**METHOD AND PRODUCTION LINE FOR PRODUCING FOAM ALUMINIUM SHEETS**

The invention relates to powder metallurgy, in particular to foam aluminium production. The invention method involves filling of a powder mixture into a sheath, heating it in a through-type furnace (6) to a temperature not less than 500°C, the hot compaction thereof, the cutting of the compacted rolled billet into sheet billets and the high-temperature heat treatment for a foaming process. The sheath is formed from two uniformly supplied coiled strips. The lower part of the sheath with a base and flanged walls is formed from the thirst coiled strip (1). Afterwards, the second coiled strip (4) is superimposed upon the lower part of the sheath and the thus assembled billet is sent for canting the flanged sections. The inventive production line comprises a device for supplying the powder mixture for heating, the through-type furnace (6), a heated chute with rollers, a stand for heat compacting of the powder mixture rolled billets, the shears (9) for cutting billets to length, an outgoing roller table (10) and a sheet billet-foaming furnace. The production line is also provided with a device for filling the powder mixture into the sheath. Said invention makes it possible to produce quality billets with uniform mechanical characteristics.
Description

[0001] The invention relates to powder metallurgy and may be applied for production of products for civil construction, elevator construction, ship building, machinery building, road construction and other industries where such properties as lightness, floatability, incombustibility, heat resistance and noise insulation are required.

[0002] There is a known method (accepted as an analog) which involves primary compaction of a powder, heating of a material up to temperature not below than 500°C, its hot roll knobbing under the same temperatures. Granulated powder with granule size of 50-200 micrometers is used as aluminum powder. The powder is filled into a closed sheath made of slab steel with thickness of 0.5-2.0 mm with uniform or different thickness of walls contacting during roll knobbing and with a cross section shape approximated to slab billet shape. Then, the sheath is heated together with the powder up to 500-600°C; then the sheath is squeezed together with the powder under rolls with diameter of not less than 500 mm at a linear speed of 0.03-0.3 m/s to shape thickness which is determined according to following expression:

\[ H_1 = (0.8-1.0) \times (H_0 + p_0/p_1 + (f_1 + f_2)/2)(1 - p_0/p_1) \]

Where:

- \( H_1 \) - is thickness of materials together with the sheath at exit from rolls, mm;
- \( H_0 \) - is thickness of materials together with the sheath at entrance to rolls, mm;
- \( p_0 \) - is density of material filling at entrance to rolls, g/cm³;
- \( p_1 \) - is a theoretical density of the material, g/cm³;
- \( f_1, f_2 \) - are thicknesses of sheath walls contacting during roll knobbing, mm.

[0003] Afterwards, the sheath is cooled down, cut and sheet billet is removed from thereof. Furthermore, the sheath is produced in form of trough-shaped chute with a lid. In order to obtain foam aluminum sheets from the sheet billets, 0.5-1.0 mas. % of expanding agent (TiH₂) powder; the sheet with the powder is heated to 500-550°C for further roll knobbing. Prior to compacting, aluminum powder granules are pre-treated with polymethylsiloxane or polyethylsiloxane (RU No. 2200647 B22F3/11, C22C1/08 dated 20.03.2003).

[0004] Shortcomings of the known method is that:

- it is aimed at single-piece low productive rolling;
- a steel sheath is technological and is subject to removal after roll knobbing thus generating expensive production wastes.

[0005] There is known a technological line for production of porous and non-porous metal sheets (accepted as an analog) which contains a bin with a metal powder of vertical design, horizontal design is for a belt conveyor, cold roll stand, heat furnace for cold rolled sheet foaming, transfer rolled table, hot roll stand and hot rolled sheet coiling machine; the belt conveyor is designed to accept the metal powder from the bin and to pass through a deformation zone of the cold rolling stand and to transfer the cold rolled sheet to the heating furnace for foaming (Patent 10324904A B22F3/18, B22F3111, H01M4/8 dated 27.02.1998, Japan).

[0006] Shortcomings of the known line include cold deformation of the powder thus requiring extremely great rolling force and low efficiency for generating new strong metallic bonding both in places of contact with clean surface and places of contact through metallized oxide film.

