8.11

Minimum leg length

The minimum length of the leg to be bent (setting of backstop) depends on the bottom tool used. (Fig. 8.11) The table below contains an overview of the minimum leg length for different types of bottom tool.

Narrow products are easier to set than wide products. It is not always possible to position wide products perfectly straight on the setting bench, which can give rise to inaccuracies.

Bottom tool		
Type	Standard sheet thickness	Minimum leg length =1/2 * groove width + radius of die + 1 mm
OZU-351	1	6.5
OZU-352	1,5	9
OZU-353	2	11.5
OZU-363	3	14
OZU-031	4	18
OZU-032	5 + 6	24
OZU-016	8 + 10	35

Setting U-profile

When it comes to the minimum U-profiles that can be bent, start with the internal dimensions (Fig. 8.12) so that the sheet thickness has no effect in the table. When bending U-profiles, work with upper blade BIU033/2. (Fig. 8.13)

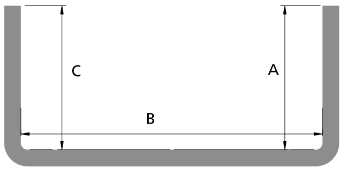


Fig. 8.12

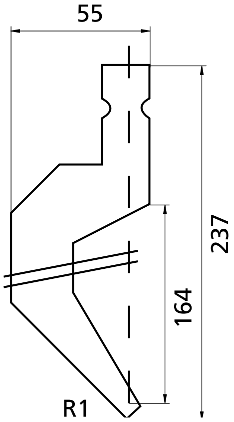


Fig. 8.13

Minimum dimensions

The minimum dimension of the U-profile to be bent depends on the sheet thickness in combination with the associated groove width (8 x s) and the dimension of the upper blade. There are three ways to look at the minimum U:

1. Starting from a minimum B length and the maximum associated A length.
2. Starting from a minimum A length to be bent and the associated minimum B length for which the product still has to be bent.
3. Minimum U dimension A=C. For the maximum U dimension, C is of no importance.

Maximum dimensions

The maximum dimensions depend on the dimensions of the blade and the machine. By allowing the length of B to increase, it becomes clear what the maximum length of A may be (see table on this page; (Fig. 8.15) intermediate values can be interpolated). Up to a B length of 130, the shape of the U-profile depends on the blade, thereafter on the upper bar. The table is compiled on the basis of using an upper blade without a spacer and without an opening between the blade and the clamping bar. For large U shapes, it can be seen what the options are if spacers are used.

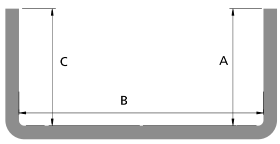


Fig. 8.15

The table assumes 2 settings for the fabrication of a profile without the set side distorting.

B	A max
25	57.5
B	B+32.5
95	127.5
105	131.1
115	129.1
125	126.7
135	123.8
145	132.2
155	127.8
165	126.8
175	132.5
185	136.9
195	142.6
215	165.5
225	182.5
B	B-42.5
770	727.5

		Minimum B length			Minimum A length	
Sheet thickness	Standard groove	Bmin given	Amax calculated	Amin calculated	Amin given	Bmin calculated
1	8	6.5	-	-	6.5	10.5
1.5	12	9	-	-	9	10.8
2	16	11.5	11.5	11.5	11.5	11.5
2.5	20	14	22.4	14	14	12.6
3	20	14	22.4	14	14	12.6
4	30	18	40.6	18	18	15.3
5	40	24	56.5	24	24	20.8
6	40	24	56.5	24	24	20.8

- Smaller shapes are possible with counterpressing. Ask us for more information. Bear in mind that this results in a slight distortion. (Fig. 8.16)

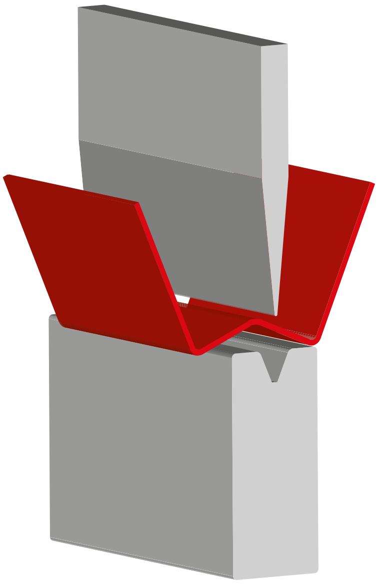


Fig. 8.16

- It is also possible, in order to set the product from one part, to choose to place additional settings in the product. This would, of course, give the product a different appearance. (Fig. 8.17)

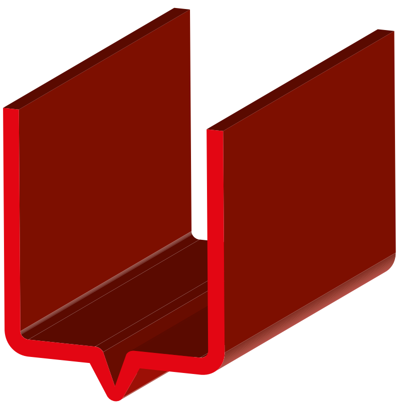


Fig. 8.17

Bending a small box

The minimum dimensions of a box depends on the minimum dimension of the U to be bent and the narrowest available blade. The narrowest gooseneck upper blade from Kepser is 20 mm

- To calculate the most critical box in terms of footprint and height, assume the smallest box surface area: 25 x 25 mm. This gives a height of 57.5 mm (see the table for bending a maximum U).
- For the feasibility of other box formats (larger footprint), look up the associated height in the table for bending a maximum U.

Z shape bending

The minimum dimension of a Z shape depends on the dimensions of the lower beam and the die. The upper blade has no influence. The maximum working height is 1050 mm (height including bottom die). The bases of the V85 and V130 (Tab. 8A) are identical; only the maximum length of the product is different. The V170 (Tab. 8B) has a wider lower beam, meaning that other values for the minimum Z shape apply here.

The Z shape can be bent in two ways, depending where the most accurate dimension should be. (Fig. 8.18)

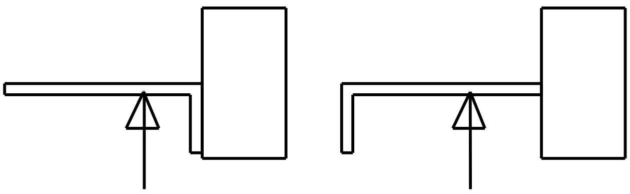
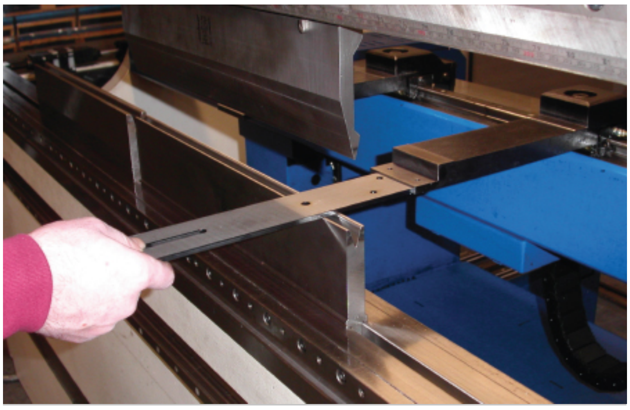


Fig. 8.18

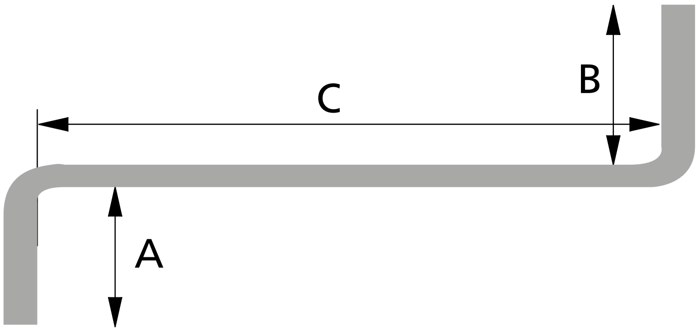


V85 en V130 (Tab. 8A)

	V85	V130
Setting width	2050	3060
Neck depth	410	410
Distance between the necks	1750	2690

