

**Folding machines and long folding machines:
Protective measures**

Subcommittee Machinery, Robotics and Automation
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Folding machines and long folding machines are used for bending sheet metal. Their areas of application are, for example, in heating and ventilation engineering, in machinery and vehicle construction, in plumbing and roofing as well as in hall construction or in contract manufacturing. These machines fall within the scope of the Machinery Directive (in the following called: MD) [1].



Figure 1– Example folding machine (front with continuous bending bar on upper beam and folding beam)

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There are no harmonized European product standards available for folding machines and long folding machines. In order to comply with the legally binding essential health and safety requirements of Annex I of the MD which are formulated as protective goals, the non-specific basic and group standards (e.g. DIN EN ISO 12100 [2], DIN EN ISO 13857 [3]) for the design and construction of machines can be applied. However, since the requirements therein are rather general, this “Fachbereich AKTUELL” recommends specific protective measures.

This “Fachbereich AKTUELL” covers exclusively power-operated folding and long folding machines, no muscle-powered machines. The subject of the accuracy requirements, e. g. in conjunction with the parallelism of upper beams, lower beams and folding beams to each other as well as the pivot axis to the bending axis is also excluded from the scope. [4].

1 Difference between folding and press braking bending

The manufacturing process „forming by bending“ [5] comprises all processes for the production of geometrically defined solid bodies. Forming by bending is a subgroup of the forming process and is subdivided into forming by bending with rotating tool movement and forming by bending with linear tool movement.

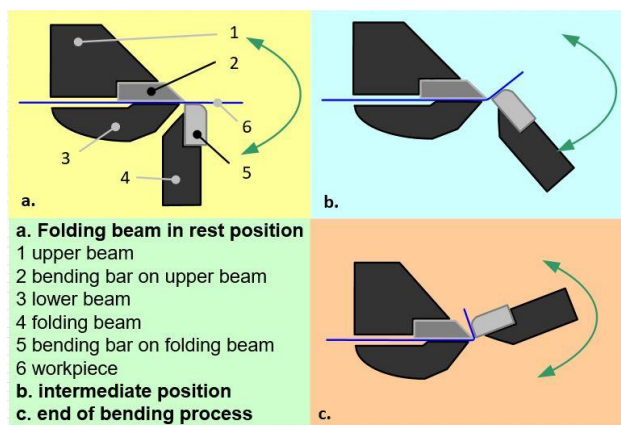


Figure 2 – Principle folding, rotating movement

Forming by bending with a rotating tool movement means that the tool parts effecting the shaping perform a rotating movement. (see Figure 2). This includes folding, in which the folding beam is applied to the part of a workpiece protruding from a saving and is pivoted therewith around the bending edge. The manufacturing process „folding“ is applied to folding machines and long folding machines.

Folding machines and long folding machines do **not** fall within the scope of Annex IV of MD [6].

Forming by bending with linear tool movement means that the tool parts effecting the shaping perform a linear movement (see Figure 3). This includes *press-brake bending*, in which the workpiece is bent between bending punch and bending die up to the end position of the workpiece. The manufacturing process „press-brake bending“ is applied for press brakes. Press brakes fall within the scope of Annex IV of MD which usually requires an obligatory EC type testing. Since press brakes are covered by product standard DIN EN 12622 [7], they are not further dealt with in this “Fachbereich AKTUELL”.

