

**TALAT Lecture 3703**

**Stretch Forming**

13 pages, 10 figures

Basic Level

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**Objectives:**

- to define important terms of the process of stretch forming
- to describe the basic processes of stretch forming

**Prerequisites:**

- Background in production engineering
- TALAT lecture 3701

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## **3703 Stretch Forming**

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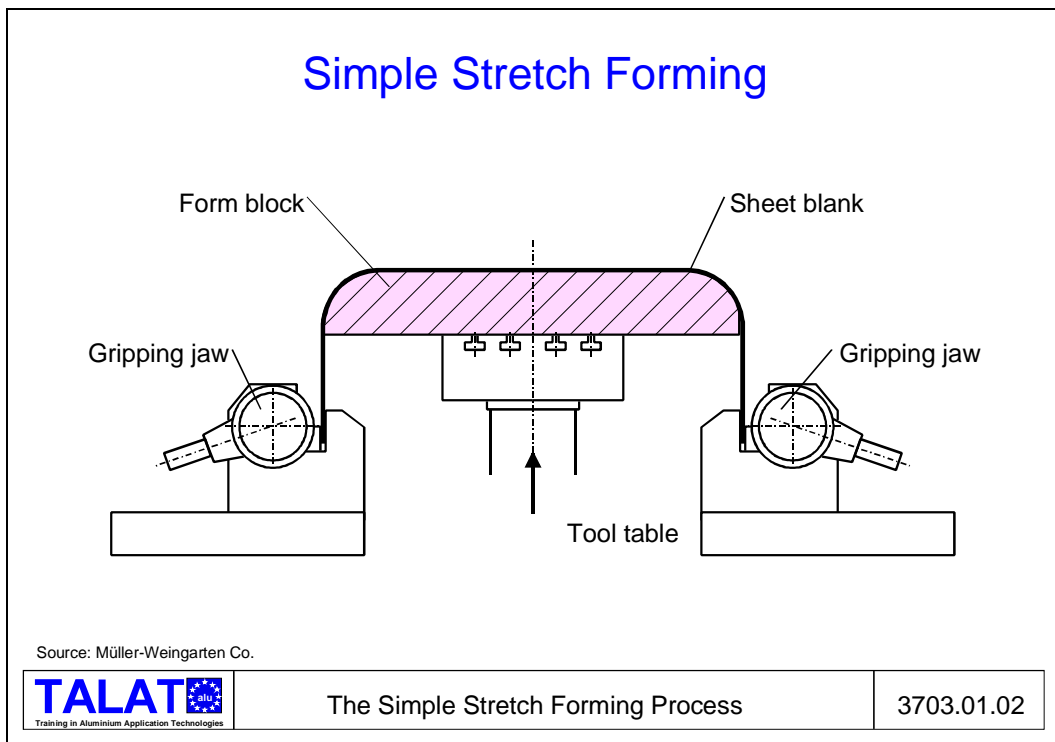
## 3703.01 Definition, Application and Types of Stretch Forming Processes

Stretch forming is the process of forming sheets and profiles by the combined application of tensile and bending forces [1]. In other words, the stretch forming of sheet blanks can be defined as the deepening by a fixed punch of an area of a sheet clamped rigidly at the edges. The sheet blank can then be formed either between rigid tool parts or be pulled between two gripping jaws. The gripping jaws can be either rigid (simple stretch forming) or can be moved during the application of the tensile force (tangential stretch forming). In general, stretch forming is used to produce basically convex forms and parts with large radii of curvature. Examples of such forms are external body parts, planking parts for the aerospace industry and parts of train coaches and waggons. Other parts which can be produced by this method are relatively steep U-forms, e.g. the leading edges of aeroplane wings, with the limitation that the contour is curved in only one direction. **(Figure 3703.01.01)**