V170 (Tab. 8B)

	V170
Setting width	4080
Neck depth	410
Distance between the necks	3680



V85 / V130			Minimum dimension of C in relation to A (mm)					
			C					
Sheet thickness	Standard groove	Min A	Min A≤A<100	100≤A<135	135≤A<260	260≤A<860	B min	B (max)
1	8	6.5	9.5	53	62.6	98	6.5	:
1.5	12	9	12.25	53	62.6	98	9	:
2	16	11.5	19	53	62.6	98	11.5	:
2.5	20	14	20.5	53	62.6	98	14	:
3	20	14	21.1	53	62.6	98	14	:
4	30	18	24.8	53	62.6	98	18	:
5	40	24	31	53	62.6	98	24	:
6	40	24	32.2	53	62.6	98	24	:

V170			Minimum dimension of C in relation to A (mm)					
			C					
Standard groove	Min A	Min A≤A<100	100≤A<135	135≤A<256	260≤A<860	B min	B (max)	B (max)
1	8	6.5	9.2	82.5	100	119	6.5	:
1.5	12	9	11.8	82.5	100	119	9	:
2	16	11.5	18.6	82.5	100	119	11.5	:
2.5	20	14	20.5	82.5	100	119	14	:
3	20	14	21.1	82.5	100	119	14	:
4	30	18	24.8	82.5	100	119	18	:
5	40	24	31	82.5	100	119	24	:
6	40	24	32.2	82.5	100	119	24	:

Offset bending

Length X (Fig. 8.19) depends on the groove width used. This is related to the total width of the lower die.

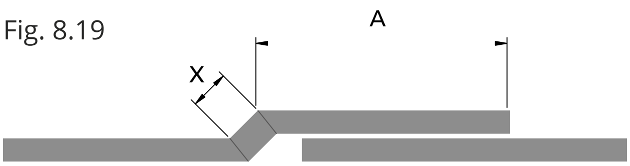


Fig. 8.19

Sheet thickness	Standard groove	Min A	Total width	Length X
1	8	6.5	16	9.2
1.5	12	9	20	12.25
2	16	11.5	30	19
2.5	20	14	35	20.5
3	20	14	35	21.1
4	30	18	40	24.8
5	40	24	50	31
6	40	24	50	32.2

Flattening

To stiffen thin sheet material in certain places or to avoid sharp edges, these places can be flattened or folded double. (Fig. 8.20) That is done in two steps. First, the flange is bent as far as possible. Next, it is flattened. After flattening, the total height is 2 to 2.5 times the original sheet thickness.

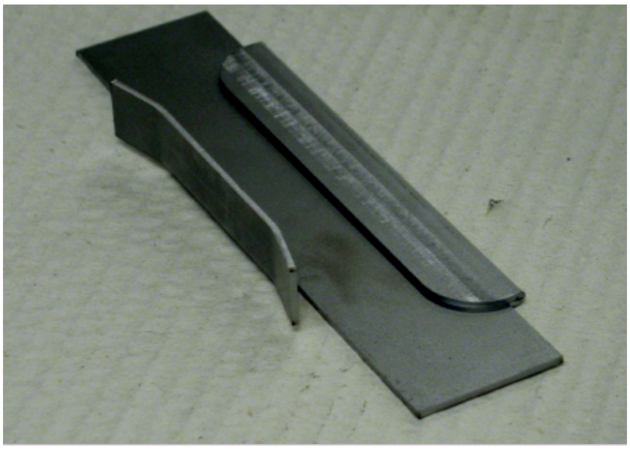


Fig. 8.20

The maximum length of the flange is not important because the material is crushed into the angle, which distorts the entire flange. The maximum sheet thickness that can be flattened is 3 mm, the maximum length of piece to be flattened is 3 metres.

Setting

- Do not let the bending line run from the other leg in the course of the contour. Bulking up and stretching are hindered in the bending zone, which causes tearing. To prevent this, make a cut in line with the outside contour of the leg to be set. (Fig. 8.21) Use 1.5 x s as minimum slot width.

Fig. 8.21

- Avoid slanting edges on the edge of the bend. These distort during setting. The minimum height from which the slanting edge may begin is: ½ x groove width + sheet thickness = Lmin. (Fig. 8.22)

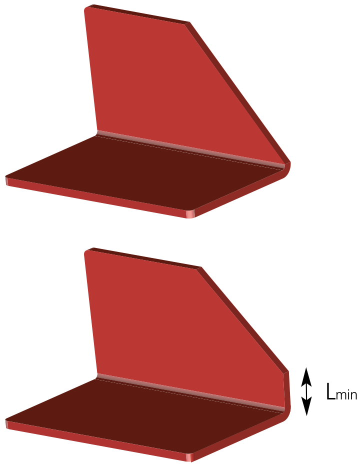


Fig. 8.22

- Better than a short bent leg Y is to shorten the edge of the other leg by size X. The size of X must be at least 0.5 x s. It is also possible to place the short bent leg on the bending line, but then a notch will have to made at the transitional point. (Fig. 8.23)

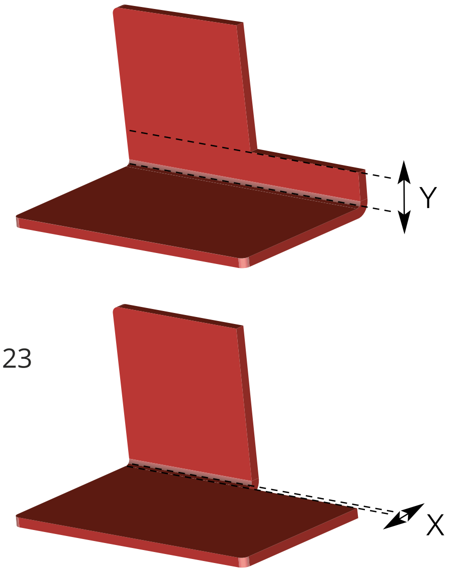


Fig. 8.23

- Better than a short bent leg Y is to let the cut-out run around the bent edge and to shorten the other leg by size X. The size of X must be at least 0.5 x s. (Fig. 8.25 and 8.26)

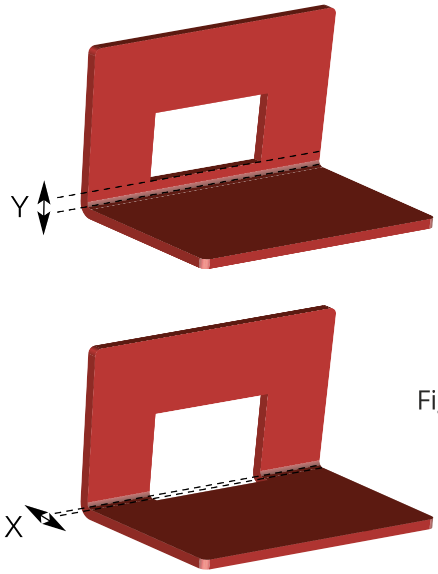


Fig. 8.25

- Make a cut-out in the area of the bending line to counteract the bulging caused by the bending. (Fig. 8.24)

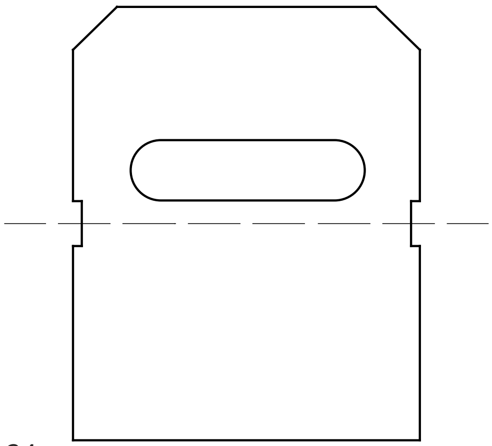


Fig. 8.24

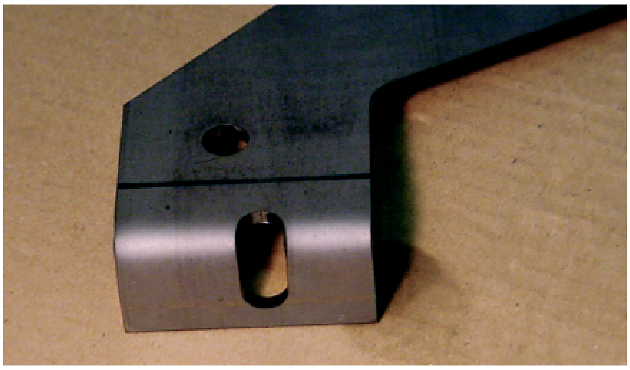


Fig. 8.26

- Placing two sets of tools next to each other on a bending bench, clamping one set the traditional way and the other set upside down (punch at the bottom and die at the top) makes it possible to make several bends without turning the product.
- For a long product with a short end setting, cutting and welding from this side are preferable to setting.
- If a certain product cannot be produced on the bending bench then there is also the option of bending it by hand. In this case, make small notches on the bending line to preserve the bending position and to reduce the bending force required. (Fig. 8.27)

