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(54) **METHOD AND DIE APPARATUS USED FOR PRODUCING WIDE MAGNESIUM PLATES**

(57) A method and a die apparatus for producing wide magnesium sheets, the die apparatus comprising at least an inner container (1) provided with a billet processing cavity, wherein the billet processing cavity comprises a die cavity (101), a forward extruding area (102), a multi-corner equal channel angular extruding area (103) and a magnesium sheet outlet (104) which are sequentially connected; wherein the forward extruding area (102) is a tapered structure with a larger top and a smaller bottom, and the multi-corner equal channel angular extruding area (103) has at least two corners.

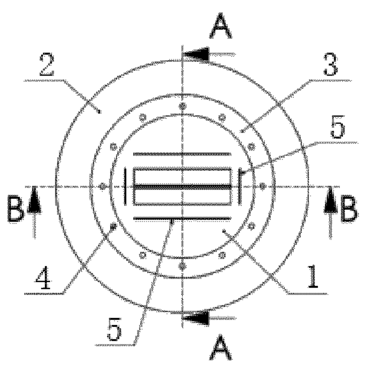

Fig. 1

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Description

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to Chinese Application No. 201811469436X filed on November 27, 2018, entitled "Method and Die Apparatus for Producing Wide Magnesium Sheets," which is hereby incorporated by reference in its entirety.

FIELD OF TECHNOLOGY

[0002] The present disclosure relates to the technical field of magnesium sheet production, and more particularly, to a method and a die apparatus for producing wide magnesium sheets.

BACKGROUND

[0003] Magnesium alloy is the lightest metallic structural material in practical applications, with a series of advantages such as small specific gravity, high specific strength and stiffness, good damping, thermal conductivity and electromagnetic shielding performance. Therefore, it is being widely used in the automotive industry, communication electronics industry, aerospace and other fields, and thus magnesium alloy industry is recognized as the most promising new material industry in the 21st century. However, due to the hexagonal close-packed crystal structure of magnesium alloy, only basal slipping and conical twinning can be initiated as for its plastic deformation when the temperature is lower than 200°C, resulting in poor plasticity of the magnesium alloy at room temperature. The common production process of the magnesium alloy is still based on low-pressure casting. Compared with cast magnesium alloy, wrought magnesium alloy has a denser structure, smaller grain size, and better mechanical properties, thereby meeting the needs of a wider variety of structural members. However, due to the structural property of being resistant to deformation, the magnesium alloy often breaks directly or forms strong anisotropy during plastic processing, which reduces the yield and quality of magnesium alloy sheets, thereby limiting the use of magnesium alloys as structural members.

[0004] At present, there are mainly the following problems in the processing and production of magnesium alloy wide sheets in industrial production:

[0005] 1. The width does not meet the application requirements. Early large-scale wide sheets were produced by widening, extruding and re-unfolding thin-walled profiles having a cross-sectional shape of a semi-circle or the like. The traditional widening and extruding method is to directly add a widening die at the end of an extrusion container to obtain wide-section extrusion, but extruded products often have defects such as underfilled edges. On the one hand, the edge of the extruded wide sheet is serrated, and the extrusion speed is quite low, resulting in very low production efficiency; on the other hand, the width-to-length ratio is generally small and the width-to-length range is also limited, which makes it difficult to extrude large-scale wide sheet materials. The thin-walled profiles having the shape of a semi-circle are subsequently subjected to plastic working to form a wide sheet, with a maximum width of 800 mm. However, because the wide sheet subjected to plastic working is deformed at the unfolding position, it is prone to form wrinkles and cracks, which affect the appearance and product quality. In addition, the service life of such necessary tongue-shaped die orifice is relatively low, the die is quickly scrapped, and the re-unfolding leads to secondary processing defects, and thus the shape is rarely used. Moreover, due to the small activated slip system of magnesium alloys, poor deformability at room temperature, and easy to oxidize and burn at high temperature, it is more complicated and difficult to produce qualified wide sheets.

[0006] 2. The plasticity does not meet the application requirements. Magnesium alloys have poor plasticity at room temperature, and sheet and strip products are more likely to form severe anisotropy and thus cannot be used. The method of improving the plasticity of magnesium alloy sheet is mainly to refine the grain, that is, to refine the grain to less than 10 μm, while increasing the elongation to more than 15%, so as to ensure the successful subsequent deep processing. For the cast structure with coarse columnar crystals, this level of fine grains can only be obtained through large plastic deformation processes.

[0007] 3. The traditional processes and methods do not meet the application requirements. The processing methods for industrial production of magnesium alloy sheet structural parts mainly include rolling and extrusion, by which the forming quality is difficult to guarantee, and defects such as waves and cracks are prone to occur, and the forming width is limited.