<h3>Stretch Forming</h3>		
<b>Definition:</b>	Stretch forming is the forming of a sheet blank with a rigid (one-piece) punch, whereby the blank is rigidly clamped at the edges. The blank can be clamped between rigid tools, corresponding to the upper and lower drawing frames of the conventional tools, or be clamped in gripping jaws.	
	Source: <b>DIN 8585</b>	
<b>Field of application:</b>	Mainly for production of relatively flat parts of large dimensions as single pieces, prototypes or for small series.	
<b>Process types:</b>	<ul style="list-style-type: none"><li>-Simple stretch forming</li><li>-Tangential stretch forming</li><li>-Stretch forming according to Cyril-Bath</li><li>-Multi-sided stretch forming</li></ul>	
	Definition,application and types of stretch forming	3703.01.01

### Simple Stretch Forming

For the simple stretch forming process, the sheet sample which has to be formed, is clamped between two gripping jaws located on opposite ends, see **Figure 3703.01.02**. The forming tool or block is fixed on to a tool table which can be moved hydraulically in a vertical direction. The forces necessary for the forming are transferred through the form block to the sheet sample.



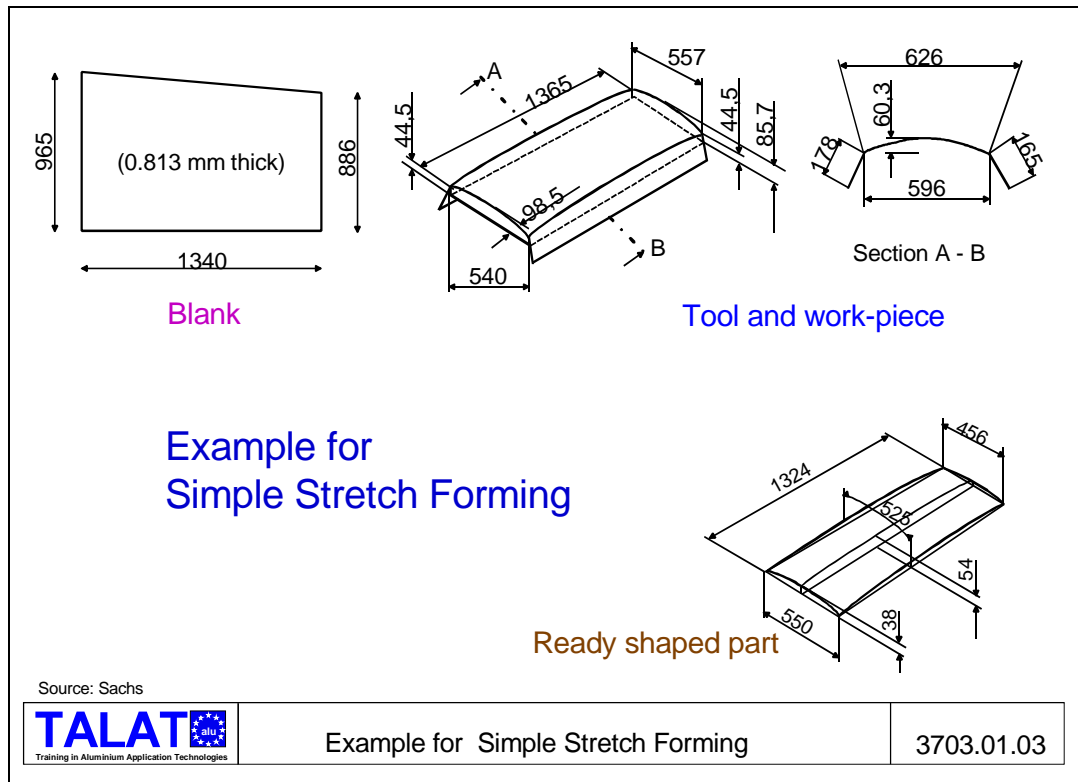
The part to be formed receives its contours during the motion of the forming block, the gripping jaws remaining stationary. At the beginning of the stroke, the sheet blank first drapes itself around the form block, following its contours. Due to the large area of contact between form block and the blank, the frictional forces prevent a deformation of the sheet in this region. This is especially true for flat shapes where even a small motion of the form block is sufficient to allow a large part of the blank to "hug" the form block.