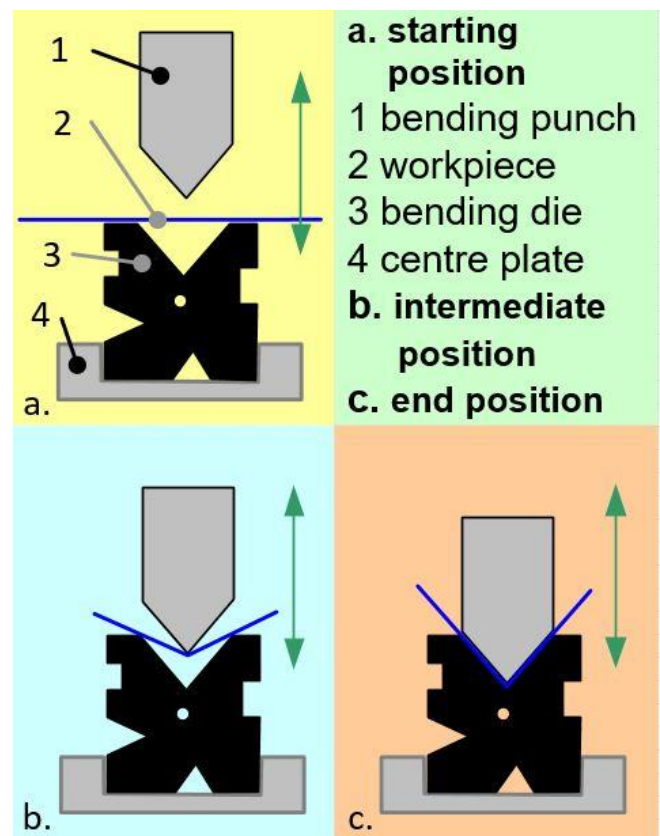


Figure 3 – For comparison: principle press-brake bending with linear movement, not further dealt with here

2 Differences between folding machines and long folding machines

Both, the folding machine as well as the long folding machine, bend sheet metal in a clamped position between the upper beam and lower beam by the folding beam. The usual bending variant is the movement of the folding beam around its pivot point upwards. In this process, it rolls off the material, as shown in Figure 2. Newer machines have the option to bend in both directions (folding machines) as a result of a modified design of the folding beam or they have two independent folding beams (long folding machines, compare Figure 8), i. e. one folding beam moves around its pivot point upwards, the other one around its pivot point downwards.

A further distinction is in the way of guiding the upper, lower and folding beam. While the three cheek elements on a folding machine are laterally guided by a side stand, the cheek elements on a long folding machine are laterally open and guided by a random number of C-shaped frames which are arranged behind the machine (multiple-column system).

2.1 Folding machines

Folding machines are currently available up to a machining length of approx. 6 m. In the basic design, the machines are composed of a left (1) and a right (2) machine column (see Figure 4) between which the upper beam (3, vertical movement) and folding beam (4, rotating movement) are attached. The control panel (5) as shown in the Figure is firmly installed. Machines with smaller machine columns on each side are normally fitted with deflector plates which should prevent squeeze and shear points between machine columns (1, 2) and folding beam.



Figure 4 – Example of a folding machine with segmented bending bar (front) on the upper beam

At the folding machine in Figure 1, the upper and the folding beam are each provided with a continuous bending bar, while in Figure 4, the bending bar of the upper beam is segmented. In the segmented design of the upper beam, different bending tools can be used, e. g. folding rail (folding blade), round rail (radius blade) or a bitefoot rail (goat's foot blade) so that different bending geometries can be implemented. The lengths of the segments depend on the workpiece and are thus determined by the application. The advantage is that a workpiece with, for example, three different bending geometries can be finished without the need for changing to a different bending tool. The segmentation enables the creation of circumferential upstands on sheet metal profiles (box shape) without the use of additional (and not permitted) chocks.

For an easy handling of the sheet metal, folding machines are usually equipped at the back with a feed table and motor-driven depth-control stop for setting the bending length in relation to the bending line of the sheet metal part (see Figure 5).