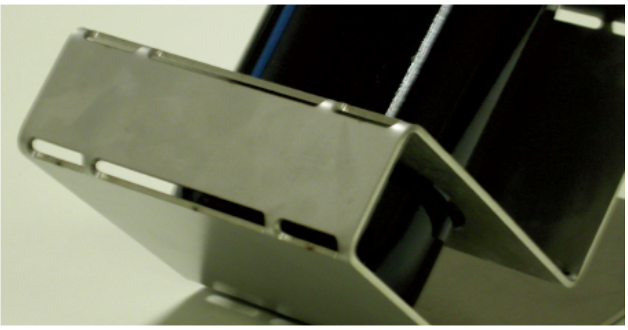


Fig. 8.27

- Of the forms opposite, the topmost is the most favourable (narrow welds and a simple result). By setting the short side first and then the long side, it is possible to use a single blade length to set the product, taking in account the rebound. (Fig. 8.28 and 8.29)

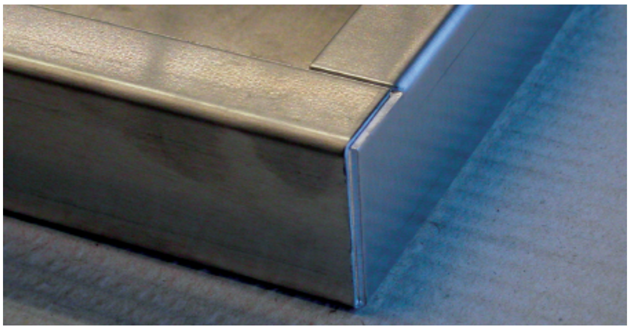


Fig. 8.28

Bending losses

The bending loss depends on many factors: type of material, material thickness, rolling direction, thermal influences, tool wear, groove width, upper blade, setting angles, internal radius, etc. At Kepser, the sheet results and associated bending losses are calculated with the 3D CAD package. The table below shows the bending losses for the most commonly used types of material, set on the standard groove at an angle of 90 degrees. Other bending losses on request.

Bending losses 90 degrees			
Sheet thickness (mm)	Groove (mm)	S235 JR	Stainless steel 304
1	8	-2.08	-2.34
1.5	12	-2.87	-3.33
2	16	-4.17	-4.34
2.5	20	-4.97	-5.27
3	20	-5.48	-6.02
4	30	-7.18	-8.13
5	40	-9.31	-10.57
6	40	-10.71	-11.60
8	60	-14.58	-
10	60	-17.46	-

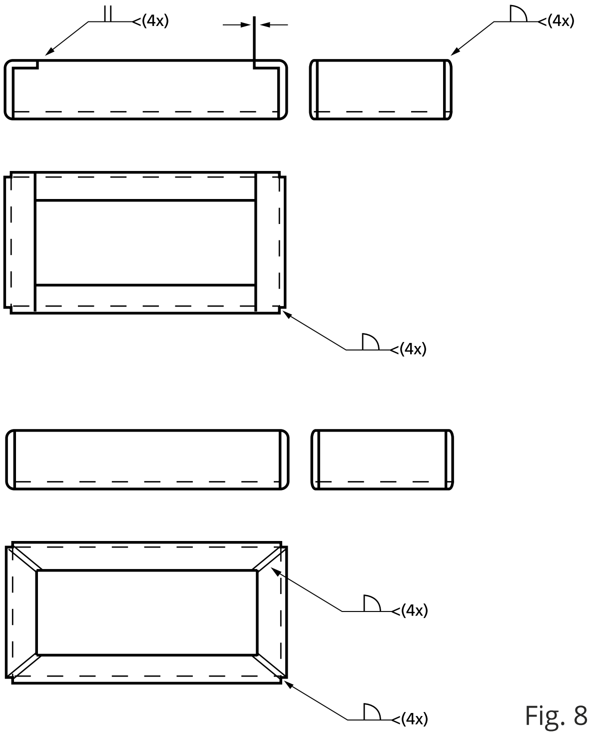


Fig. 8.29

9 rolling

Sheet rolling

Rolling width	Rolling diameter
1500 mm	90 mm
1500 mm	100 mm
2500 mm	205 mm

Whether sheets can be rolled in terms of the dimensions depends on a number of factors. To be precise, the combination of sheet thickness, sheet width and type of material determines the force needed to roll the workpiece.
Assume the neutral line when calculating the rolling result. Remember that the feed-in into the roller will cause a flat edge on the product. This can be partly addressed by first bending a number of facets in the feed-in.

Profile rolling

Profiles are rolled on a specially designed profile roller. To create different profiles, the rollers have to be custom set, which means that dozens of profiles are possible. However, this does not mean that they can all be produced. Kepser checks every profile for whether it can be rolled.

Take a profile to be rolled with excess length, but also indicate the net size.

- Avoid U-profiles with different flanges.
- Keep the material that has to be rolled constant in order to prevent the torsional buckling of products. Therefore, do not add any extra ribs, large openings or the like, and keep the width constant.
- Do you want holes in the material to be rolled that can't be added afterwards? Then go for the combination of laser cutting and rolling. When laser cutting. Ensure that the material to be pushed out is connected to the product by a tab so that it can still be rolled. The slugs in the holes can then be removed afterwards. (Fig. 9.1, 9.2 and 9.3)

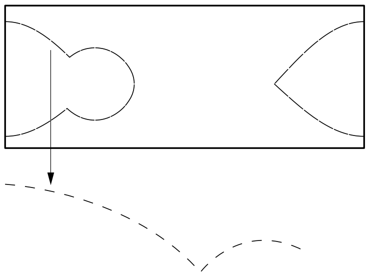


Fig. 9.1

Fig. 9.2

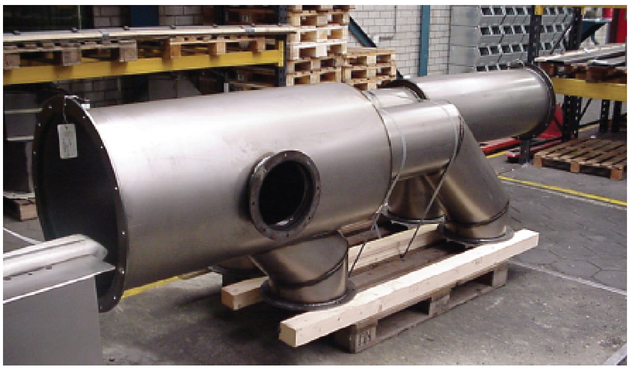


Fig. 9.3

- Holes that are made in the sheet before rolling will distort during rolling. However, you can mark them by indicating the location of these holes or pre-drilling a small hole.