A further motion of the form block causes the sheet blank to be strained, but mainly in the region of the frame. Due to the frictional forces acting between form block and blank, the middle regions hardly undergo any deformation, i.e., the maximum possible straining capacity of the sheet is not attained. This means that the maximum attainable theoretical elongation, calculated on the basis of the length of blank between the gripping jaws, cannot be attained, since the middle regions of flat shapes are hardly deformed and, therefore, do not contribute much to the total deformation strain. The sheet material flows under the tensile stress only out of the sheet thickness, so that the surface of the sheet expands [2].

### Examples for Simple Stretch Forming

Wing parts for the aeroplane industry can be made by simple stretch forming, starting from trapezoidal blanks, see e.g. **Figure 3703.01.03**. Assuming that the maximum attainable straining of a sheet under stretch forming is equal to the uniform elongation evaluated using the tensile test, one can conclude that only relatively flat and

predominantly convex sheet shapes, as shown in the overhead, can be produced. During the stretch forming operation, care must be taken to ensure that the blank does not slip sideways from the form block [3]. Furthermore, flat sheet forms should have only relatively small convex domes, unless one uses a stretch forming press with counter pressing arrangements. A disadvantage of stretch forming is that the middle regions of the sheet are not sufficiently formed, so that the strain distribution in the sheet cross-section is not uniform. This leads on the one hand to a springback and consequently a loss in dimensional accuracy and on the other hand to insufficient work hardening.



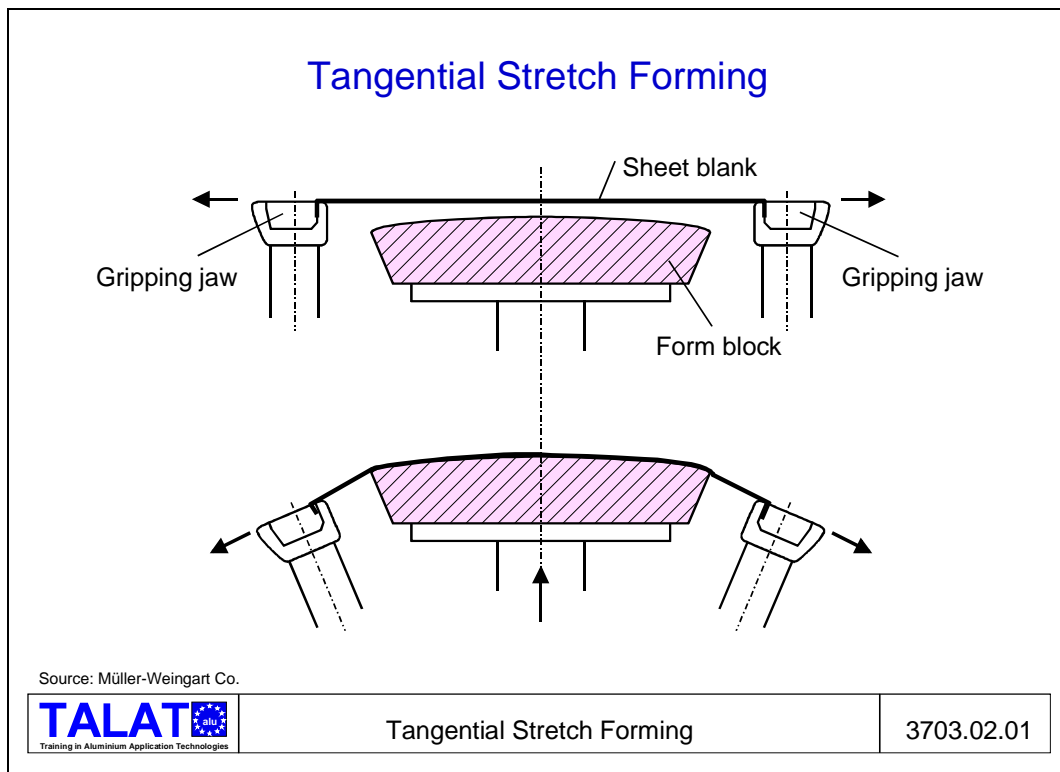
A variation of the simple stretch forming is the forming of stress segments on the punch of a hydraulic drawing press and the assembly of the form block on the press table. This variation is, however, only suitable for small sheet shaped parts with small draw depths, whereby the above mentioned disadvantages apply here also.