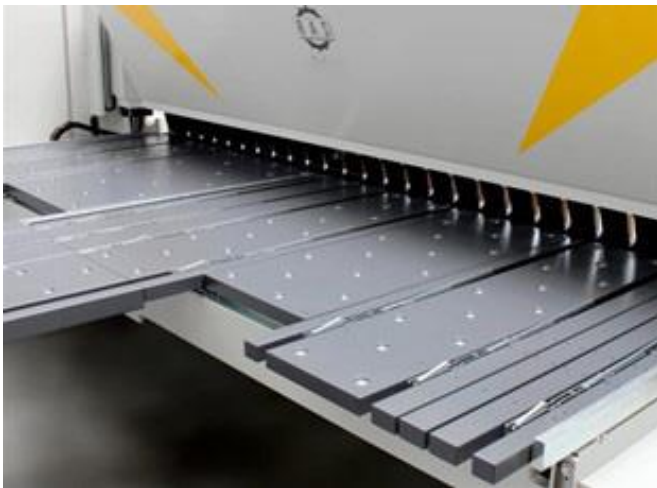


Figure 5 – Example of a feed table on the back of a folding machine

2.2 Long folding machines

Long folding machines are currently available up to a machining length of approx. 18 m. In the basic design, the machine is composed of a multiple-column system, i. e. in a distance of approx. 1 m, the upper beam and the folding beam are fastened. As a result, the surfaces for holding the bending tool on the upper beam and the folding beam can be considerably smaller since the static deflection with a column distance of approx. 1 m is considerably less than at a distance of 6 m.

As a result of the massive stand construction of the long folding machine, the maximum insertion depth of approx. 1,5 m is low in comparison to design-related unlimited insertion depths on folding machines (comp. Figure 6, insertion depth).

Most of the long folding machines also have a power-operated cutting device (comp. Figure 11), by means of which the clamped sheet metal can be cut to final size prior to bending

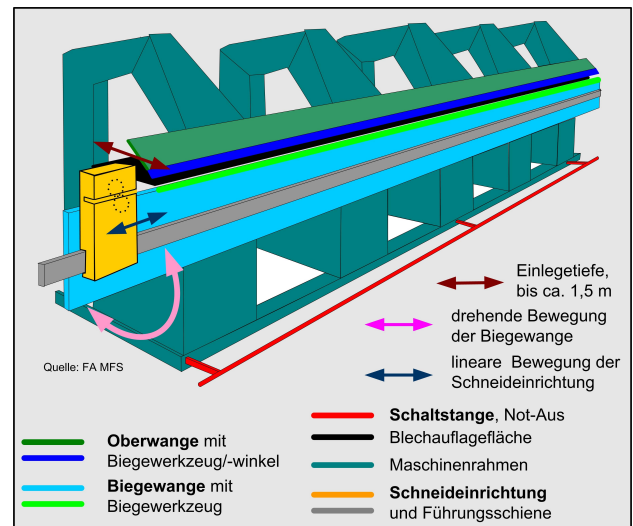


Figure 6 – Long folding machine with power-operated cutting device (orange), limited insertion depth and an emergency stop pressure sensitive bar (red)



Figure 7 – Example long folding machine with red emergency stop pressure sensitive bar (in analogy to Figure 6)

3 Protective measures

Hazardous movements on folding machines and long folding machines can be found particularly on the following elements:

- upper beam (also known as *clamping beam*)
- folding beam
- power-operated depth-control stops
- cutting device (long folding machine only)

Unexpected start-ups, for example due to malfunction in electronic control systems, have to be safely prevented for: the downward movement of the upper beam, the downward and upward movement of the folding beam, the power-operated cutting device (only long

folding machine) and for the power-operated depth-control stops.

Safely stopped, prevented, monitored or reduced means that no hazards shall occur to persons in case of malfunctions in the control system due to internal faults or external interference (interference pulses).

The safety-related parts of electromechanical control systems should reach at least “Performance Level c” category 1 and those of electronic and programmable electronic control systems at least „Performance-Level c“ category 2 according to DIN EN ISO 13849-1 [8].



Figure 8 – Example of a long folding machine with two folding beams, i. e. bending upwards and bending downwards

3.1 Machines under manual control

A machine is manually controlled if all processing steps, if necessary, with the support of an NC-processing program, are individually started and thus controlled by the operator (manual operation). For this purpose, the operator must be able to view all machine areas from the location of command action, in order to start the next processing step only in the absence of persons in the hazard area.

The lateral and rear access to the machine must be designed in such a way that persons

are kept away in a sufficient distance from hazardous places (e. g. clamping position, etc.) according to DIN EN ISO 13857.

If the risk assessment permits, in the case of small machines in which the operator can easily view all machine areas from the location of command action, rear safeguards can be dispensed with.

3.1.1 Emergency stop device

For stopping a hazardous movement, a manually-operated emergency stop device shall be provided on the control panel or in the immediate vicinity.