Facet bending

An alternative to rolling is facet bending. This involves making a large number of bends with a small setting angle at a short distance from each other. Note: in facet bending, the settings always remain visible. (Fig. 9.4)

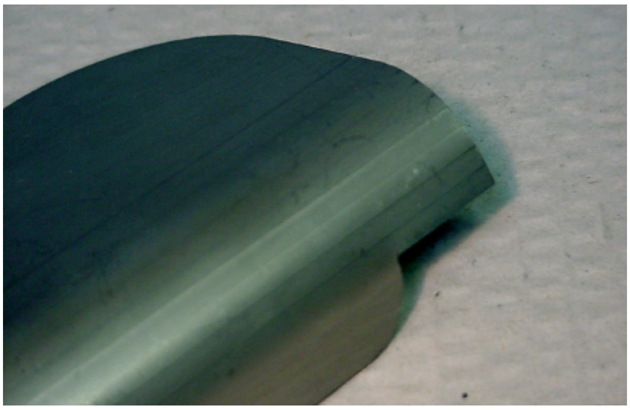


Fig. 9.4

Shaft pressing

If facet bending takes too much time due to the size of the production run then shaft pressing is the most suitable method In contrast to facet bending, shaft pressing - bending with a round shaft - does produce an exact inner radius. (Fig. 9.5)

Fig. 9.5

10 welding

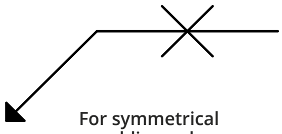
Welding symbols are used to indicate the weld position, the type of weld and the post-processing in a clear and unambiguous manner. A good knowledge of these symbols is important both for people who sit at the computer and for people who work in production. Welding is an expensive process and accounts for a considerable portion of a product's cost price. Consistent application of the correct standard avoids mistakes and ambiguities

For each weld, indicate the necessary weld markings and the standard of finish.

Weld markings

Symbolic representation of welded and soldered joints on drawings as per NEN-ISO 2553.
Welding process as per NENENISO 4063. Quality level as per NENENISO 5817 and NENISO 10042.
Welding position as per NENENISO 6947. Welding consumables as per NENENISO 544, ISO 2560 and ISO 3581.

Fig. 10.2



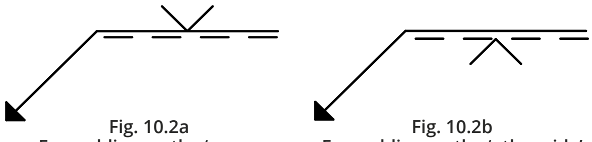
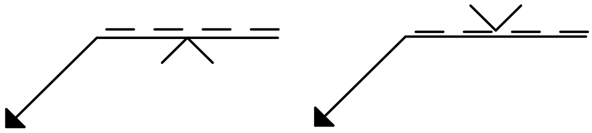


Fig. 10.2a
For welding on the 'arrow

Fig. 10.2b
For welding on the 'other side'



Indicating welds

- Indicate the welding position with the tip of the arrow. This can be placed at any desired angle. When welding a joint where one side is to be processed first, the arrow points in the direction of the surface that has to be processed first. (Fig. 10.1)
- Use a continuous reference line to indicate that the joint has to be welded on the arrow side. (Fig.10.2a)
- Use a dashed reference line to indicate that the joint must not be welded on the arrow side, but on the other side. (Fig.10.2b)
- Place the welding symbol as shown in Fig. 10.3.

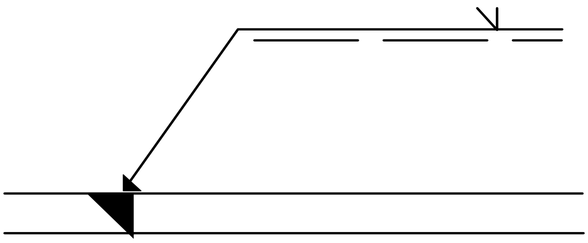


Fig. 10.1

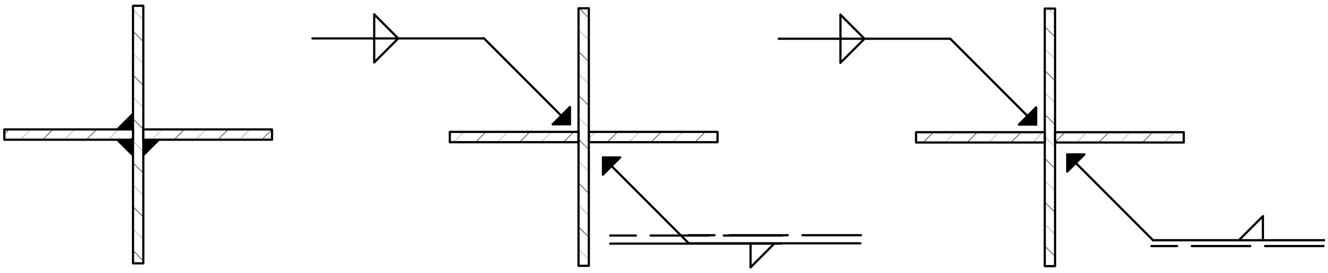


Fig. 10.3

Welding symbols (Fig. 10.4)

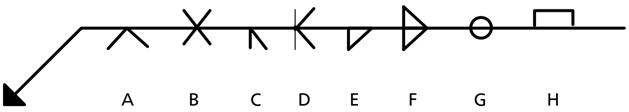


Fig. 10.4

A = Vgroove weld E = fillet weld
B = double Vgroove weld F = double fillet weld
C = half Vgroove weld G = spot weld
D = double-bevel groove weld H = plug weld

Weld finishing (Fig. 10.5)
Apart from symbols for the weld, there are also symbols for the weld finishing.

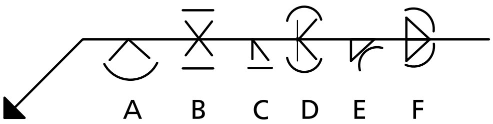


Fig. 10.5

A = V-groove weld, convex profile
B = double V-groove weld, ground flat
C = half Vgroove weld, ground flat
D = double-bevel groove weld with convex profile
E = fillet weld with concave profile
F = double fillet weld with convex profile

Weld size inscription

- To the right or left of the symbol, place numbers to ensure that the weld is applied in the correct size. For fillet welds, the symbol indicates what the throat height is (expressed as “a” or “s”). Also indicate the length of the weld. (Fig. 10.6 and 10.7)
  Weld marking
  a = nominal throat height
  s = penetration depth
  z = nominal leg length

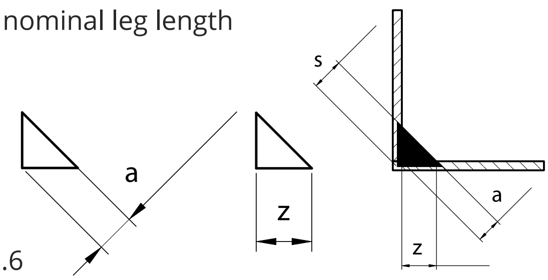


Fig. 10.6

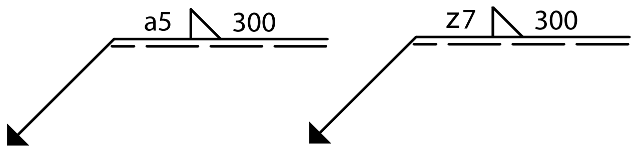
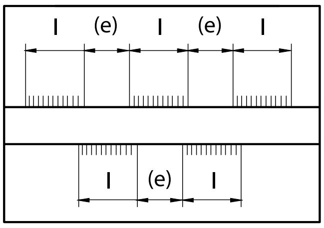


Fig. 10.6



l = length of the weld
e =distance between the successive welds
n = the number of welds

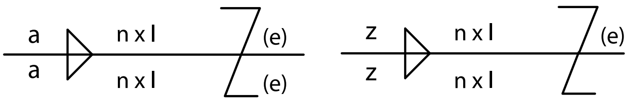


Fig. 10.7

Guidelines for indicating welds

- Always indicate the welding position, the type of weld and the quality standard (chain weld, fully welded, through-welding, double-sided welding) on the drawing. See also the examples above.
- Do not indicate welds for which the position of the weld is very important by means of a chain weld, but as individual welds. This lets the welders know that the position of the weld is important.
- Remember that the weld must never be smaller (less strong) than indicated.
- Bear in mind that the welder himself determines which type of weld he will make if only an arrow is indicated and not the type of welded joint.
- Clearly indicate whether welds have to be processed on both sides and what the finishing requirements are.
- Indicate areas where welding is not allowed with the text ‘do not weld’.

Preventing distortion

Distortion is caused by strong localised heating. The heated part expands, causing pressure in the cold part. After cooling, contraction occurs in the heated part, which causes expansion in the cold part.

