The disadvantage is that only full-surface workpieces can be processed using the known methods and arrangements. Machined workpieces, which, for example, already have pockets, rivet holes or cut-outs for windows, cannot be processed satisfactorily with the known methods and arrangements, since such mould recesses in the workpiece lead to uncontrollable deformations of the workpiece in the region of these mould recesses when using the known forming methods.

As a result of this, it is necessary to shape the workpieces first in a bending process and to then machine them afterwards to produce the desired mould recess. As the geometry of the workpiece obtained after the bending process extends spatially, the use of 5-axis portal milling machines is unavoidable for subsequent machining and this is associated with large space requirements and high acquisition and maintenance costs.

It is therefore the object of the present invention to propose a method by means of which sheet-like workpieces that have already been machined can be formed cost-effectively, with high precision and very high repeat accuracy by means of step-by-step free bending. The object is further to propose a corresponding arrangement.

The object is achieved by a method with the features referred to hereinbefore in that, before the workpiece is formed into the final shape, a filling element, which is adapted to the mould recess and designed to make up the material thickness, is produced and is arranged in the region of the mould recess. The method according to the invention offers many advantages over the method known in the prior art. Thus, by means of the invention, a method is created which for the first time allows the bending of workpieces that have already been machined. The workpieces can then be machined before the bending process due to their sheet-like geometry. For this purpose, it is sufficient to use a three-axis metal-cutting machine which in particular also considerably reduces the effort required to clamp the workpiece compared to complex machining using a 5-axis portal milling machine on an already bent workpiece. In this way, the workpieces can be machined significantly more cost-effectively. In addition, using the filling element ensures a high-precision bending operation, particularly in the region of the mould recesses, i.e. in the region of milled-in pockets, rivet holes, window openings or the like and thus achieves extremely good repeat accuracy of the entire bending process.

According to a first aspect of the present invention, there is provided a method for changing the shape of a sheet-like workpiece, which has a mould recess formed by reducing the thickness of the material, comprising arranging the workpiece on at least two spaced-apart supporting elements of a machine bed, forming the workpiece into a final shape by step-by-step free bending, in that the steps of bending a part of the workpiece by lowering an upper

die between the supporting elements from a waiting position into a forming position, raising the upper die into the waiting position and moving the position of the workpiece relative to the machine bed in at least one infeed direction are performed repetitively, characterised in that before the workpiece is formed into the final shape, a filling element, which is adapted to the mould recess and designed to make up the material thickness, is produced and is arranged in the region of the mould recess.

According to a second aspect of the present invention, there is provided an arrangement for changing the shape of a sheet-like workpiece, which has a mould recess formed by reducing the thickness of the material, comprising at least two spaced-apart supporting elements designed for arranging the workpiece on the machine bed, a forming device designed for forming the workpiece into a final shape by step-by-step, repetitive free bending with an upper die, which is designed to be controllably lowerable from a waiting position into a forming position for bending a part of the workpiece as well as with positioning means which are designed for moving the position of the workpiece relative to the machine bed in at least one infeed direction, characterised in that the arrangement further comprises a filling element adapted to the mould recess and designed to make up the material thickness which is designed to be arranged in the region of the mould recess before the workpiece is formed into the final shape.

A preferred development of the invention is characterised in that the filling element is produced at least substantially as a negative form of the mould recess. In other words, the filling element is designed in such a manner that it fits into the mould recess in a positive-locking or substantially positive-locking manner. The filling element thus forms a re-usable intermediate layer which is arranged between the upper die and the workpiece. The filling

magnesium with high tensile strength ranging from 400 to 450 N/mm^2. Such sheets, for example, have dimensions of 800 x 800 mm up to 6000 x 6000 mm. The maximum material thickness of the workpiece 10 varies between 0.5 and 16 mm depending on the application. The method according to the invention and the arrangement according to the invention are suitable for forming workpieces 10 made of plastic or metal, such as sheet aluminium and sheet steel.

The workpiece 10 has a mould recess which is formed by reducing the thickness of the material. As can be gathered from the schematic view in Figure 1, the workpiece 10 has regions 11 of reduced material thickness. These regions 11 form the mould recess. When using the workpieces 10 in the aircraft industry as the outer skin of the aircraft, also referred to as "skins", these regions 11 are introduced into the workpiece 10, for example, by rivet holes, pockets for weight saving, cut-outs for windows or the like. Processing of the workpiece for introducing the mould recess is carried out by machining, for example, on the sheet-like, i.e. flat, workpiece 10 by means of three-axis cutting machines.

To change the shape, for example to adapt the workpiece 10 to the desired aircraft contour, the workpiece is preferably arranged on at least two spaced-apart supporting elements 12 of a machine bed13. The forming process into the final shape takes place by means of step-by-step free bending. For this purpose, a part of the workpiece 10 is brought from a waiting position, not shown in the drawing, into a forming position 15 by lowering an upper die 14 between the supporting elements 12.

The upper die 14 is then raised, i.e. moved again in z direction 16 into the waiting position. Now the position of the workpiece 10 relative to the machine bed is moved in at least one infeed direction 17. Figure 2 shows the workpiece 10 schematically after one or a plurality of forming processes. The previously described steps are carried out repetitively until the desired final shape is achieved by multiple forming.

More preferably, the positioning means, not shown in the drawing, are designed and configured to move the workpiece 10 not only in the infeed direction 17 shown but additionally in a further direction perpendicular to the infeed direction 17. The workpiece can thus be positioned and moved largely at will in the XY plane. In addition, it is possible to incline the upper die 14 with respect to the Z direction 17. In this way, the workpieces can be twisted to a certain extent during forming.