Folding machines with a machining length exceeding 2,5 m shall be at least equipped with two emergency stop devices (compare Figure 9) which are easily accessible from the operating positions or with a pressure sensitive wire or bar which is mounted over the whole machining length (DIN EN ISO 13856-2 [9]) as emergency stop device which can be easily actuated by foot and which should be coloured striking red (compare Figure 7).

Long folding machines of a machining length exceeding 2,50 m shall be equipped with a pressure sensitive wire or bar which is mounted over the whole machining length as emergency stop device which can be easily actuated by foot and which should be coloured striking red (compare. Figure 7).

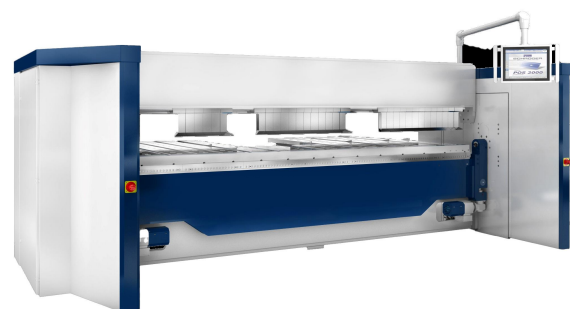


Figure 9 – Example of a folding machine with emergency stop button on both machine columns (left, right)

The effect of the emergency stop device for the folding machine as well as for the long folding machine shall correspond to that of the foot switch „pedal fully pressed down“ or position 2 in table 2.

The requirement of easy operation of a pressure sensitive wire or bar is fulfilled if it is located vertically underneath the front edge of the lower beam, approx. 200 mm above the floor and initiates the emergency stop function when it is lightly pushed (compare Figure 7).

3.1.2 Foot switch

For operating the machine with a foot switch, the operator requires at least a 2-pedal foot switch. Examples of operating modes with 2- or 3-pedal foot switches are shown in table 2 und table 3 at the end of this “Fachbereich AKTUELL”.

In case of multi- person operation, a foot switch as enabling switch is required for each bending assistant in addition. The number of required enabling switches is among other factors dependent on the machining length of the machine. It is useful to provide two enabling switches from a machining length of 8 m (operator plus two bending assistants). This consequently requires a selection switch with the three-position control.

For this reason, it is sufficient to provide a 1-pedal foot switch to the bending assistants with the three positions

- OFF – not actuated
- Release (*enabling*) – actuated in center position
- Stop – actuated in lowest position (emergency stop)

(see Figure 10). In cases in which operation is set for single-person operation, the foot

switches provided for the bending assistants should remain effective as stop switch.

For changing over from one-person operation to multi-person operation and vice versa, a lockable selection switch which is lockable in each position has to be provided. The lockable selection switch can also be replaced by a safe and reliable software solution.

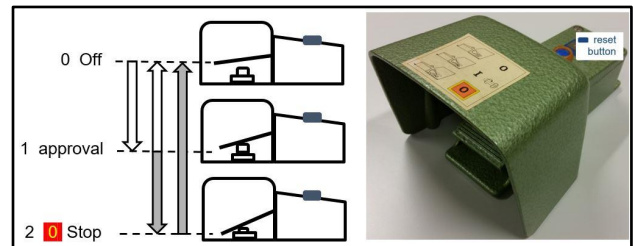


Figure 10 – Example 1-pedal foot switch with reset button as enabling switch for bending assistants

In case of multi-person operation, the hazardous movement, in particular the closing of the upper beam or the movement of the cutting device must not be started until the control devices are simultaneously actuated. On release of one of the controls, the respective control command must be cancelled.

Simultaneous actuation means the continuous actuation of all controls during the same period of time, independent of the time shift between the start of an input signal and the start of a different one. [10]. Simultaneity is ensured for example, if a simultaneity relay is used which cancels a given control command after max. 3 s if the enabling command is not confirmed by the other controls. If there is no confirmation by all controls, all controls have to be brought to a rest position before a new control command can be initiated. If relays with adjustable time delay are used, unauthorized change of the preset delay time has to be prevented.

Simultaneous monitoring can be dispensed with, if

- it is ensured by control measures that all actuated foot switches have been released prior to each cycle (clamping, bending) (position 0), and
- each switching position of the foot switch is queried by the control system, and
- the foot switches are regularly checked for their functionality, i. e. at least on each start of the machine.