One way to avoid distortion is to apply a deviation in advance, so that the desired shape/size is achieved after contraction. The advantage of this method is that residual stresses remain low and no expensive clamping devices are required. A disadvantage is that it is difficult to predict the distortion in advance. Another method involves clamping the components to be joined. (Fig. 10.8) The disadvantage of this is that it prevents all movement, which can lead to distortion when removing the workpiece or even cracking due to internal stresses. The machining sequence can also influence the (degree of) distortion

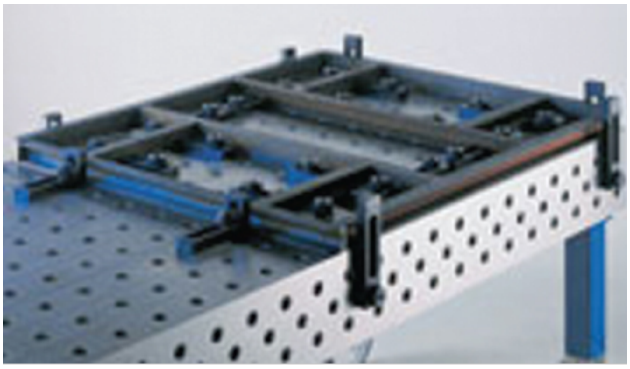


Fig. 10.8

Buckling can be prevented by applying stiffening ribs beforehand.

- Take unwanted weld distortion into account during the design stage; limit the number of welds in the product, or avoid them altogether.
- Limit the volume of the weld. The greater the volume, the greater the distortion of the product. From a financial perspective too, it is more attractive to use smaller weld volumes.
- Products that have to be welded on both sides should be welded with a large weld volume that alternates between top and bottom. This counteracts any buckling of the product caused by the application of heat. For thick sheets, use a double V-groove weld instead of a V-groove weld for this. (Fig. 10.9)
- Choose a favourable location for the weld. Welding on the neutral line ensures an even distribution of the contraction forces. This reduces the risk of twisting and distortion. (Fig. 10.10)

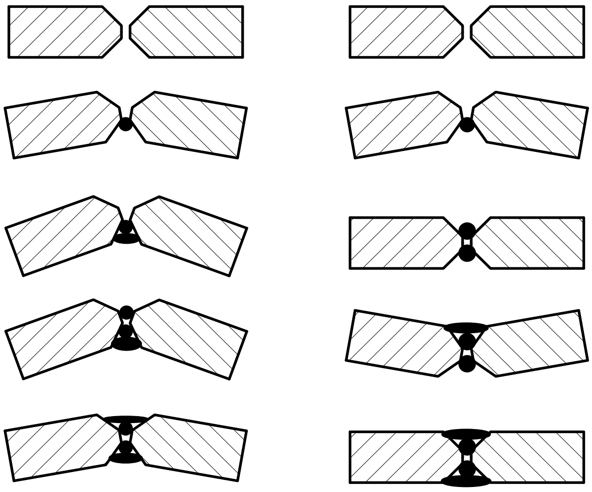


Fig. 10.9

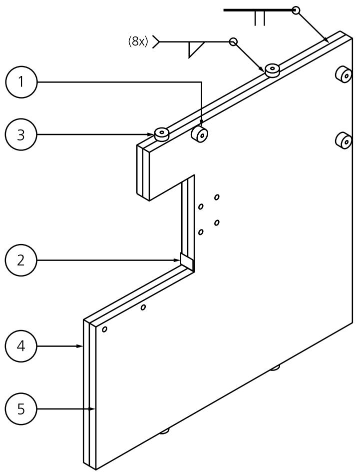


Fig. 10.10

Welded I-groove weld arrow side, weld all round. Weld lies in the middle of the set sheet metal parts. The symmetrical location of the weld ensures even expansion in the product, resulting in little distortion. Fillet weld arrow side, welded all round.

- Weld products evenly instead of fully welding one side first. Otherwise, there is a high probability of there being too much distortion on one side. This can be corrected by welding more on the other side first. This method is recommended especially when using tabs. Expansion can actually cause the tab to burst out of the slot.

Joint types

Some frequently used joint types are presented below together with their advantages and disadvantages.

Fillet welding

Corner to corner (Fig. 10.11)

Advantages:

- Good overall welding of the opening. Through-weld to the inside.
- The strongest joint (lots of filler material). Post-processing depends on the sheet thickness and customer's finishing requirements (sometimes redundant). Easy-to-achieve result, without the need for modern techniques.

Disadvantages:

- Distortion (depending on the sheet thickness).

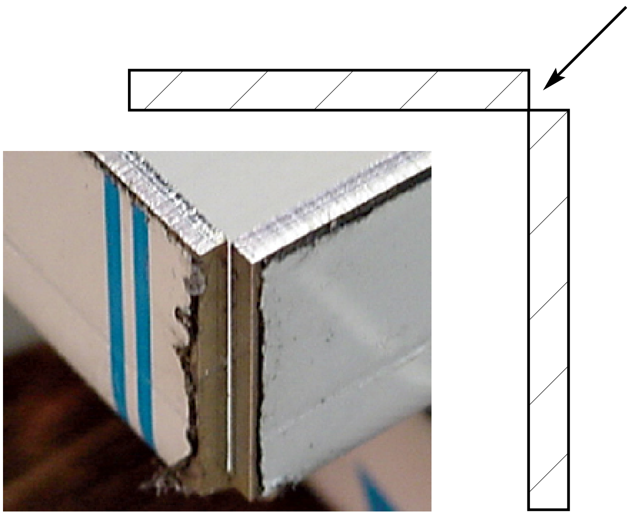


Fig. 10.11

Half lap (Fig. 10.12)

Advantages:

- Less distortion due to less heat input. Easy processing due to one sheet touching the other (positioning).
- Often used when welding a head plate to a tube or pipe.

Disadvantages:

- No through-weld
- Appearance is less attractive, no rounded weld
- Always post-process

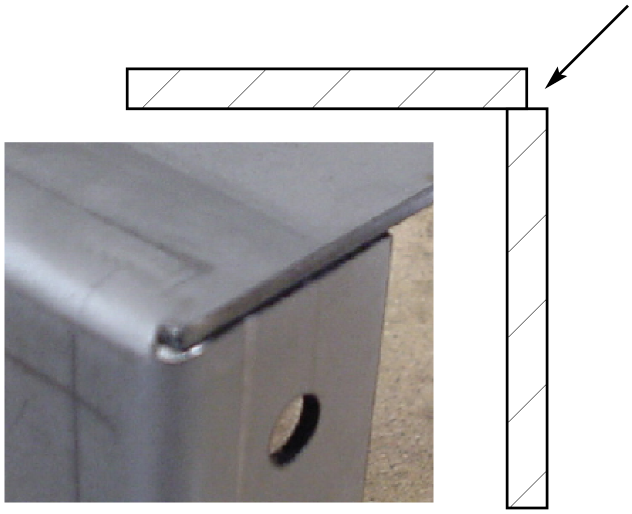


Fig. 10.12

Full lap welding on outside (Fig. 10.13)

Advantages:

- Little distortion.

Disadvantages:

- A lot of grinding, which removes part of the weld.
- Weak joint.
- Grinding of the V-groove weld before welding can be done.
- Cannot be used on thick sheet.

Fig. 10.13

Full lap welding on inside (Fig. 10.14)

Advantages:

- Strong joint, but slightly weaker than corner to corner.
- Little post-processing: grinding of sharp edge on outer corner, no post-processing of inner corner.
- Little to no distortion.
- Good joining of different thicknesses.

Disadvantages:

- No through-weld, so slightly weaker.

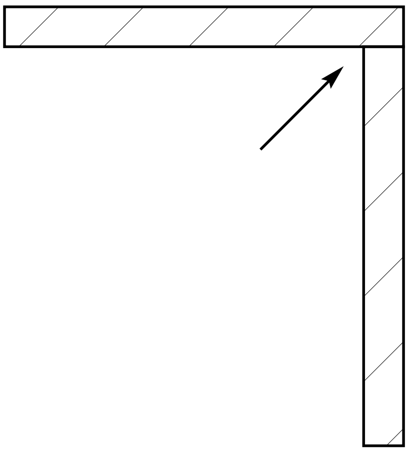


Fig. 10.14

'Invisible' joint (Fig. 10.15)

An 'invisible' joint, which looks like the welding of corners with a full lap, is suitable for products that have to be sprayed, ground or sanded.