[0007] There is known a method and technological line (accepted as a prototype) which implements production of porous semi-finished products made from aluminum alloy powders which include: a powder mixture batcher, a through-type furnace with a belt conveyor passing through thereof for feeding the cold powder mixture, transfer of the heated powder mixture and output of the heated powder mixture to a chute of vertical design equipped with devices for heating and vibration compacting of the powder mixture; a guidance bin and a roll stand for the hot compacted powder mixture of horizontal design; shears for cross cutting hot compacted sheet billets to regular length as well as devices for high temperature treatment for foaming of the hot compacted sheet billets (RU No. 2200647 B22F3/11, C22C1/08 dated 20.03.2003).

[0008] The line allows producing hot compacting with rather high deformations. However, the prototype has following shortcomings:

- non-uniformity of mechanical properties along width of the compacted sheet billets;
- high power inputs due to two occasions of heating, additional heating and production of powder mixture compacting at significant heat emission by rolls;
- vertical design of the technological line which requires a specialized production building and causes complications for combining reliable process control and ensuring explosion safety as well as necessity for protection of environmental cleanness.

[0009] The proposed invention has a task to obtain high quality sheet billets with uniform mechanical characteristics both according to its width and length, to reduce their prime cost, to create a process for production of foam aluminum with high technological effectiveness with reduction of explosive conditions of the production process to a permissible level.

[0010] This task is achieved in following manner. The method involves filling of the powder mixture into the sheath made of steel or aluminum alloys, heating the powder mixture rolled billets in the through-type furnace.
to a temperature not less than 500°C, the hot compaction of the rolled billets, cutting of the compacted rolled billet into sheet billets of regular length, placing the rolled billets in forms and following high-temperature heat treatment for a foaming process at a liquidus temperature of the powder alloy. The sheath is formed from two uniformly supplied coiled strips of unlimited length. The lower part of the sheath with a base and flanged walls is formed from the thirt coiled strip. Afterwards, the second coiled strip is superimposed upon the lower part of the sheath which equates to width of upper surface of the lower part of the flanged sheath and the thus assembled billet is sent for canting the flanged sections along entire length. Furthermore, hot compacting of the powder mixture in the sheath is performed in a closed pass of the working rolls; the roll pass is determined according to the following formula:

$$h_H = \frac{R(1-\cos \alpha) + H - \Delta h}{\cos \alpha}$$

Where:

- $h_H$ - is a height of roll pass;
- $\alpha$ - is an acceptance angle;
- $\Delta h$ - is powder mixture roll knobbing;
- $H$ - is thickness of rolled billets;

meanwhile, the working rolls for hot compacting of the powder mixture in the sheath are lubricated with a smoke-free lubricant, for instance, colloidal graphite aqueous suspension of "Aqwadak" type. (V.M.Steinberg, I.L.Akaro, "Press-Forging Production", Moscow, Mechanical Engineering, 1977, pages 150-160).

**[0012]** The production line for production of foam aluminum sheets which implements this method involves a device to feed the powder mixture for heating, a throughput furnace, a heated chute with rolls which feed the compacted rolled billets into sheet billets of regular length; a collecting roller table and a furnace for foaming the sheet billets supplemented, prior to the device for feeding the powder mixture for heating, with a device for packing of the powder mixture into the sheath having a shape approximated to the rolled billet shape including two bending machines for forming the lower and upper parts of the sheath provided with coiled strip decoilers.

**[0013]** Between the bending machines, there are located a transfer mechanism for advancing the lower part of the sheath, roughing and finishing batchers for filling the powder mixture into the sheath and a mechanism for superimposing the lower part of the sheath with its upper part. Moreover, the transfer mechanism for advancing the lower part is designed in form of two and more drive three-roll group of draw rollers; the lower roller of the group is designed as a double-seat one with a grooving in the central part of its body at a width and depth exceeding not less than 2 mm of the width and depth of the sheath; the upper rollers, the left and right ones, are designed as console ones which contact with the lower part of the sheath only along the width of its flanges. The batchers and the transfer mechanism for advancing the lower part of the sheath for the device for packing the powder mixture into the sheath are installed onto the vibrator casing; also, prior to the foaming furnace and behind thereof, there are installed schleppers which are perpendicular to the line axis; and the schlepper which is prior to the foaming furnace is equipped with a mechanism for configuring the sheet billets into a molding shape; behind the throughput furnace, there are installed press shears for cross cutting of the rolled billets; behind the collecting roller table, there are installed shears for cross cutting of edge flanges of the sheet billets; the working rolls with inner heating are installed in the stand for hot compacting of the powder mixture in the sheath.