3.1.3 Intermediate stop at 15 mm

Folding machines and long folding machines use an intermediate stop which enables the operators to remove the fingers from the hazardous area between upper beam and lower beam prior to the final clamping.

The closing movement of the upper beam has to make an automatic intermediate stop at 15 mm above the maximum permissible sheet metal thickness. The upper beam must only move to the lowest position (clamping position) after the foot switch has been actuated again. The closing speed has to be ≤ 10 mm/s from the intermediate stop. For machines with eccentric drive, the average closing speed can be applied from the intermediate stop due to design-related reasons.

The movement of the folding beam must not be started until the clamping process has been completed. In case of long folding machines, the cutting device has to be located additionally outside the range of motion of the folding beam.

An electronic position measuring system for controlling the upper beam should also be used for controlling the intermediate stop. This has the advantage that a manual adjustment of the hardware limit switches (e. g. position switch) to the individual sheet metal thickness can be omitted. To ensure that the position measuring system meets the requirements according to

DIN EN ISO 13849-1 „Performance Level c“ category 2, an additional testing device has to be created. This may be an additionally mounted hardware switch which is preset to a fixed value. An information provided by IFA on the change of DIN EN ISO 13849 states about the test rate: *„For category 2, it exclusively applied the rule of a requirement rate $\leq 1/100$ of the test rate so far. Alternatively, testing can be done immediately on requesting the safety function if the total time for detecting the failure and for bringing the machine into a safe state (normally the machine will be stopped) is shorter than the time to reach the hazard“.* [11]

3.1.4 Safeguarding by laser beams

The safeguarding shown on the long folding machine in the example (comp. Figure 11) is implemented by means of laser beams above the lower beam or folding beam and can be applied on laterally open machines. As soon as a laser beam is interrupted, the closing movement of the upper beam or the travel movement of the cutting device is stopped.

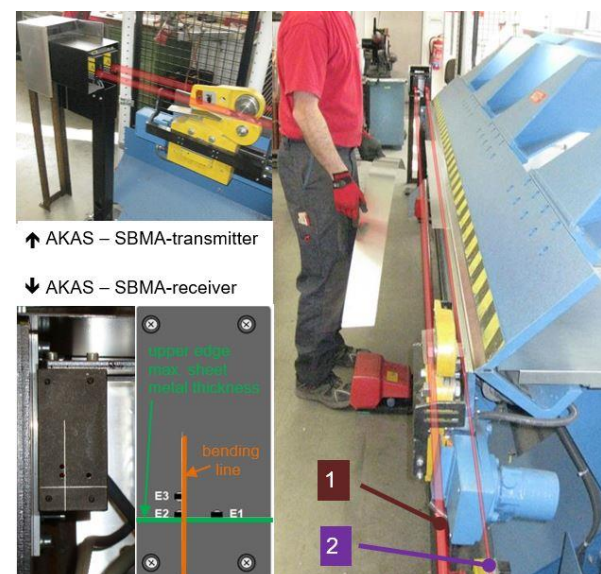


Figure 11 – Example of laser protection with AKAS-SBMA during cutting process. Light beam 1 is active during cutting process and light beam 2 for inserting and clamping the sheets [12]

With the protective measure „safeguarding by laser beams“, the hands of all operators involved are equally protected and one single foot switch can be used with several people.

Additionally, the protective measure „intermediate stop“ can be deactivated in favour of the protective measure „safeguarding by laser beams“. For switching-over, a mode selection switch (key switch) or an equivalent solution by access code has to be provided.

3.1.5 Safeguarding by light curtain or laser scanner

There are also folding machines available which can be operated from the rear side. These folding machines must be at least equipped with the following:

- lockable selection switch for changing between front or rear operation and,
- light curtain or laser scanner at the front so that no one can reach the area of the folding beam or protruding sheet metal parts, and
- foot switch for operating the upper beam and folding beam, and
- setting depth-control stop by hold-to-run operation or reduced speed



Figure 12 – Example folding machine, front side, safeguarded by a light curtain (green circle)

3.1.6 Cutting device (long folding machines)

The movement of the cutting device can be generated in hold-to-run operation or by start initiation in conjunction with protective devices (e. g. laser beams and cut-off clips).