## 3703.02 Tangential Stretch Forming

### Process of Tangential Stretch Forming

In tangential stretch forming, see **Figure 3703.02.01**, the sheet blank is also gripped from two opposite ends. The main difference to the simple stretch forming is that both the form block as well as the gripping jaws are movable. Using this process, it is possible to subject the blank to a plastic pre-strain prior to the actual forming, so that the whole cross-section of the material undergoes a uniform plastic deformation [4].

Another advantage is that the tensile forces applied always act tangentially in the body of the blank.



The process can be divided into two steps:

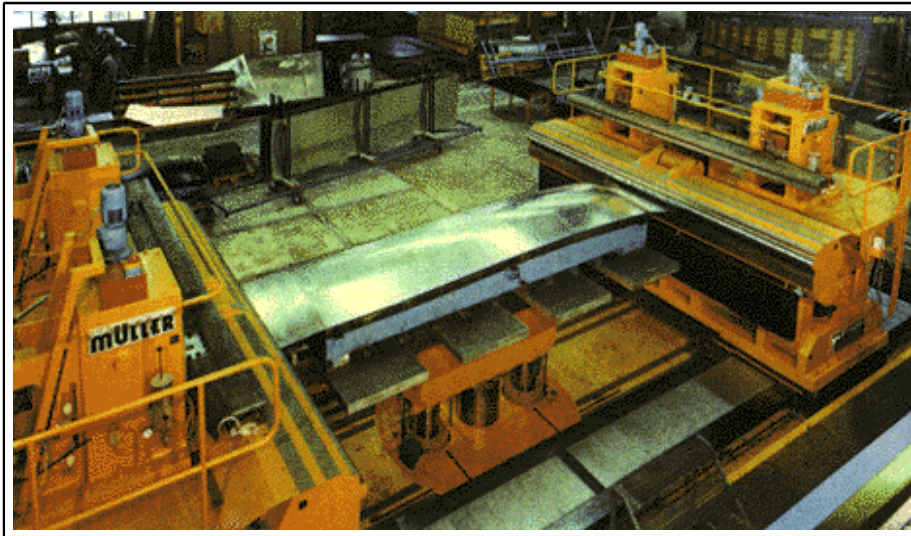
In the first step, the blank is gripped by two jaws arranged opposite to each other. The jaws then move horizontally away from each other and create a uniform plastic strain in the whole cross-section of the blank. In the second step, the form giving block is moved vertically towards the sheet blank. The gripping jaws tilt and orient themselves in the direction of the tensile stressing of the blank, so that the blank, still under the constant tensile stress required for the plastic deformation, is draped tangentially over the form block.

Due to the prior elongation given to the blank before contact occurs between form block and blank, the middle regions of the blank are formed without being influenced by friction. Another advantage is that the application of an overlaid tensile stress to the work-piece during deformation reduces the residual stress. The reduction of residual stress leads to lower springback than in the case of simple stretch forming so that the form accuracy is higher and accompanied by a higher blister strength of the sheet part.

## Equipment for Tangential Stretch Forming

The tangential stretch forming machines, see **Figure 3703.02.02**, are used to fabricate roofing arches for train coaches, door frames and planking for busses, planking parts for the aerospace industry and for the outer covering sheets for cars. The largest stretch forming machines can accommodate sheet blanks up to 6,100 mm wide and up to 9,300 mm long. The stroke force of the table piston in these cases reaches up to 10,000 kN. Such large presses are mostly used for forming planks for wings and bodies [5].