**[0014]** Such constructional design of the production line for producing aluminum sheets allows:

- reducing production areas due to completeness of the technological process in a single production line starting from feeding the powder mixture and finishing with output of a finished product;
- raising productivity of the process owing to reduction of production idle time to minimum;
- producing panels of sufficiently large sizes;
- reducing power inputs during hot compacting of the powder mixture in the sheath due to performance of compacting in the working rolls heated to 150-300°C and lubricated with colloidal graphite aqueous suspension of "Aqwadak" type and due to foaming non-cooled sheet billets due to hot immersion;
- creating conditions for maximum permissible mechanization and automation of the production process for producing foam aluminum sheets due to stabilization of operation of each mechanism of the line in time sequence;
- raising quality of the sheet billets due to uniformity of the process of compacting the rolled billets in the closed roll pass thus reducing swelling the billets;
- raising explosive safety as well as environmental safety due to elimination of operations with the open powder mixture in heated state.

**[0015]** The proposed method and production line for producing foam aluminum sheets are depicted in following figures:

Figure 1. demonstrates a diagram for implementation of the method for production of foam aluminum
sheets;  
Figure 2 demonstrates a sectional view A-A of Figure 1 for the formed lower part of the sheath;  
Figure 3 demonstrates a sectional view B-B of Figure 1 for the lower part of the sheath filled with the powder mixture;  
Figure 4 demonstrates a sectional view C-C of Figure 1 for the formed rolled billets including the sheath and the powder mixture compacted by vibration;  
Figure 5 demonstrates the production line for producing foam aluminum sheets;  
Figure 6 demonstrates a plan for the sheet billets foaming section (view according to A arrow in Figure 5);  
Figure 7 demonstrates a sectional view A-A of Figure 5 for draw rollers of the transfer mechanism for advancing the lower part of the sheath.

[0016] According to Figure 1, the coiled strip 1 is continuously fed for forming the lower part of the sheath into the bending machine 2 where the shape is formed as shown in Figure 2, which is the lower part of the sheath including a base and flanged walls with 30-50 mm flanges.

[0017] As the formed lower part of the billets advances, the powder mixture is fed from the batchers 3 into its inner cavity until its complete replenishment (refer to a sectional view B-B of Figure 3). Then, the lower part of the sheath filled with the powder mixture is superimposed with the second flat coiled strip 4 with width equal to width of the lower part of the sheath according to its flanges; the assembled billet is transferred to the second bending machine 5 which rolls over the sections of both parts of the sheath thus finishing forming the rolled billet made the powder mixture in the sheath. The rolled billet is heated in the through-type furnace 6 up to temperature not below 500°C and is transferred through the heated guide 7 for compacting into the closed pass of the working rolls 8 with height \( h_k \) determined with a value which is derived from the following expression:

\[
\frac{R \cdot (1 - \cos \alpha)}{\cos \alpha} + H = \frac{\Delta H}{2}
\]

Where:

- \( h_k \) - is a height of roll pass;  
- \( \alpha \) - is an acceptance angle;  
- \( \Delta H \) - is powder mixture roll knobbing;  
- \( H \) - is thickness of rolled billets;

[0018] The height \( h \) of the closed pass excludes side escape of the powder mixture from the deformation zone: the width of the closed pass approximated to the width of the rolled billet ensures uniform compaction along entire its width. Lubrication of the working surface of the closed pass with a smoke-free lubricant of colloidal graphite aqueous suspension of “Aqwadak” type reduces power inputs for compaction down to 10+25%.

[0019] The sheet billet exiting the working rolls is cut into regular lengths using flying shears 9 for cross sectional cutting. The sheet billet is transferred to a roller table 10 and, if defective, is removed from the flow by a pusher. The sheet billet is transferred to the cross cutting shears 11 for cutting off the side edges. The sheet billet cut around all sides is transferred to a molding shape 12 and the foaming furnace 13. The finished sheet of foam aluminum is extruded from the shape and transferred to the receiving roller table of the furnace 14 where it is cooled down and further transferred for storing.