Welding two sheets tightly to one another with small welds on the inside and outside results in a very small gap between the sheets. Welding the gap in only a few places reduces the post-processing time; the product exhibits no distortion, while the joint is sturdy enough. If the product is sprayed, the gap fills nicely with paint and the joint becomes completely invisible.

The weld can also be rendered invisible during post-processing by means of grinding and sanding.

Note: 'Invisible' welding is only possible with TIG welding up to a sheet thickness of 2 mm. Also ensure that the two sheets fit perfectly to each other.

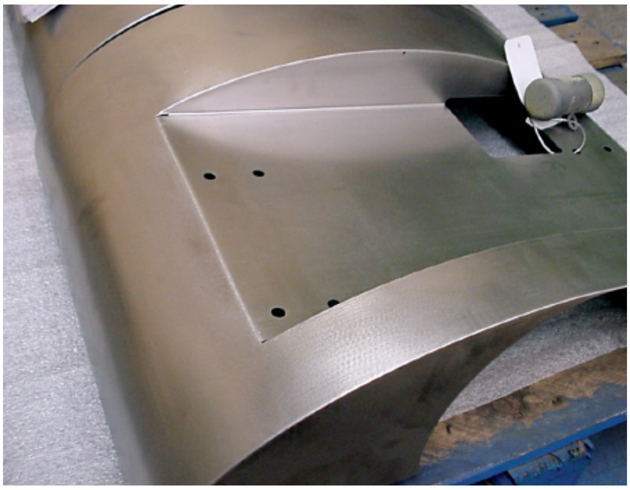


Fig. 10.15

Welding leakproof joints (Fig. 10.16)
To ensure that a welded tank is watertight, a double fillet weld is often used. Allowing one sheet to extend past the other enables the creation of two welds. However, the tank looks less attractive.

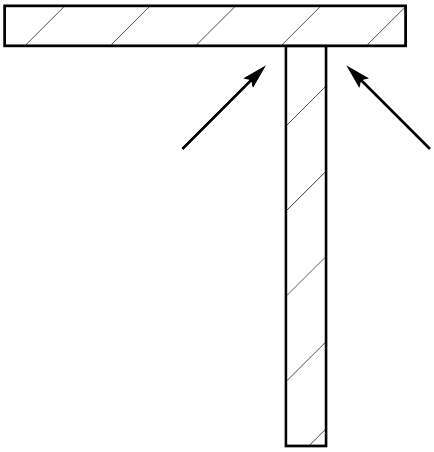


Fig. 10.16

Welding different sheet thicknesses (Fig. 10.17)

- In the case of different sheet thicknesses, choose the overlap so that a square area remains for welding.
- If the strength of the construction so requires, the inside edge can also be welded. In this case, pay attention to the contraction of the thinnest sheet.

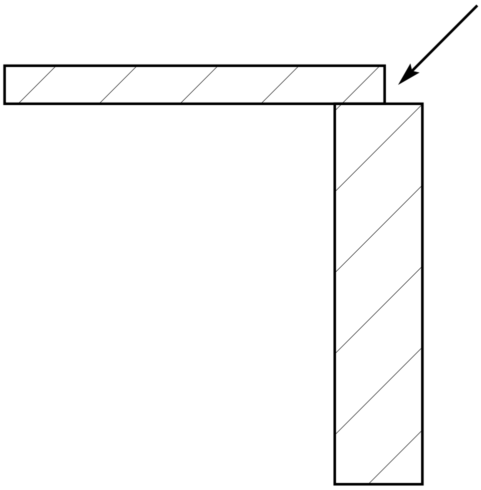


Fig. 10.17

Butt weld (Fig. 10.18)
For a smooth corner finish, a butt weld is often used instead of a fillet weld. However, the preference here is to not weld at all, but instead to make the corner from a single piece. Chamfering the edges of the sheet creates a large surface area, which makes a butt weld stronger. This can be done in various ways.

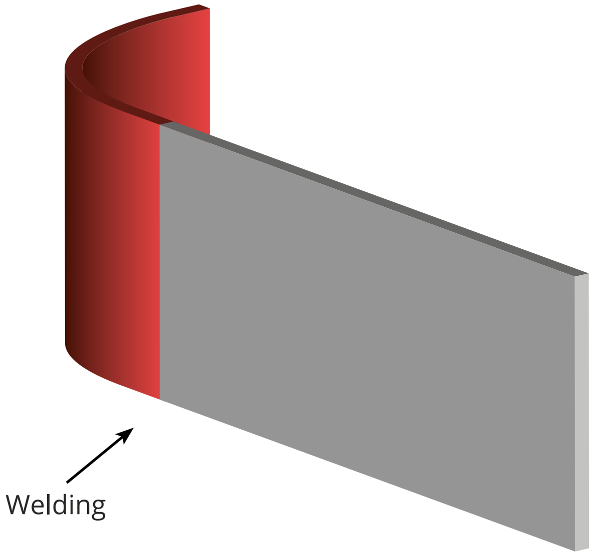


Fig. 10.18

Plug welding (Fig. 10.19)
So-called plug welding is ideal for the application of lap welds. By making some holes in the upper sheet, the welding position is fixed. By welding the holes, the upper sheet remains flat. Post-processing is therefore unnecessary. The strength of the joint depends on the shape and dimensions of the opening.

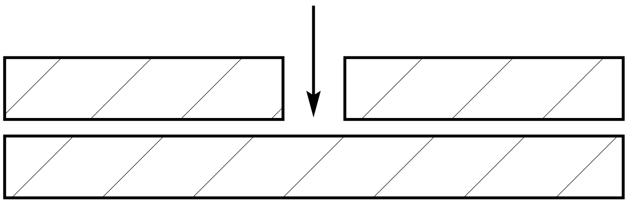


Fig. 10.19

11 joining

We distinguish between three kinds of joints:
1. Permanent joints (e.g. welded joints).
2. Non-permanent joints (e.g. bolted joints).
3. Limited non-permanent joints (e.g. blind rivets).

Stud welding

Stud welding is the welding of a metal stud (e.g. a screw thread or cylinder) onto a substrate. (Fig. 11.1) Simple, cheap and quick.

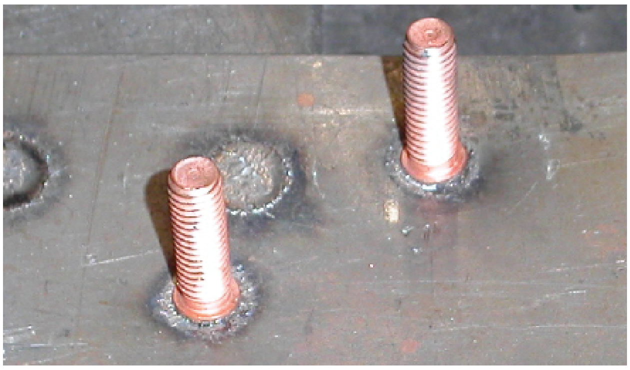


Fig. 11.1

The penetration depth in stud welding is about 0.3 - 0.5 mm. This means an attractive joint can be made on thin sheet metal without it being visible on the other side of the sheet. The maximum sheet thickness for stud welding on steel is 5 mm, and 8 mm for aluminium. We use 8 mm as the maximum diameter of the welding stud.

Stud welding demands accurate positioning, often by means of a template. (Fig. 11.2) That is why this technique is often used in series production. An alternative to stud welding, particularly for smaller quantities, is a tapped hole with a threaded end.