[0008] 4. The traditional production equipment does not meet the application requirements. In the traditional magnesium sheet manufacturing method, the production equipment is relatively simple and has the disadvantages of multi-pass, low speed, and uneven performance of the magnesium sheets. The large plastic deformation process can greatly improve the performance of the magnesium sheet. However, the design structure of the die is more complicated, the equipment has limited tonnage, and the specification of the magnesium sheet is smaller, hence industrial application has not yet been achieved. The magnesium alloy with better performance can be obtained at the first pass by a composite process of traditional method combined with large plastic deformation process, however, the lubrication structure is not optimized, which leads to serious die wear and thus continuous production is not enabled.

SUMMARY

(I) Technical problems to be solved

[0009] An objective of the present disclosure is to provide a method and a die apparatus for producing wide magnesium sheets, so as to solve the problems of low yield and poor quality of magnesium alloy sheets, low production efficiency, and inability to achieve continuous production in the prior art.

(II) Technical solutions

[0010] In order to solve at least the above technical problems, the present disclosure provides a die apparatus for producing wide magnesium sheets, including at least an inner container provided with a billet processing cavity, wherein the billet processing cavity includes a die cavity, a forward extruding area, a multi-corner equal channel angular extruding area and a magnesium sheet outlet which are sequentially connected; wherein the forward extruding area is a tapered structure with a larger top and a smaller bottom, and the multi-corner equal channel angular extruding area has at least two corners.

[0011] In an embodiment, the die apparatus further includes an outer container, within which the inner container is detachably mounted.

[0012] In an embodiment, a middle lining is disposed between the outer container and the inner container, and a plurality of heating tubes are embedded in the middle lining and are uniformly arranged on a periphery of the inner container in a ring shape.

[0013] In an embodiment, a thermal insulation layer is provided between the outer container and the middle lining.

[0014] In an embodiment, the inner container is provided with a plurality of lubricant flowing holes along a circumference of the die cavity, an upper end of the lubricant flowing hole passes through an upper surface of the inner container to communicate with the outside, and a lower end of the lubricant flowing hole communicates with the die cavity.

[0015] Specifically, the outer container has a split structure.

[0016] In order to solve at least the above technical problems, the present disclosure provides a method for producing wide magnesium sheets, including at least the following steps:

mounting a die apparatus onto a main engine so that an indenter on the main engine corresponds to a die cavity of the die apparatus, wherein the die apparatus is the die apparatus for producing wide magnesium sheets mentioned above;

preheating the die apparatus to a first predetermined temperature and maintaining the first predetermined temperature;

preheating a magnesium alloy billet to a second predetermined temperature;

placing the magnesium alloy billet into the die cavity of the die apparatus; and

starting the main engine to allow the indenter to apply pressure to the magnesium alloy billet in the die cavity, and sequentially extruding the magnesium alloy billet in the forward extruding area and the multi-corner equal channel angular extruding area and obtaining a formed magnesium sheet from a magnesium sheet outlet.

[0017] In an embodiment, a process temperature at which the magnesium alloy billet is extruded in the forward extruding area is maintained at the first predetermined temperature.

[0018] In an embodiment, a process temperature at which the magnesium alloy billet is extruded in the multi-corner equal channel angular extruding area is lower than the first predetermined temperature.

[0019] Specifically, the process temperature is gradually reduced when the magnesium alloy billet passes through a plurality of corners of the multi-corner equal channel angular extruding area from top to bottom.

[0020] In an embodiment, lubricant is injected into the lubricant flowing holes of the die apparatus before staring the main engine.

[0021] Specifically, the die apparatus is preheated to the first predetermined temperature by the heating tubes, and the preferred range of the first predetermined temperature is 200°C to 400°C.

[0022] Specifically, the preferred range of the second predetermined temperature is 250°C to 400°C.

(III) Beneficial effects

[0023] The above technical solutions of the present disclosure have the following advantages:
As for the method and die apparatus for producing wide magnesium sheets according to the present disclosure, the two methods of forward extruding and multi-corner equal channel angular extruding are combined by providing a forward extruding area and a multi-corner equal channel angular extruding area in the inner container. Because the material strength and production efficiency are improved by the forward extruding, and the material plasticity and the uniformity of the structure are improved by the multi-corner equal channel angular extruding, the technological advantages of the two are fully combined, thereby reducing the pretreatment requirements for the billet, such that wide magnesium alloy medium-thick sheets and thin sheets with high plasticity are directly produced in a single processing stroke, enabling continuous production of magnesium sheets. Therefore, it not only improves the production efficiency, but also improves the yield and the quality of the finished product of magnesium alloy sheets. The size and properties of the produced magnesium alloy sheets can meet the size and plasticity requirements of the subsequent deep processing of the magnesium alloy sheets, thereby providing a guarantee for the subsequent processing and forming; moreover, the magnesium alloy sheets can be used directly for industrial applications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