[0020] The proposed production line for producing foam aluminum sheets depicted in Figures 5, 6 and 7 contains:

- the first decoiler with its coiled strip 1;  
- the first bending machine 2;  
- the vibrator 15 as well as roughing and finishing batchers 3 (3a for the roughing one and 3b for the finishing one) for feeding the powder mixture as well as the transfer mechanism 13 for advancing the lower part of the sheath which is designed in form of two and more drive three-roll groups of draw rollers depicted in Figure 7;  
- the lower roller of the group is designed as a double-seat one with a grooving in the central part of its body at a width and depth exceeding not less than 2 mm of the width and depth of the sheath; the upper rollers, the left and right ones, are designed as console ones which contact with the lower part of the sheath only along the width of its flanges.

Moreover, following are installed: the second decoiler 4; the mechanism 17 for superimposing the flat coiled strip of the decoiler onto the lower part of the sheath; the second bending machine 5; the mechanism 18 for packing the exposed face of the rolled billet; the through-type furnace 6; the press shears 19; heat insulated guide 7; the rolled stand 8; the flying shears 9; the collecting roller table 10 with a pusher for defective billets; the cross cutting shears 11; the roller table 20 behind the cross cutting shears; the schlepper 21 in front of the foaming furnace; the molding shape 12 and furnace for foaming the sheet billets 13; the collecting roller table 22 and the schlepper 14 behind the furnace for removal of the foamed sheet billets; the section for extrusion of a foam aluminum sheet from the molding shape 23 and the encircling roller table 24 for transfer of the molding shape from this section to the schlepper located in front of the foaming furnace.

[0022] Operation of the proposed production line is performed in following manner. The first decoiler continuously delivers a coiled strip for shaping the lower part of the sheath in the first bending machine. The formed lower part of the sheath made of a base and side flanged walls is transferred to the vibrator section where the
roughed and finishing batchers fill the lower part of the sheath with the powder mixture.

[0023] The transfer mechanism for advancing the lower part of the sheath in Figure 7, mounted onto the casing of the working vibrator ensures uniform advancement of the lower part of the sheath during the process of filling of its inner cavity with the powder mixture. The second decoiler delivers a coiled strip into the mechanism for superimposing the flat coiled strip of the decoiler onto the lower part of the sheath. The assembled billet is accepted by the second bending machine 5 which performs rolling over of the flanged sections of the sheath filled with the powder mixture. The front section of the sheath with 300-500 mm length which is unfilled with the powder mixture is accepted by mechanism for packing the exposed face of the formed rolled billet.

[0024] The through-type furnace 6 heats the continuously moving rolled billet. The flying press shears installed behind the through-type heating furnace are activated into operation in cases of emergency or stoppages of the machine which are technologically required

[0025] Maintenance of temperature of the rolled billet at its entrance into the working rolls is ensured by heat insulating guidance which directs the rolled billet into the closed pass of the working rolls which are heated up to temperature of 150-300°C.

[0026] The rolling mill performs compacting of the powder mixture in the sheath at roll knobbing levels of up 62%.

[0027] The compacted billet exiting the working rolls is transferred to the flying shears for cross cutting and is cut into regular sheet billets which are delivered to the cross cutting shears for cutting of side faces.

[0028] The sheet billet cut off all sides is delivered by the roller table to the schlepper in front of the furnace for foaming and is mounted on front of a molding shape of one of chambers of the foaming furnace. The pusher delivers the sheet billet into the molding shape and then transfers it together with the shape into the foaming furnace. After foaming, the shape containing a foam aluminum sheet is transferred to the schlepper installed behind the foaming furnace for transporting to the section for extrusion of the foam aluminum sheet from the shape; and the shape which is not chilled yet is delivered to the schlepper in front of the foaming furnace thus becoming ready for acceptance a next sheet billet.

[0029] Thus, hot compacting of the powder mixture in the sheath formed directly in the production line using two uniformly supplied continuous coiled strips of unlimited length is performed. Forming of the lower part of the sheath which includes a base and flanged walls is made using the first coiled strip.

[0030] Afterwards, the second coiled strip is superimposed upon the lower part of the sheath which equates to width of upper surface of the lower part of the flanged sheath and the thus assembled billet is sent for canting the flanged sections along entire length. Implementation of this method in the production line for producing foam aluminum sheets by installing, prior to the device for feed-

Claims

1. A method for the production of foam aluminum sheets comprising filling a powder mixture into a shell made of steel or aluminum alloys, heating a rolled workpiece of the powder mixture in the shell in a through-type furnace to a temperature not less than 500°C, hot compacting of the rolled workpiece, cutting the compacted rolled workpiece into sheet workpieces of regular length, placing the sheet workpieces into a mould and subsequent high-temperature heat treating for the implementation of a foaming process at liquidus temperature of the powder alloy, characterized in that forming of the shell is made from two uniformly supplied continuous coiled strips, wherein initially forming of the lower part of the shell comprising a base and flanged walls is made from the first coiled strip, further as the lower part is filled with the powder mixture compacted by vibration the second coiled strip having a breadth equal to the breadth of the upper surface of the lower part of the shell with flanged edges is placed on the lower part of the shell and the assembled workpiece is directed to folding the flanged sections over the entire length.