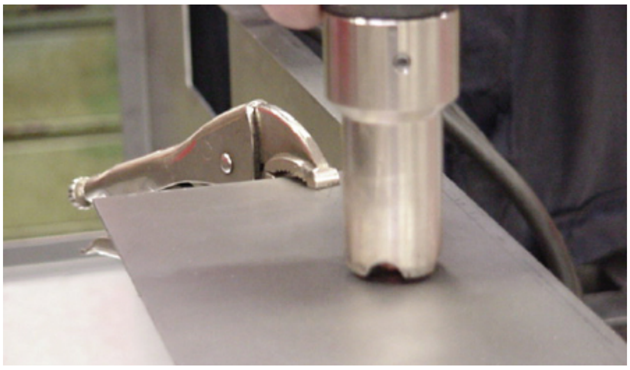


Fig. 11.2

Blind riveting

Blind riveting is a great option for constructions that can only be reached from one side. The rivet is pushed through the hole; pulling the setting mandrel creates a bulge, securing the rivet in place. The connection is made when the mandrel breaks off. (Fig. 11.3)

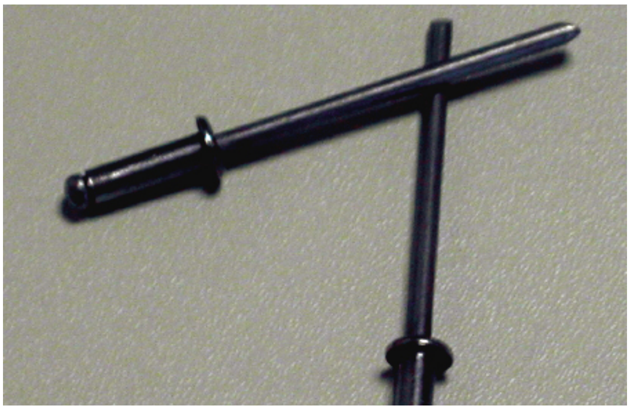


Fig. 11.3

Blind riveting can be used on virtually every material. Due to the particularly extensive range of blind rivets, a suitable rivet can be found for every application. (Fig.11.4)

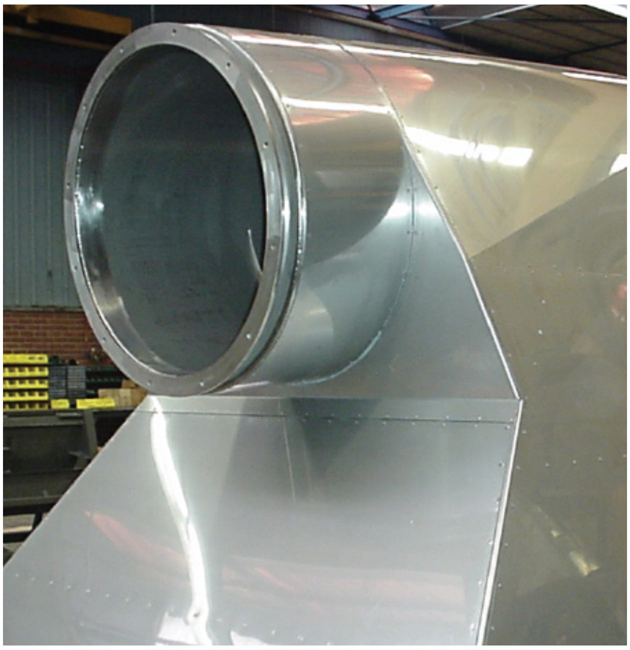


Fig. 11.4

If holes have already been made prior to assembly, a nice tight pattern can be created.

Diameter of shaft	S
Drill diameter	9S+0.1

Blind rivet screw thread / blind rivet nut

Instead of mandrels, blind rivet nuts (Fig. 11.5) with an internal thread can also be used following the same principle. For this joint, a hexagonal hole is laser cut to prevent the blind rivet nut from spinning in the hole. The dimensions of the hexagonal hole (Fig. 11.6) are determined by the largest inscribed circle.

Fig. 11.5

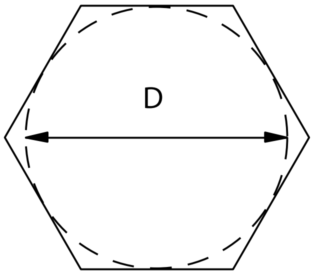


Fig. 11.6

Blind rivet nut	M3	M4	M5	M6	M8	M10	M12
Diameter	5.5	6.5	7.5	9.5	11.5	13.5	16.5

Flanged nuts

The flanged nut is pushed into a hole and fixed with the aid of a simple tool. A bolt is then screwed into the nut to create the joint. A disadvantage of this technique is that practically each sheet thickness requires a different nut.

Weld nuts

As the name says, the nut is welded to the sheet here. (Fig. 11.7 and 11.9) The disadvantage of this technique is that the weld can touch the surface of the part to be joined. To position a normal nut, a bolt with a countersunk head is often used. This positions the threaded hole exactly above the cut hole. In the case of so-called tab weld nuts, two small holes can be cut alongside the hole to be positioned. (Fig. 11.8)

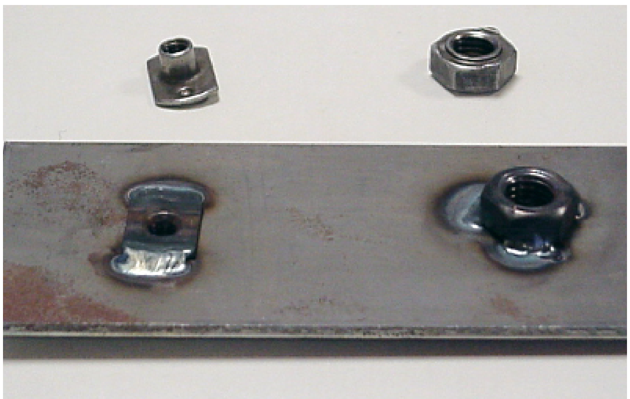


Fig. 11.7

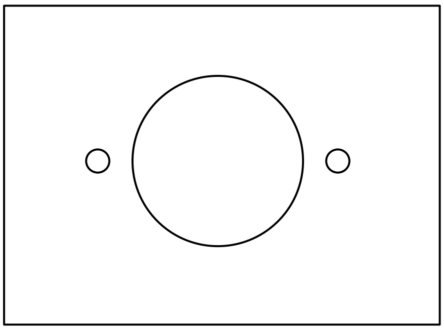


Fig. 11.8

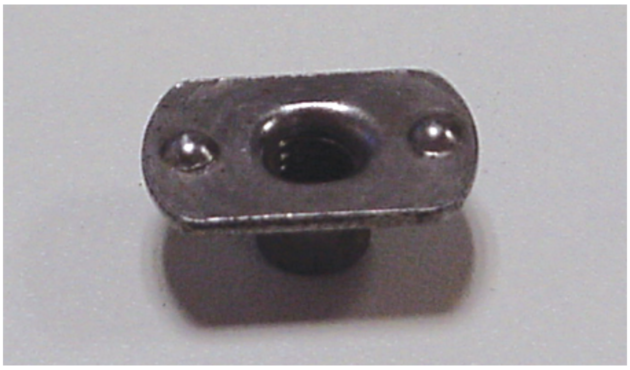


Fig. 11.9

Fig. 11.10

Finally, there are also weld nuts with a centring edge.

Plate nuts/clips

Plate nuts or clips are made from sheet material. The nut is often shaped so that it can be clamped in or on the bottom sheet to enable assembly from one side (blind). These joints are easy to remove.

Jack nut

This is a normal nut that has a collar with ribs. (Fig.11.11) Tightening the nut draws the collar into the hole and the nut sits securely in the sheet. At Kepser, the fixing point of the jack nut is indicated by an additional cut-out in the hole.