FIG. 1 is a schematic diagram of the assembly structure of a die apparatus for producing wide magnesium sheets according to an embodiment of the present disclosure;

FIG. 2 is a cross-sectional view along A-A in FIG. 1 of a die apparatus for producing wide magnesium sheets according to an embodiment of the present disclosure;

FIG. 3 is a cross-sectional view along B-B in FIG. 1 of a die apparatus for producing wide magnesium sheets according to an embodiment of the present disclosure;

FIG. 4 is a schematic diagram of the structure of an inner container in a die apparatus for producing wide magnesium sheets according to an embodiment of the present disclosure;

FIG. 5 is a cross-sectional view along C-C in FIG. 4 of a die apparatus for producing wide magnesium sheets according to an embodiment of the present disclosure;

FIG. 6 is a cross-sectional view along D-D in FIG. 4 of a die apparatus for producing wide magnesium sheets according to an embodiment of the present disclosure; and

FIG. 7 is a schematic diagram of the structure of an outer container adopting a split structure in a die apparatus for producing wide magnesium sheets according to an embodiment of the present disclosure.

Reference Numerals:

[0025]

1 inner container	101 die cavity
102 forward extruding area	
103 multi-corner equal channel angular extruding area	
104 magnesium sheet outlet	2 outer container
3 middle lining	4 heating tube
5 lubricant flowing hole	

DETAILED DESCRIPTION

[0026] In order to specify the objectives, technical solutions and advantages of the embodiments of the present disclosure, the technical solutions in the embodiments of the present disclosure will be described clearly and completely in conjunction with the accompanying drawings in the embodiments of the present disclosure. Obviously, the embodiments described below are part of the embodiments of the present disclosure, rather than all of the embodiments. Based on the embodiments in the present disclosure, all other embodiments obtained by those of ordinary skill in the art without creative effort shall fall within the protection scope of the present disclosure.

[0027] As shown in FIGS. 1-7, an embodiment of the present disclosure provides a die apparatus for producing wide magnesium sheets, including at least an inner container 1 provided with a billet processing cavity, wherein the billet processing cavity includes a die cavity 101, a forward extruding area 102, a multi-corner equal channel angular extruding area 103 and a magnesium sheet outlet 104 which are sequentially connected; wherein the forward extruding area 102 is a tapered structure with a larger top and a smaller bottom, and the multi-corner equal channel angular extruding area 103 has at least two corners sequentially arranged from top to bottom.

[0028] In this embodiment, the multi-corner equal channel angular extruding area 103 is preferably provided with six corners, wherein the two corners disposed at the uppermost end and the lowermost end are obtuse angles greater than 90°, and the four corners disposed at the middle position are all 90° right angles. This configuration of the multi-corner equal channel angular extruding area 103 ensures that the outlet and the inlet of the multi-corner equal channel angular extruding area 103 are in a straight line and thus the best process effects are provided.

[0029] During operation, a magnesium alloy billet is placed into the die cavity 101, and then is extruded by an indenter. The magnesium alloy billet is sequentially extruded in the forward extruding area 102 and the multi-corner equal channel angular extruding area 103 to obtain a processed formed magnesium sheet from a magnesium sheet outlet 104.

[0030] In the first half of the process, the magnesium alloy billet is forwardly extruded by the forward extruding area 102. The thickness of the magnesium alloy billet can be thinned by the forward extruding, and the restriction on the size range of the magnesium alloy billet for subsequent multi-corner equal channel angular extruding is relaxed, avoiding secondary processing of the magnesium alloy billet. In the forward extruding area 102, since a tapered structure with a larger top and a smaller bottom is adopted, the direct contact area between the magnesium alloy billet and the indenter is relatively large, which is beneficial to the stable progress of the deformation process and reduces the instability and wrinkle of the magnesium alloy billet and die wear. The forward extruding can provide greater three-dimensional compressive stress, partially refine the original coarse grains, heal structure defects, improve material strength, and provide well structural preparation for the subsequent equal channel angular extruding.

[0031] In the second half of the process, the magnesium alloy billet forwardly extruded is subjected to multi-corner equal channel angular extruding through the multi-corner equal channel angular extruding area 103. The multi-corner equal channel angular extruding can provide shear strain at an angle of 45° to the extrusion direction, change the texture orientation of the forwardly extruded structure, and avoid the anisotropy of the magnesium alloy billet. The continuous shear deformation of multi-corner equal channel angular extruding promotes the complete dynamic recrystallization of the microstructure of the magnesium alloy billet, so that the grains of the magnesium alloy billet are refined and the plasticity is significantly improved.