2. The method for the production of foam aluminum sheets according to claim 1, characterized in that the hot compacting of the powder mixture in the shell is performed in a closed pass of working rolls, wherein in the depth of incision of the roll pass is determined according to the formula:
where:

- $h_H$ - is the depth of incision of the roll pass;
- $\alpha$ - is the angle of nip;
- $\Delta h$ - is the powder mixture reduction;
- $H$ - is the thickness of the rolled workpiece.

3. The method for the production of foam aluminum sheets according to any of claims 1 or 2, characterized in that the working rolls for hot compacting of the powder mixture in the shell are lubricated with a smoke-free lubricant.

4. A production line for producing foam aluminum sheets containing a device for feeding a powder mixture to heating, a through-type furnace, a preheated chute with rolls feeding the powder mixture to compaction, a stand for hot compaction of the rolled workpieces of the powder mixture, a cutter for cross cutting the compacted rolled workpieces into sheet workpieces of regular length; a run-off table and a furnace for foaming the sheet workpieces, characterized in that a device for packing the powder mixture into a shell having the shape approximated to the rolled workpiece shape, comprising two bending machines for forming the lower and upper parts of the shell each provided with own coiled strip decoilers is arranged prior to the device for feeding the powder mixture to heating, wherein a transfer mechanism for advancing the lower part of the shell, a rough and a fine feeder for filling the powder mixture into the shell and a mechanism for applying the upper part of the shell on the lower part thereof are arranged between the bending machines.

5. The production line for producing foam aluminum sheets according to claim 4, characterized in that the transfer mechanism for advancing the lower part of the shell is formed as two or more driven groups of three pinch rolls, wherein the lower roll of the group is formed double-seated with a cavity in the central part of its body at a breadth and a depth exceeding not less than 2 mm the breadth and depth of the shell and the upper left and right rolls are formed over-hanging and contacting the lower part of the shell only at the breadth of its flanges.

6. The production line for producing foam aluminum sheets according to claim 4, characterized in that the feeders and the transfer mechanism for advancing the lower part of the shell of the device for packing the powder mixture into the shell are installed on a vibrator housing.

7. The production line for producing foam aluminum sheets according to claim 4, characterized in that transfer mechanisms perpendicular to the line axis are arranged prior to the furnace and after the downstream thereof foaming.

8. The production line for producing foam aluminum sheets according to claim 4, characterized in that press shears for cross cutting the rolled workpieces are arranged after the through-type furnace.

9. The production line for producing foam aluminum sheets according to any of claims 4 and 8, characterized in that a cutter (shears) for length cutting the side edges of the sheet workpieces are arranged after the run-off table.

10. The production line for producing foam aluminum sheets according to claim 4, characterized in that working rolls with inner heating are arranged in the stand for hot compaction of the powder mixture in the shell.
Plan according to arrow A
Figure 5.

Figure 6.

A—A
Figure 5.

Figure 7.
# INTERNATIONAL SEARCH REPORT

**International application No.**

PCT/RU 2008/000640

## A. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both national classification and IPC:

- B22F 3/18 (2006.01)
- B22F 3/24 (2006.01)
- C22C 1/08 (2006.01)

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols):

- B22F 3/00, 3/10, 3/11, 3/18, 3/24, C22C 1/00, 1/04, 1/08, F27B 3/00, 3/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used):

- DEPATISNET, EAPATIS, Esp@cenet, PAJ, PCT Outline, RUPTO, USPTO, WIPO

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>A</td>
<td>RU 2206430 C1 (SEREDKIN VLADIMIR PAVLOVICH) 20.06.2003, the abstract</td>
<td>1-3</td>
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* Further documents are listed in the continuation of Box C.  
* See patent family annex.

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Name and mailing address of the ISA/Authorized officer:

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 10324904 A [0005]
- RU 2200647 [0007]

Non-patent literature cited in the description