In the hold-to-run operation, the operator must actuate the start button and the bending assistants the enabling switch during the entire duration of the forward/backward movement of the cutting device. If the start button and/or the enabling switch are released, the cutting device has to stop after a short overtravel.

A short overtravel of the cutting device is considered to be a maximum overtravel distance of 60 mm in idle running, i.e. without material. This value has to be adhered to even after ageing signs, so that the overtravel distance must already be lower for new machines. Longer overtravel distances exceeding 60 mm are not acceptable and induce a reduction of the maximum cutting speed.

On initiation of the start in conjunction with protective devices, the overtravel according to DIN EN ISO 13855 [13] should be so low that a part of the body between the cutting device and the workpiece or fixed parts of the surrounding cannot be injured.

The run-in points of the roller cutters have to be adequately protected against reaching into (compare Figure 13). The opening width of the cutting device has to be restricted to a maximum dimension of 6 mm at a minimum safety distance of 10 mm to the cutting edge to prevent injuries of the fingertips (compare table 4 of DIN EN ISO 13857).

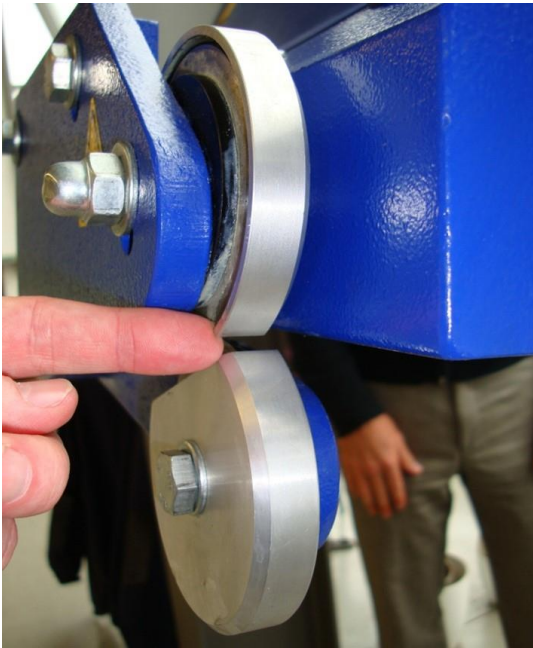


Figure 13 – Example of finger safe cutting device

3.2 Machines with automatic processing steps

All machines which can automatically process a bending sequence, must be fitted with a surrounding access protection and should only be operated from one side.

A sufficient minimum distance in combination with protective devices consisting of at least one light barrier with three single beams according to table E.1 of DIN EN ISO 13855 is considered as access protection for the operating side.

Owing to the visibility of the work area in front of the machine, a reset button (hand or foot-operated) is sufficient to actuate the protective device in the absence of persons within the work area. The reset button must be located outside the work area and must not be accessible from inside the work area.



Figure 14 – Example long folding machine as double bend with vertical and horizontal light curtain as access protection and step-behind protection as well as protective fence and laser beams (compare chapter 3.1.4)

If the reset button is accessible from inside the work area, a step-behind protection has to be provided by means of horizontally mounted light curtains or comparable technical safety measures. In addition, the functional control time it is prevented that due to daily routine activities inadvertency may lead to an accident.

4 Older machines

Older folding machines and long folding machines are often not equipped with safety devices such as multi-pedal foot switches for the operator, enabling foot switches for the bending assistants and mode selection switches (key switches or access code). Furthermore, the intermediate stop may not be

available on older machines or is adjusted to a different opening width than shown in Table 1. This is generally due to the fact that some manufacturers offered the protective measure „intermediate stop“ as an option at extra charge in the course of the introduction of this safeguard. As a result, types of folding machines and long folding machines of the same year of construction are available with and without intermediate stop.