The local bending radius desired for each forming process is predetermined by specifying the immersion depth of the upper die 14, which is determined by the lowering path. The workpiece 10 is formed into the desired final shape by repetitively carrying out this forming process. Different radii can be introduced into the workpiece 10 by specifying individual immersion depths for each bending operation.

Before the workpiece 10 is formed into the final shape, a filling element 18 adapted to the mould recess and designed to make up the material thickness is produced and is arranged in the region of the mould recess. As shown in Figures 1 and 2, the filling element 18 is arranged on the workpiece 10 to be formed and thus fills in particular the regions 11 of reduced material thickness of the mould recess.

This makes it possible for the first time to subsequently form already machined workpieces 10 by free bending with the said mould recesses without obtaining forming results in these regions, which run contrary to the close tolerances specified, due to regions of reduced material thickness already introduced in the workpiece 10.

Advantageously, the upper die 14 has a sword end 22 coming into contact with the workpiece 10 or the filling element 18. This is preferably made of plastic and has a large radius, preferably greater than 50 mm, on the one hand to bend the workpiece 10 gently and on the other hand to ensure the smoothest possible transitions of the bending radii.

The filling element 18 is preferably produced as a negative form or at least substantially as a negative form of the mould recess. In other words, the filling element 18 has a shape which corresponds to the shape of the regions 11 of reduced material thickness, such that the filling element 18 arranged on the workpiece 10 preferably fills the whole surface of the mould recess and completely compensates the removed material of the workpiece 10 in the region of the mould recess. The filling element 18 with the workpiece 10 thus forms a flat or smooth pressure surface 19 on the upper die side. It is also possible to design the filling element 18 such that it only partially covers selected regions of the workpiece 10.

More preferably, in regions 11 of the mould recess with reduced material thickness, the filling element 18 has a minimum thickness in each case which corresponds at least to the amount of reduction in the material thickness of the workpiece 10 in this region. The workpiece 10 with the filling element 18 thus forms the previously described flat pressure surface 19, such that a flat contact between upper die 14 and the workpiece 10 or the filling element 18 is basically guaranteed during the forming process.

Claims

1. Method for changing the shape of a sheet-like workpiece, which has a mould recess formed by reducing the thickness of the material, comprising

arranging the workpiece on at least two spaced-apart supporting elements of a machine bed,

forming the workpiece into a final shape by step-by-step free bending, in that the steps of

- bending a part of the workpiece by lowering an upper die between the supporting elements from a waiting position into a forming position,

- raising the upper die into the waiting position and

- moving the position of the workpiece relative to the machine bed in at least one infeed direction

are performed repetitively, **characterised in that**

before the workpiece is formed into the final shape, a filling element, which is adapted to the mould recess and designed to make up the material thickness, is produced and is arranged in the region of the mould recess.

2. Method according to claim 1, characterised in that the filling element is produced at least substantially as a negative form of the mould recess.

3. Method according to one of claims 1 or 2, characterised in that, in regions of the mould recess with reduced material thickness, the filling element has a minimum thickness in each case which corresponds at least to the amount of reduction in the material thickness of the workpiece in this region.

4. Method according to any one of claims 1 to 3, characterised in that the filling element is produced in such a manner that, when arranged in the mould recess, it finishes flush with the upper side of the workpiece, forming an at least substantially smooth pressure surface.

5. Method according to claim 4, characterised in that the filling element is produced so as to protrude with respect to the pressure surface in predetermined raised regions.

6. Method according to claim 5, characterised in that a pressure-resistant foil is arranged on the pressure surface of the filling element for producing the raised regions.

7. Method according to claim 6, characterised in that the foil is glued on.

8. Method according to any one of claims 1 to 7, characterised in that the filling element is made of acrylonitrile butadiene styrene (ABS).

9. Method according to any one of claims 1 to 8, characterised in that the filling element is produced by machining.

10. Method according to any one of claims 1 to 9, characterised in that a resilient supporting surface element is arranged between the supporting elements of the machine bed and the workpiece.

11. Arrangement for changing the shape of a sheet-like workpiece, which has a mould recess formed by reducing the thickness of the material, comprising

at least two spaced-apart supporting elements designed for arranging the workpiece on the machine bed,

a forming device designed for forming the workpiece into a final shape by step-by-step, repetitive free bending with an upper die, which is designed to be controllably lowerable from a waiting position into a forming position for bending a part of the workpiece as well as

with positioning means which are designed for moving the position of the workpiece relative to the machine bed in at least one infeed direction,

characterised in that

the arrangement further comprises a filling element adapted to the mould recess and designed to make up the material thickness which is designed to be arranged in the region of the mould recess before the workpiece is formed into the final shape.

12. Arrangement according to claim 11, characterised in that the filling element is designed at least substantially as a negative form of the mould recess.

13. Arrangement according to one of claims 11 or 12, characterised in that, in regions of the mould recess with reduced material thickness, the filling element has a minimum thickness in each case which corresponds at least to the amount of reduction in the material thickness of the workpiece in this region.

14. Arrangement according to any one of claims 11 to 13, characterised in that the filling element is designed in such a manner that, when arranged in the mould recess, it finishes flush with the upper side of the workpiece forming an at least substantially smooth pressure surface.

15. Arrangement according to claim 14, characterised in that the filling element is designed so as to protrude with respect to the pressure surface in predetermined raised regions.

16. Arrangement according to claim 15, characterised in that a pressure-resistant foil is arranged on the pressure surface for producing the raised regions.

17. Arrangement according to claim 16, characterised in that the foil is joined to the pressure surface by means of an adhesive bond.

18. Arrangement according to any one of claims 11 to 17, characterised in that the filling element is made of acrylonitrile butadiene styrene (ABS).

19. Arrangement according to any one of claims 11 to 18, characterised in that a resilient supporting surface element is arranged between the supporting elements of the machine bed and the workpiece.