### Equipment for Tangential Stretch Forming



Source: Müller-Weingarten Co.



Equipment for Tangential Stretch Forming

3703.02.02

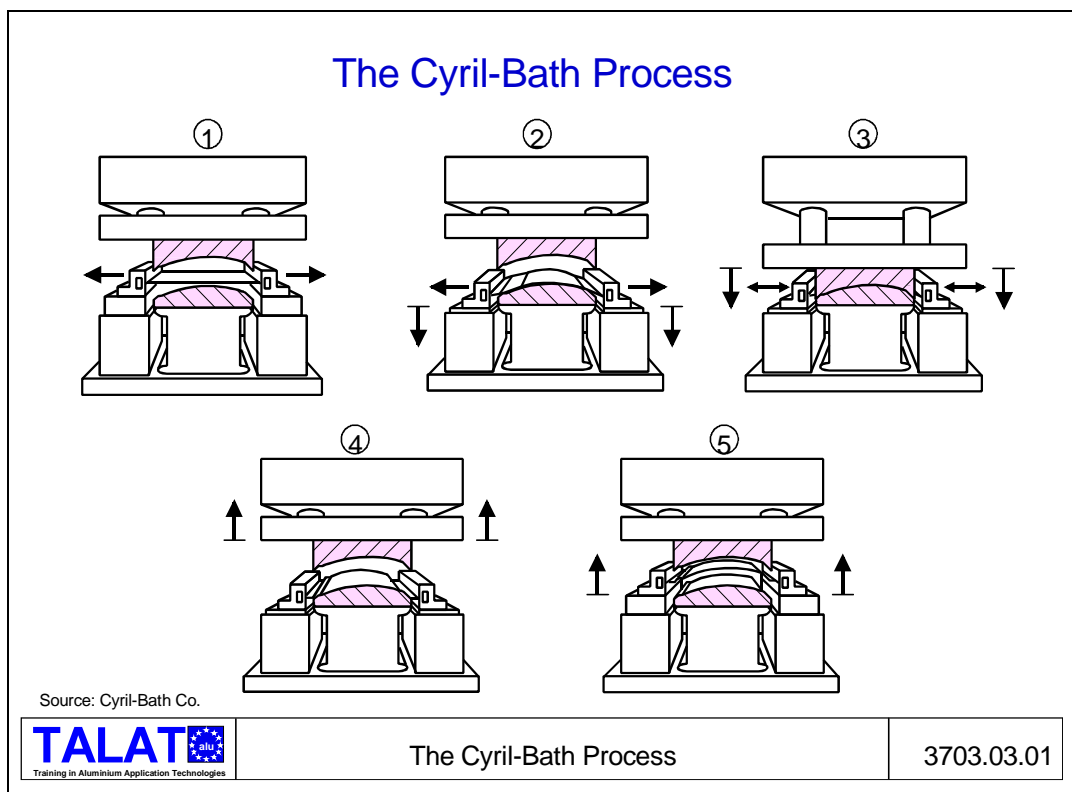
The modern tangential stretch forming machines have to be able to form complicated sheet shapes which have to meet the ever increasing demands on accuracy required for the stretch formed sheet shapes, a typical example being parts for aeroplanes and space-ships which have to be able to fulfil the high aerodynamical requirements. Parts of the tanks of the American space-shuttles are formed from an aluminium alloy and have a final size of 2,464 mm x 5,182 mm x 12.7 mm. In these cases it is not possible to apply the principle of "trial and error" to produce such parts. The machines used here must be equipped with the necessary sensors for measuring force and distances moved, regulating and controlling algorithms and a programmable process control [6].

The stretch forming of sheet metal parts having convex-concave contours is only possible with stretch forming machines in which a counter pressure can be applied. While a tensile stress is being applied to the sheet metal part with the gripping jaws, the counter pressure equipment presses the contours into the sheet metal part.