Jack nut	M2	M3	M4	M5	M6	M8	M10	M12	M3
Drill diameter	4.5	4.5	5.5	6.5	8	10	12.6	14.5	18.5

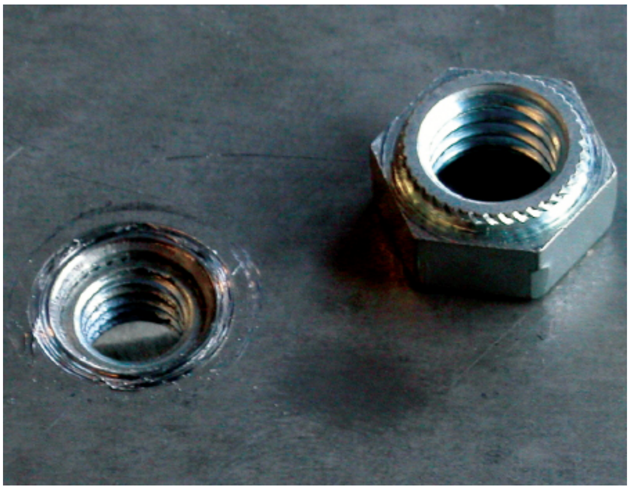


Fig. 11.11

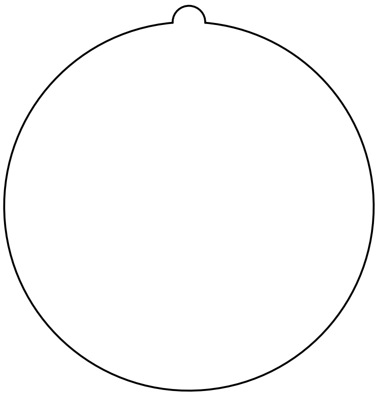


Fig. 11.12

12 Conserving

This chapter deals with the most commonly used conservation methods.

Pickling/passivation
Achievable roughness 0.5 µm.

Pickling and passivation are the most common ways of treating stainless steel. The aim of this process is the removal of oxides and extraneous metal particles from the surface and the creation of a passive surface layer of good quality. The result of the treatment is an even, matt appearance.

The pickling and passivation happen in a single process. First, the product is treated with a pickling liquid (in an immersion bath or using a pickling paste). The pickling liquid contains components that remove the discolouration caused by the welding and components that create the chrome oxide layer. After that, the pickling agents are sprayed off.

Now that the metal is free of all contaminants, the surface is highly reactive. By exposing the product directly to the air, the material oxidises and a passive surface layer forms – the passivation – that makes the stainless steel stainless again. The chromium oxide layer can actually be affected by machining operations during the production process.

Sanding, brushing, grinding and polishing
Achievable roughness 0.5-5 µm.

These operations, mostly in the form of final processing, are carried out to improve the surface properties of stainless steel and to give the product a more attractive appearance. However, hygiene requirements also play a role in the food and chemical industries.

Choosing a different grain size, machining direction or brush type caninfluence the outcome of the process.

For example, the grain size of the tool used determines the amount of material that is removed during grinding and sanding to eliminate signs of damage.

Bear in mind that the tool may not be able to reach all areas. In some cases, it is advisable to perform these operations before welding or assembly.

Electrolytic polishing
Achievable roughness 0.2-0.3 µm.

This dissolves a part of the top layer of the material including any contamination. Since the peaks in the material dissolve quicker than the troughs, the process has an smoothing effect. Scratches disappear, causing the surface to shine.

Electrolytic polishing of stainless steel causes the iron in the surface to dissolve quicker than the nickel. Because the quantity of nickel increases proportionately, the stainless steel becomes even more resistant to corrosion.

The difference from mechanical polishing is that the surface is much cleaner and less sensitive to corrosion. Mechanical polishing actually rubs grindings and contamination into the surface. Electrolytically polished material also has a much more even structure, which makes it less susceptible to the nesting of bacteria in the pores.

Thermal galvanising
(galvanising, hot-dip galvanising)

Thermal galvanising forms an alloy layer by immersing the products in a liquid zinc bath at a temperature of 450 °C. A layer of pure zinc adheres to the topmost layer of the steel product. This surface layer is hard-wearing, corrosion-proof over the long term and highly resistant to knocks and scrapes.

In the event of damage, the zinc surface restores itself to a certain extent through the cathodic action. Small parts are suspended in the zinc bath inside a drum. When the drum is lifted out of the bath, it is centrifuged to remove any excess zinc.

Advantages:
- Thick (50-150 μm) closed layer.
- Usually no post-treatment required.
- Long-lasting corrosion resistance.
- Good adhesion to the surface.
- Cathodic protection.
- Hollow products are also covered with a layer of zinc internally.

Disadvantages:
- Risk of distortion.
- Layer thickness difficult to adjust.
- Post-treatment of screw thread.
- The alloy layer is hard and brittle, so difficult to process afterwards.
- Additional holes for venting and zinc draining. Coagulated drips have to be removed by hand after the galvanising process.
- Colour differences in different materials (depending on the silica content).

The corrosion resistance can be further improved by applying a powder coating to the zinc layer, the so-called duplex system.

Blasting

Achievable roughness with glass bead blasting 1.5-3.0 μm. Achievable roughness with ceramic blasting 0.8-2.0 μm.

The product is 'bombarded' with blasting medium, which cleans the surface. Blasting is also used as a finishing treatment. There are dozens of blasting media on the market, ranging from very coarse to very fine, round and sharp-edged, metallic and inert. A distinction is also made between single-use and multi-use media.

The difference between glass bead blasting and ceramic blasting is the blasting medium. In the case of glass bead blasting, the glass particles shatter, which produces a greater roughness than ceramic blasting. For an optimal result, it is a good idea to pickle stainless steel products first to remove any contamination before blasting.

Drumming

Drumming is mainly suited to smaller products. During the process, the edges are broken up, which gives the product a matt appearance. The drum itself contains small stones or other material of a certain hardness.
The end result of this finishing technique depends on the coarseness of the stones.

Electrolytic galvanising

Layers of zinc are primarily used to protect steel. The zinc layer is less refined than the base material and 'sacrifices itself' to any corrosion that occurs. The layer thickness is 540 μm. As the layer becomes thicker or the chromium content increases, the corrosion resistance improves. The zinc layer is mostly passivated (chromated or bichromated). The passivating layer not only enhances the appearance of the zinc layer, but also provides additional protection against corrosion.
An advantage of this method is that heat does not cause any distortion.

Powder coating

Powder coating is the application of a synthetic coating containing paint in powder form as the starting material. The powder is melted by heating it to a temperature of at least 180 degrees. The molten powder flows across the product to form a closed coating. Powder coating often replaces wet painting because it doesn't use any solvents.

Powder coating is suitable for all heat-resistant materials. The coating is hard and wear-resistant. Powder coating provides protection against corrosion and is weatherproof. In areas with an aggressive climate (e.g. sea, industry or city), a two-layer system is often applied.

There are various ways to apply the powder:

- Powder spraying: pneumatically (on preheated objects) or electrostatically (whereby the product attracts the powder).
- Whirl sintering, whereby heated parts are passed through a bath of swirling powder.
- Flame spraying, whereby powder is melted with a flame and then sprayed on.

Advantages:

- No expensive, unhealthy, flammable or explosive solvents needed.
- Less harmful for the environment.
- 100% yield through recovery of lost powder.
- Better edge covering.
- Material costs per m2 are quite low.

Disadvantages:

- Colour setting difficult.
- No fast colour change.
- 'Orange peel' appearance.
- Thin layers not possible.
- Repairs with powder not possible.
- The powder adheres poorly if there is an oxide layer on the cut edges.

It is up to the customer to choose whether to powder coat or wet paint the product. However, here are a few tips:

- If opting for wet painting, bear in mind that products mostly have to be blasted in order to be able to spray them well.
- Opt for wet painting if different layers have to be applied to the product.
- Bear in mind that wet painting has a long curing time.
- If opting for powder coating, bear in mind that blank material can be coated immediately after degreasing. This saves expensive and time-wasting pre-treatments.

Epilogue

It has taken years to put this handbook together. We had actually amassed the knowledge needed to do so through many years of experience in the metal industry.
By talking to various customers and suppliers, some good technical solutions were thought up and developed in the past. Many of these solutions have found their way into this handbook. But the book isn't finished yet. Because new ideas are bound to be added at some point in the future.

"Constructive thinking" is a helping hand for both junior and senior design engineers who want to fabricate their product from sheet metal. Additions, new tips and techniques as well as questions – from both junior and experienced designers, but also from engineers, developers, advisers and purchasers of sheet metal – are always welcome.

We'd like to take this opportunity to thank our customers and suppliers for thinking with us about designs and mutually increasing the knowledge of product solutions. It is also thanks to the diversity of our clientèle that we have arrived at the wealth of information in this handbook.

We hope that you will benefit greatly from this publication and get an idea of what Kepser can offer your company.

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