(57) The present invention relates to a method that uses the so-called punching bundle-assembling technique for producing bundles of sheet iron having an iron core with a circular or oval cross-section. To this end, the laminates are punched from a strip while forming recesses on one side and protrusions on the other, wherein the protrusions are located opposite the recesses and conform to their shape. The protrusions are pressed into the recesses so as to form at least two circular warts when assembling each bundle. In each bundle, one laminate used as a separation laminate is formed with cylindrical holes instead of recesses for engaging the
lesquels s’engagent les boutons des lames voisines. L’invention est caractérisée en ce qu’à partir de la bande, on estampe des lames présentant des profils extérieurs différents, en particulier des largeurs différentes, et en ce qu’on relie ces lames entre elles de manière à former un paquet présentant au moins partiellement une section de fer circulaire. Le paquet de tôles présente des bords étagés.

warts of adjacent laminates. The laminates punched from the strip exhibit different outer profiles and particularly different widths, and said laminates are attached together so as to form a bundle having an iron core with an at least partially circular cross-section. The bundle of sheet iron further exhibits stepped edges.
METHOD AND DEVICE FOR PRODUCING BUNDLES OF SHEET METAL LAMINATES FOR MAGNETIC CORES

The present invention relates to a method that uses the so-called punching bundle-assembling technique for producing bundles of sheet iron having an iron core with a circular or oval cross-section. To this end, the laminates are punched from a strip while forming recesses on one side and protrusions on the other, wherein the protrusions are located opposite the recesses and conform to their shape. The protrusions are pressed into the recesses so as to form at least two circular warts when assembling each bundle. In each bundle, one laminate used as a separation laminate is formed with cylindrical holes instead of recesses for engaging the warts of adjacent laminates. The laminates punched from the strip exhibit different outer profiles and particularly different widths, and said laminates are attached together so as to form a bundle having an iron core with an at least partially circular cross-section. The bundle of sheet iron further exhibits stepped edges.

With the present invention, one can produce a variety of magnetic cores made from sheet steel or other magnetic materials, which can be used in various applications such as transformers, inductors, and other magnetic components. The method allows for the production of bundles of laminates that can be easily integrated into magnetic cores, providing flexibility in terms of core design and size.
Abstract
Method and Apparatus for Manufacturing Packets Composed of Sheet Metal Lamellae for Magnetic Cores

The present invention offers a manufacturing method that also makes sheet metal packets in what is referred to as the punch-packeting technology available that comprise a round or oval iron cross section. Lamellae are thereby punched from a tape and are provided with depressions at one side and with elevations at the other side that coincide with the depressions and lie opposite them, whereby the elevations in the form of at least two circular nipples are pressed into the depressions upon assembly of each packet. In one lamella per packet, this serving as separating lamella, cylindrical holes are punched instead of the depressions, the nipples of the neighboring lamella engaging into said holes. Lamellae are thereby punched from the tape that exhibit a different outside contour, particularly a different width, and are joined with one another to form a packet that at least partially comprises a round iron cross section. The sheet metal packet comprises graduated edges.

Figure 3
METHOD AND APPARATUS FOR MANUFACTURING PACKETS
COMPOSED OF SHEET METAL LAMELLAE FOR MAGNETIC CORES

The invention is directed to a method for manufacturing packets composed
of linked sheet metal lamellae for magnetic cores, what are referred to as sheet metal
packets.

Given a method disclosed by EP-B 0 133 858 for manufacturing such
sheet metal packets, lamellae are punched from a tape and are provided with
depressions at one side and with elevations at the other side that coincide with the
depressions and lie opposite them. In the form of at least two circular nipples these
elevations are pressed into the depressions upon assembly of each packet. Instead of
the depressions, cylindrical holes are punched into one lamella per sheet metal packet,
this serving as parting lamella. The nipples of the neighboring lamellae engage into
these circular holes. The subject matter of EP-B 0 133 858 is hereby expressly
incorporated into the application by reference.

Among other things, sheet metal packets of this type are used in various
electromagnetic apparatus such as, for example, inductors, transformers, actuating
drives, actuators such as, for example, solenoid valves, etc.

The employment of sheet metal packets in magnetic circuits has been state
of the art for many years and serves the purpose of reducing eddy currents that, for
example, in transformers, contribute to an increase in the losses or, given solenoid
valves, contribute to a lengthening of the switching times. As an alternative to sheet
metal packets, toroidal tape cores are employed that, however, exhibit the
disadvantage compared to sheet metal packets that the coils required for the drive
must be slipped on before closing the magnetic circuit.