## 3703.03 The Cyril-Bath Process

### Principles of the Process

Based on the principle of tangential stretch forming, the Cyril-Bath company has developed a process which makes it possible to apply tangential stretch forming in a mechanical or hydraulic drawing press, see **Figure 3703.03.01**. The Cyril-Bath process is used to fabricate large, relatively plane sheet shapes in small and large series, e.g. car bonnets (hoods).



The process can be classified as a combination of stretch forming and deep drawing operations [7]. It was the Cyril-Bath process, also called the stretch-draw process, which made it possible to introduce stretch forming for the mass-production of body parts. Depending on the body design, about 6 % to 10 % of the parts are made by the Cyril-Bath process. Using this process, body parts can be produced at a rate of 8 strokes per minute.


The system consists of two gripping jaws arranged opposite to each other and which can be moved horizontally and vertically. These are mounted between the stands of a simple hydraulic press. A form block is mounted on the table of the press between the gripping jaws. The counter pressing equipment is mounted on the ramming punch of the press.



## Operational Steps of the Cyril-Bath Process

The whole process is conducted in five process steps: **Figure 3703.03.02**

1. The sheet blank is clamped between two gripping jaws located opposite to each other. The grips are moved away from each other stressing the blank, without touching the form block, to an elongation of  $e = 2\%$  up to  $4\%$ .
2. Without reducing this applied stress, the gripping jaws are moved downwards so that the blank is wrapped around the form block to produce the convex contour.
3. The ramming punch is now moved downwards to produce the counter pressure required for forming the concave contours. In order to prevent tearing in the over-stressed regions of the concave contours, the gripping jaws are moved horizontally and vertically in well-defined and controlled steps during the downward motion of the counter pressing punch.
4. The punch is moved back to its original starting position.
5. The gripping jaws are opened and also moved to their original starting position, enabling the shaped part to be removed.

Operation Steps of the Cyril-Bath Process		
1. Clamping and pre-straining the sheet blank		
2. Drawing the sheet blank over the form block		
3. Application of counter pressure		
4. Moving back the counter pressure equipment		
5. Opening the gripping jaws and removing the sheet shape		
	Operation Steps of the Cyril-Bath Process	3703.03.02


The main difference between the Cyril-Bath process and stretch forming lies in the third process step, in which the gripping jaws are moved in a controlled manner. Due to this controlled movement of the gripping jaws, the stress applied to the blank through the jaws can be kept constant or even reduced. This allows the sheet material to "flow in", so that the additional surface area of the formed part does not solely have to be provided by stretching the material volume, i.e. by thinning of the sheet cross section alone.

One of the advantages of the Cyril-Bath process is the good forming of the middle regions of low-profile sheet metal parts, making it possible to attain a high amount of work hardening and consequently a good dent resistance. At the same time, due to the forming characteristics in the plastic state, the residual stress is reduced causing a smaller springback of the shaped part and making it possible to replicate the required form accurately. Furthermore, since an upper and a lower frame are no longer required, the cost and assembly time for the equipment are reduced, thereby increasing the economy of the process. An economical tool is thus available for producing prototypes made of plastic or kirkosite (Zamak).

The Cyril-Bath process is limited by the fact that it is only possible to apply a two-sided stressing, so that only sheet shapes which require little deformation transverse to the stressing direction can be formed. Thus it is not possible to effectively produce three-dimensional, doubly curved contours, e.g., closed hollow bodies.