Table 1 – „History“ of intermediate stop

since	Intermediate stop of the upper beam
before 05.1983	No intermediate stop available
05.1983	- up to 8 mm two-hand control - from 8 mm foot switch Value taken from a Danish study saying that bruise injuries of fingers from 8 mm can be cured.
01.1990	- up to 13 mm two-hand control - from 13 mm foot switch Change resulting from knowledge from accident investigations.
06.1990	- 25 mm intermediate stop, - only foot switch Change due to accident prevention.
12.1999	- 15 mm intermediate stop - only foot switch New findings from accident investigations. At 25 mm, the operator does not perceive that hands are within the hazard zone due to the lack of pressure.
10.2007	- 15 mm intermediate stop - foot switch only - speed ≤ 10 mm/s

Due to the existing hazard, all older folding machines and long folding machines in service should be retrofitted at least with an intermediate stop at 15 mm above the maximum permissible sheet metal thickness.

5 Operation of folding machines and long folding machines

According to the provisions of the BetrSichV [14], the user or employer has to assess the occurring hazards prior to using work equipment (risk assessment) and derive and implement necessary and appropriate safety measures. The state of the art has to be taken into account. For determining the state of the art, the publication on operational safety BekBS 1114 „Anpassung an den Stand der Technik bei der Verwendung von Arbeitsmitteln“ [15] can be used.

The measures for working safety during the operation of folding or long folding machines also comprise non-technical measures in addition to the technical safety measures which are basically given preference. The non-technical measures also comprise the behaviour of users. This includes for example:

- display operating instructions on the folding machine or long folding machine
- operation by instructed and charged persons only
- inspection of safeguards to effectiveness prior to work
- application of safety devices provided for multi-person operation (mode selection switch, enabling foot switch for the bending assistants).

The users of folding machines or long folding machines have to be made familiar with the hazards by the user or employer by regular instructions. (at least once a year).

6 Summary and limits of application

This “Fachbereich AKTUELL” is based on expert knowledge gathered by the expert committee Woodworking and Metalworking, subcommittee Machinery, Robotics and Automation when placing onto the market and operating new and used (second-hand) folding machines and long folding machines.

It is particularly intended to provide guidance to traders, purchasers, safety specialists and safety inspectors in the visual inspection of the state of the safety equipment.

The provisions according to individual laws and regulations remain unaffected by this “Fachbereich AKTUELL”. The requirements of the legal regulations apply unrestrictedly. In order to get complete information, it is necessary to consult all applicable regulation texts and current standards.

The expert committee Woodworking and Metalworking is composed of representatives of the German Social Accident Insurance Institutions, federal authorities, social partners, manufacturers and users.

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Further “Fachbereich AKTUELL” and Information Sheets of the expert committee Woodworking and Metalworking (Fachbereich Holz und Metall) can be downloaded from the internet [16].

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Annex – Tables 2a, 2b and Tables 3a,3b – Example operation modes with 2- or 3-pedal foot switch



Figure 1: Example of 2-pedal foot switch

Table 1a – Example – operation mode intermediate stop with 2-pedal foot switch

Protect. measure	Left pedal (upper beam)	Position	Right pedal (folding beam)
Intermediate stop	OFF Upper beam is in in initial position.	Position 0 pedal not actuated	OFF Folding beam is in initial position (rest position).
	<ul style="list-style-type: none"> • closing of upper beam in hold-to-run operation, ❶ • automatic stop of upper beam at intermediate stop at 15 mm above the max. permissible sheet metal thickness. • after releasing and new actuation, upper beam closes in hold-to-run operation with max. 10 mm/s. ❷ 	Position 1 pedal against pressure point	start of folding beam cycle, when clamping position is reached
	Upper beam moves with max. speed during period of actuation.	Position 2 pedal fully pressed down	<ul style="list-style-type: none"> • upper beam <u>not</u> in clamping position: Upper beam moves with max. speed to an opening height of at least 80 mm. • upper beam in clamping position: folding beam stop, upper beam stop
❶ On release of the pedal, before the intermediate stop is reached, the upper beam remains in the current position. ❷ On release of the pedal. the upper beam remains in the current position.			