Due to the prescription of a rectangular iron cross section in sheet metal
packets, the use of sheet metal packets was not capable of being optimized up to now
in various instances. In many applications, namely, it is desirable to keep the recesses
for the sheet metal packets to be introduced round or, respectively, oval.
When a sheet metal packet having a rectangular iron cross section is then introduced into such a round or, respectively, oval recess, the comparatively low iron cross section relative to the diameter of the recess is disadvantageous. This disadvantage becomes particularly serious when the conditions of use require a miniaturization of the components, as is particularly necessary in internal combustion engines.

It is therefore an object of the present invention to develop the initially cited manufacturing method to the effect that sheet metal packets are also available that comprise a round or oval iron cross section.

This is inventively achieved by a method for manufacturing packets composed of linked sheet metal lamellae for magnetic cores wherein lamellae are punched from a tape and are provided with depressions at one side and are provided with elevations at the other side that coincide with the depressions and lie opposite them, whereby the elevations in the form of at least two circular nipples are pressed into the depressions upon assembly of each packet, whereby cylindrical holes instead of the depressions are punched in one lamella per packet, this serving as separating lamella, the nipples of the neighboring lamella engaging thereinto. Lamella are thereby punched from the band that comprise a different outside contour and are linked with one another to form a packet that at least partially comprises a round iron cross section. Accordingly, the sheet metal packet comprises graduated edges.

As a result of this measure, sheet metal packets can be fabricated that have their outside contour adapted to a round shape and whose iron cross section corresponds to the ideal circular shape to more than 95%.

Typically, lamella are thereby punched from the tape that comprise a different width. These lamellae of different widths are then linked to form a packet that comprises a nearly circular iron cross section.

In an alternative embodiment of the inventive method, E-shaped lamellae are punched from the tape, their outside and/or middle leg exhibiting different widths. Due to the variation of the widths of the middle leg sheets, middle legs can be
manufactured whose iron cross section nearly corresponds to the ideal circular shape. As a result thereof, it is possible to slip circular coils onto the middle leg. Due to the variation of the widths of the outside leg sheets, the arising sheet metal packets can in turn be adapted to the circular or oval installation requirements.

An extremely high work output with only a single apparatus is achieved when the depressions and the nipples of each lamella are flow-coined with dies given simultaneous application of opposing force with counter-dies, whereby the nipple diameter is greater than that of the corresponding depression, and the nipple height is less than the depth of the corresponding depression, which has achieved at least 50% of the lamella thickness.

The depressions and the nipples are preferably flow-coined for at most another 10 ms by the dies after the counter-dies have reached their final position.

In a development of the present invention, the nipple diameters are formed at most 20 μm larger than the diameter of the corresponding depression, and the nipple height is formed at most 0.1 mm less than the depth of the corresponding depression.

Further, the lamellae can be pre-coined or pre-punched at the rated locations of the depressions and the nipples.

The inventive apparatus for the implementation of the method is characterized in that at least two dies and two counter-dies that are height-adjustable in the matrix are provided in the coining station of the depressions and the nipples; in that each counter-die is provided with a collar for defining its limit position at the support of the matrix; and in that braking elements are installed in the cut-out station of the finished lamella under the matrix, these braking elements proceeding transversely relative to the counter-die axes and exerting the required resistance in the joining of the individual, finished lamellae to one another. Cutting dies that can be moved apart or, respectively, moved into one another in turn in defined steps are located in the cut-out station. This setting of the cutting dies to different widths typically ensues automatically with an actuating drive.
The invention is explained in greater detail below by way of example and with reference to the drawing.

According to the prior art, lamellae 1 are punched from a punch tape and layered on top of one another in a successor tool with a plurality of work stations in order to form packets. According to the prior art, identical lamellae 1 are thereby provided with depressions 2 at the one side in the successor tool and are provided with nipples 3 coinciding with the depressions 2 and lying opposite them at the other side. Upon assembly of each packet, at least two circular nipples 3 are pressed into the corresponding depressions 2. Clear packet, respectively, respectively one lamella that serves as separating lamella 1' is provided with cylindrical holes 4 instead of being provided with depressions. The nipples 3 of the neighboring lamellae then engage into these holes 4. This is schematically shown in Figure 1. Figure 2 shows a separating lamella 1' in cross section.