### 3703.04 Multiaxial Stretch Forming

The increasing popularity of the Cyril-Bath process and of the tangential stretch forming process stimulated the design of flexible and programmable stretch forming equipment. The aim of this development was to use the advantages of both these processes and, at the same time, to eliminate the disadvantage of the two-sided stressing by arranging gripping jaws all around the form block. In order to achieve these goals, the requirements listed in the overhead were set up: **Figure 3703.04.01.**

Requirements for a Flexible Stretch Forming Machine		
1.	The gripping jaws should be able to be arranged around the sheet blank in order to increase the variety of shape types which can be produced.	
2.	A segmented gripping system, allowing optimal control of material flow and production of shapes with unsymmetrical contours, should be used.	
3.	The system should be able to be enhanced and adapted to fabricate convex-concave shaped parts.	
	Requirements for a Flexible Stretch Forming Machine	3703.04.01

A consequence of these requirements is a flexible sheet stressing system consisting of individual stressing systems. The individual stressing systems must each be individually programmable and be able to be arranged flexibly around the form block.

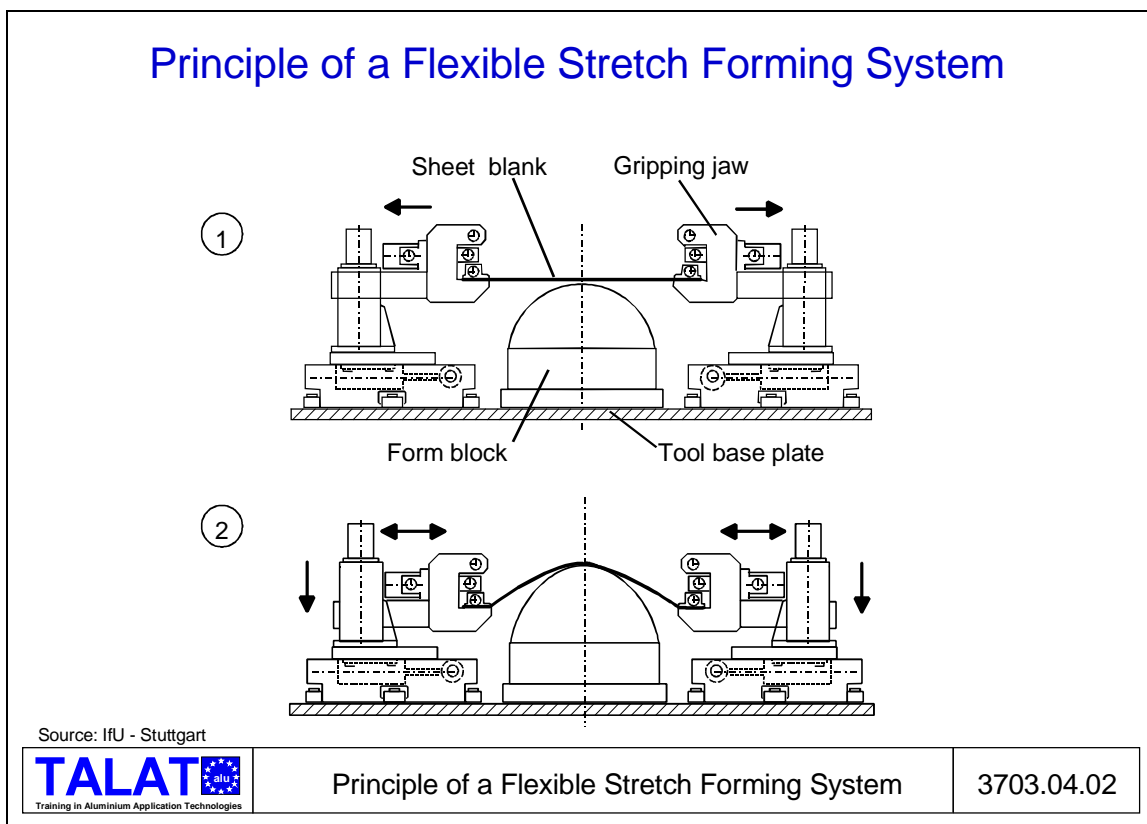
The principle of a flexible stretch forming machine is illustrated in **Figure 3703.04.02**.