Table 2b – Example – operation mode laser beams with 2-pedal foot switch

Protect. measure	Left pedal (upper beam)	Position	Right Pedal (folding beam)
Laser beams	<p>Off Upper beam is in initial position.</p>	<p>Position 0 pedal not actuated</p>	<p>OFF Folding beam is in initial position (rest position).</p>
	<ul style="list-style-type: none"> • Upper beam moves downwards in hold-to-run operation with unlimited speed, as far as no laser beams are interrupted. • stop of upper beam if a laser beam is interrupted. After new actuation of foot switch and continuously uninterrupted laser beam (e. g. corrugated sheet metal), reduction of speed to max. 10 mm/s. • switching off laser beams after having safely reached the speed of max. 10 mm/s 	<p>Position 1 pedal against pressure point</p>	<p>start of folding beam cycle, when clamping position is reached</p>
	<p>Upper beam moves with max. speed during period of actuation.</p>	<p>Position 2 pedal fully pressed down</p>	<ul style="list-style-type: none"> • upper beam <u>not</u> in clamping position: Upper beam moves with max. speed to an opening height of at least 80 mm. • upper beam in clamping position: folding beam stop, upper beam stop
	<ul style="list-style-type: none"> ❶ On release of the pedal, before the intermediate stop is reached, the upper beam remains in the current position. ❷ On release of the pedal. the upper beam remains in the current position. 		



Figure 2 – Example 3-pedal foot switch

Table 3a – Example – operation mode intermediate stop with 3-pedal foot switch

Pedal position	Left pedal	Center pedal	Right pedal	Protective measure
Position 0 (not actuated)	OFF Upper beam is in initial position.	OFF Folding beam is in initial position.	OFF Upper beam (and folding beam) is in initial position.	Intermediate stop
Position 1 (actuated up to pressure point, center Position)	<ul style="list-style-type: none"> • closing of upper beam in hold-to-run operation ❶ automatic stop of upper beam at intermediate stop at 15 mm above the maximum admissible sheet metal thickness ❶ • After releasing and new actuation, upper beam closes in hold-to-run operation with max. 10 mm/s. ❷ 	Start of folding beam cycle, when clamping position has been reached <u>in automatic mode:</u> After bending, the upper beam opens automatically up to the programmed value.	<ul style="list-style-type: none"> • Folding beam is in initial position • Upper beam opens in hold-to-run operation • folding beam swivelled-out Folding beam moves to initial position (hold-to-run operation) After release and new actuation, upper beam opens in hold-to-run mode	
Position 2 (fully pressed down, lowest position)	Upper beam moves to an opening height of at least 80 mm, as far as collision with folding beam is prevented.	Stop Folding beam stops immediately.	Not existent!	
❶ On release of the pedal, before the intermediate stop is reached, the upper beam remains in the current position. ❷ On release of the pedal, the upper beam or the folding beam remains in the current position.				

Table 3b – Example – operation mode laser beams with 3-pedal foot switch

Pedal position	Left pedal	Center pedal	Right pedal	Protective measure
Position 0 (not actuated)	OFF Upper beam is in initial position.	OFF Folding beam is in initial position	OFF Upper beam (and folding beam) is in initial position	Laser beams
Position 1 (actuated up to pressure point, center position)	<ul style="list-style-type: none"> moving down of upper beam in hold-to-run operation with unlimited speed, provided no laser beams are interrupted. ❷ stop of upper beam, when laser beam is interrupted. After new actuation of foot switch and continuously uninterrupted laser beam (e. g. corrugated sheet metal), reduction of speed to max. 10 mm/s. shut-off of laser beams after having safely reached the speed of max. 10 mm/s ❷ 	Start of folding beam cycle, when clamping position has been reached <u>in automatic mode:</u> After bending, the upper beam opens automatically up to the programmed value.	<ul style="list-style-type: none"> Folding beam is in initial position Upper beam opens in hold-to-run operation folding beam swivelled-out Folding beam moves to initial position (hold-to-run operation) After release and further actuation, upper beam opens in hold-to-run operation.	
Position 2 (fully pressed down, lowest position)	Upper beam moves at an opening height of at least 80 mm, as far as collision with the folding beam is prevented.	Stop Folding beam stops immediately.	Not existent!	
	❶ On release of the pedal, before the intermediate stop is reached, the upper beam remains in the current position. ❷ On release of the pedal, the upper beam or the folding beam remains in the current position.			