As proceeds from Figures 3 and 4, identical lamellae are now no longer punched in the same successor tool according to the present invention; rather, the sheet metal widths are varied after the introduction of the nipples. Via the control of the successor joining tool, the width of the sheet metal lamellae that have been punched out is reset after every punching step by lateral displacement of the cutter die. In the exemplary embodiment shown in Figure 3, a narrow lamella whose width amounts to approximately 30% of the desired diameter of the packet is punched first. This narrow lamella serves as separating lamella 1 and comprises two cylindrical holes 4. The two cylindrical holes are centrally punched and their diameter amounts to approximately 10% of the packet diameter. Nipples of the neighboring lamella 2 are pressed into these cylindrical holes. Before the next punching stroke of the tool, the cutter die is shifted under motor drive to the width of the next sheet metal. This next lamella 2 comprises approximately 50% of the width of the coil core. In the same successor tool, depressions are introduced into this lamella 2 at the one side and nipples 3 are introduced therein at the other side that coincide with the depressions 2
and lie opposite them. Subsequently, the lamellae 3 through 11 are then analogously linked to one another with increasing width.

For the lamellae 10' through 1' that now follow, the lateral cutting dies are then in turn successively moved together, so that the packet shown in Figure 3 and in Figure 4 can be removed from the successor joining tool as finished part.

In this way, it is possible, for example, to manufacture a cylindrical coil core for a round ignition coil that fills up a large part of the cross sectional area of the circle.

The following table 1 describes embodiments wherein a rod core having a diameter of 30 mm was manufactured of lamellae with different thicknesses according to the method according to the invention. The iron cross section has thereby been measured compared to a sheet metal packet having rectangular iron cross section.

**Table 1:**

<table>
<thead>
<tr>
<th>Band Thickness [mm]</th>
<th>Iron Cross Section, Round Sheet Metal Packet (%)</th>
<th>Iron Cross Section, Rectangular Sheet Metal Packet (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>93</td>
<td>63</td>
</tr>
<tr>
<td>1.0</td>
<td>95</td>
<td>64</td>
</tr>
<tr>
<td>0.7</td>
<td>97</td>
<td>64</td>
</tr>
<tr>
<td>0.5</td>
<td>98</td>
<td>64</td>
</tr>
<tr>
<td>0.3</td>
<td>99</td>
<td>64</td>
</tr>
</tbody>
</table>

Cylindrical coil cores of 0.5 mm thick grain-oriented iron silicon were manufactured with the inventive method, these varying in diameter from 5 mm through 20 mm.

Figure 5 shows a EK core 20 having a rectangular iron cross section according to the prior art. Such EK cores are employed as actuators for diesel injection valves. The object here was to fabricate a EK core that can be screwed into a limited installation volume and that can achieve a high force level. The EK core 20
shown in Figure 5 thereby exhibits only inadequate results since the area utilization of
the round outside contour 21 for the iron cross section amounts to only 31%.

With the inventive method, the round EK core 30 shown in Figure 6 was
adapted to the round outside contour 31. The design of the successor joining tool
ensued as in the fabrication of the cylindrical coil cores shown in Figures 3 and 4,
namely by shifting the cutting die. The round EK core 30 of the following invention
shown in Figure 6 comprises an essentially higher area utilization compared to the EK
core 20 of Figure 5. An approximately 20% higher area utilization was thereby
achieved.

The sheet metal packets were again manufactured of iron silicon and
compared to sheet metal packets of the prior art. An increase in the force level of the
magnetic circuit of 20% was achieved in the actuator for a diesel injection valve.

Figure 7 shows a EK core 40 according to the present invention having a
clearance at the middle leg, as can be derived from German Utility Model 2951 4508.
The subject matter of German Utility Model 2951 4508 is hereby expressly
incorporated by reference. For the middle lamellae 41, 42, a recess 43 is provided
toward the middle, so that a central guidance for the valve rod (not shown) is enabled
in the utilization. In this application, too, the force level was capable of being
increased by 19% compared to a comparable sheet metal packet having a rectangular
iron cross section. The illustrated EK core 40 is again composed of grain-oriented
iron silicon.