The process steps involved in the forming of shaped sheet parts with a flexible, segmented stretch forming machine, are as follows:

1. The sheet blank is fixed to the leading edge of the gripping jaws. The gripping segments are then moved towards each other so that the blank can be clamped in all four gripping jaws. The gripping segments then move apart, thereby pre-straining the blank.
2. The vertical and horizontal movements are coordinated, making it possible to trace a curved path with which the blank can be drawn over the form block.

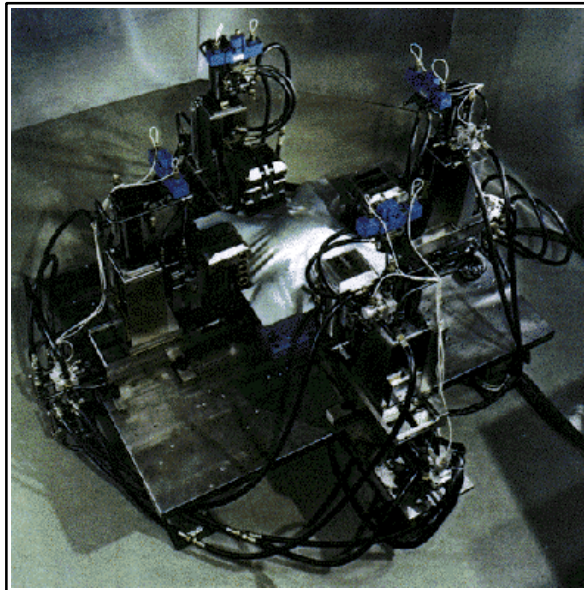
The determination and programming of the path to be traced is decisive for both the forming operation as well as for the accuracy with which the contours can be replicated. Each stressing segment can thus be programmed to describe its own individual path. This can be achieved either by linear movements or by simple curves traced by applying small discreet movements directly to the supports.

For form blocks with complicated geometries, the travel paths must be manually pre-determined using the part drawing as a basis. The fine adjustment is then carried out experimentally, using an iterative method.



The basic module consists of a gripping jaw which can be moved horizontally or vertically by means of a hydraulic cylinder. The gripping jaws can move 200 mm horizontally and 250 mm vertically. A further hydraulic cylinder activates the toggle-lever sheet gripping jaws, whereby the gripping width is 250 mm. The total constructional height of a module is 1,223 mm with a constructional length of 820 mm.

### Four-sided Stretch Forming Using a Hemispherical Punch



Source: IFU - Stuttgart



Four-sided Stretch Forming  
Using a Hemispherical Punch

3703.04.03

**Figure 3703.04.03** illustrates the arrangement of the segments of a four-sided stretch forming machine with a hemispherical punch. Each of the four gripping segments can be operated individually, i.e., each grip can be positioned and controlled independently. Four such gripping modules were constructed for experimental purposes.

### 3703.05 Literature

- [1] VDI-Richtlinie 3140: Streckziehen auf Streckziehpressen.
- [2] **Möhrlin, W.:** Die grundlegenden Tiefziehverfahren. Industrie-Anzeiger, Essen 79(1962) p. 53 - 55
- [3] **Oehler, G.:** Gestaltung gezogener Blechteile. Konstruktionsbuch No. 11, 2nd edition, Springer Verlag Berlin, Heidelberg, New York.
- [4] **Kursetz, E.:** Das Streckformen als modernes Verfahren der Blechformteilherstellung. TZ für praktische Metallbearbeitung, 65 (1971) No. 8, p. 357 - 362.
- [5] **Kursetz, E.:** Blechumformung im amerikanischen Flugzeugbau. Blech 7(1969) No. 5, p. 260 - 268
- [6] **Spallarossa, G.; Gropetti, R.:** Numerisch gesteuertes Streckziehen. Werkstatt und Betrieb 114 (1981) No. 8, p. 565 - 567
- [7] **Kursetz, E.:** Kombiniertes Streckformen und Tiefziehen. Maschinenmarkt 75 (1969) No. 60, p. 1368 - 1370.

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