In the optimization of the EK core 40 shown in Figure 7 with contours
rounded off at the outside, the limitation of the utilization of the circular area is
defined by the width of the outer sheet metal layers. A further optimization can
inventively ensue in that the inner cutting die of the successor joining tool required for
the manufacture of cores is also shifted under motor drive. As a result thereof, the
middle leg of the sheet metal packet is rounded off and, consequently, adequate space
is created for the outer layers so that a punch-oriented joining in the tool is still
possible.
Figure 8 shows a sheet metal packet 50 adapted to the round shape, whereby a 44% larger iron cross sectional area is achieved compared to the sheet metal packet of Figure 6 having a rectangular iron cross section.

A corresponding sheet metal packet 50 in an installation space of 20 mm composed of lamellae of 1 mm thick iron silicon achieved a force of 78 N instead of 54 N compared to a sheet metal packet 40 having rectangular iron cross section.
Patent Claims

1. Method for manufacturing packets composed of linked sheet metal lamellae for magnetic cores wherein lamellae (1-11, 1'-10') are punched from a tape and are provided with depressions (2) at one side and are provided with elevations at the other side that coincide with the depressions and lie opposite them, whereby the elevations in the form of at least two nipples (3) are pressed into the depressions (2) upon assembly of each packet, whereby holes (4) instead of the depressions (2) are punched in one lamella per packet, this serving as separating lamella (1), the nipples of the neighboring lamella (2) engaging thereinto, characterized in that lamellae (1-11, 1'-10') are punched from the tape that exhibit a different outside contour and are joined to one another to form a packet that at least partially comprises a nearly round iron cross section.

2. Method according to claim 1, characterized in that the elevations in the form of at least two circular nipples (3) are pressed into the depressions (2) upon assembly of each packet, whereby cylindrical holes (4) instead of the depressions (2) are punched in one lamella per packet, this serving as separating lamella (1), the nipples (3) of the neighboring lamella (2) engaging thereinto.

3. Method according to claim 1 or 2, characterized in that lamellae (1-11, 1'-10') are punched from the tape that comprise a different width and are joined to one another to form a packet that comprises a nearly round iron cross section.

4. Method according to claim 1 or 2, characterized in that E-shaped lamellae are punched from the tape, their outside legs and/or middle legs exhibiting different widths.

5. Method according to one of the claims 1 through 4, characterized in that the depressions (2) and the nipples (3) of each lamella (1-11, 1'-10') are flow-coined with dies given simultaneous influence of opposing force of counter-dies, whereby the nipple diameter is larger than that of the corresponding depression (2) and the nipple height is smaller than the depth of the corresponding depression (2), which has achieved at least 50% of the lamella thickness.

6. Method according to claim 5, characterized in that the depressions (2) and the nipples (3) are flow-coined for at most another 10 ms by the dies after the counter-dies have reached their limit position.
7. Method according to claim 5, characterized in that the nipple diameter is formed at most 20 μm larger than that of the corresponding depression (2), and the nipple height is formed at most 0.1 mm smaller than the depth of the corresponding depression (2).
8. Method according to claim 4, characterized in that the lamellae (1-11, 1'-10') are pre-coined or pre-perforated at the rated locations of the depressions and the nipples.
9. Apparatus for implementing the method according to patent claim 1, composed of a successor tool having laterally adjustable cutting dies.
10. Apparatus according to claim 9, composed of a successor tool having matrix and matrix and a plurality of work stations, characterized in that at least two dies are provided in the coining station of the depressions (2) and of the nipples (3) and two height-adjustable counter-dies are provided in the matrix; in that each counter-die is provided with a collar for determining its limit position at the support of the matrix; and in that braking elements are installed in the cut-out station of the finished lamellae (1-11, 1'-10') under the matrix, said braking elements proceeding transversely relative to the counter-die axes and providing the required resistance in the joining of the individual, finished lamellae (1-11, 1'-10') to one another.
11. Employment of a packet of joined sheet metal lamellae (1-11, 1'-10') manufactured with a method according to one of the claims 1 through 8 as magnetic core in a solenoid valve.
12. Employment of a packet of joined sheet metal lamellae (1-11, 1'-10') manufactured according to one of the claims 1 through 8 as magnetic core in an actuating drive.
13. Employment of a packet of joined sheet metal lamellae (1-11, 1'-10') manufactured with a method according to one of the claims 1 through 8 as magnetic core in a transformer.
14. Employment of a packet of joined sheet metal lamellae (1-11, 1'-10') manufactured according to one of the claims 1 through 8 as magnetic core in an actuator.