[0032] As for the method and die apparatus for producing wide magnesium sheets according to the present disclosure, the two methods of forward extruding and multi-corner equal channel angular extruding are combined. Because the material strength and production efficiency are improved by the forward extruding, and the material plasticity and the uniformity of the structure are improved by the multi-corner equal channel angular extruding, the technological advantages of the two are fully combined, thereby reducing the pretreatment requirements for the raw billet, such that wide magnesium alloy medium-thick sheets and thin sheets with high plasticity are directly produced in a single processing stroke, enabling continuous production of magnesium sheets. Therefore, it not only improves the production efficiency, but also improves the yield and the quality of the finished product of magnesium alloy sheets. The size and properties of the produced magnesium alloy sheets can meet the size and plasticity requirements of the subsequent deep processing of the magnesium alloy sheets, thereby providing a guarantee for the subsequent processing and forming; moreover, the magnesium alloy sheets can be used directly for industrial applications.

[0033] Furthermore, the die apparatus for producing wide magnesium sheets according to the embodiments of the present disclosure further includes an outer container 2, within which the inner container 1 is detachably mounted, so as to facilitate the removal of the inner container 1 from the outer container 2, followed by the maintenance of the inner container 1.

[0034] The outer container 2 may adopt an integrally formed structure, as shown in FIG. 1; alternatively, the outer container 2 may adopt a split structure, as shown in FIG. 7. If the outer container 2 adopts a split structure, it is necessary to connect the parts of the outer container 2 to form a whole by connecting pieces. Wherein the connecting piece can be arbitrarily selected according to actual use requirements, for example, a steel wire can be wound around the outer container 2 to pre-tighten and fix the outer container 2.

[0035] Likewise, the inner container 1 may also adopt an integrally formed structure or a split structure, depending on the actual use requirements.

[0036] Furthermore, a middle lining 3 is disposed between the outer container 2 and the inner container 1, and a plurality of heating tubes 4 are embedded in the middle lining 3 and are uniformly arranged on a periphery of the inner container 1 in a ring shape. The heating tubes 4 are provided to heat the inner container 1, and the process temperature is adjusted and controlled by controlling the temperatures of the heating tubes 4.

[0037] Furthermore, a thermal insulation layer (not shown in the figures) is provided between the outer container 2 and the middle lining 3 to prevent heat from being diffused and lost to the outer container 2.

[0038] Furthermore, the inner container 1 is provided with a plurality of lubricant flowing holes 5 along a circumference of the die cavity 101, an upper end of each lubricant flowing hole 5 passes through an upper surface of the inner container 1 to communicate with the outside, and a lower end of each lubricant flowing hole 5 communicates with the die cavity 101. The lubricant flowing holes 5 are configured to add lubricant to the die cavity 101 to ensure the continuous supply of lubricant during the process.

[0039] In this embodiment, the die cavity 101 has a rectangular structure, and four lubricant flowing holes are provided on each side of the rectangle corresponding to the circumference of the die cavity 101. The lubricant flowing holes include the lubricant flowing holes 5A arranged on the two long sides of the die cavity 101 and the lubricant flowing holes 5B arranged on the two short sides of the die cavity 101, respectively, each lubricant flowing hole 5A and each lubricant flowing hole 5B being rectangular in shape. With this arrangement of lubricant flowing holes, lubricant can be filled from the four sides of the die cavity 101 at the same time, so as to achieve the best lubrication effect during the process.

[0040] An embodiment of the present disclosure further provides a method for producing wide magnesium sheets, in this method, the die apparatus in the foregoing embodiments is employed to produce wide magnesium sheets, and the method includes at least the following steps:

S 1. selecting a magnesium alloy billet;

S2. mounting an assembled die apparatus onto a main engine so that an indenter on the main engine corresponds to a die cavity 101 of the die apparatus;

S3. preheating the die apparatus to a first predetermined temperature by heating tubes 4 and maintaining the first predetermined temperature, wherein the range of the first predetermined temperature is preferably 200°C to 400°C;

S4. preheating the magnesium alloy billet to a second predetermined temperature, wherein the range of the second predetermined temperature is preferably 250°C to 400°C, and the second predetermined temperature may be 10°C to 20°C higher than the first predetermined temperature depending on actual requirements.

S5. injecting lubricant into the lubricant flowing holes 5A and the lubricant flowing holes 5B of the inner container 1;

S6. placing the preheated magnesium alloy billet into the die cavity 101 of the inner container 1;

S7. starting the main engine to drive the indenter to apply pressure to the magnesium alloy billet in the die cavity 101, and sequentially extruding the magnesium alloy billet in the forward extruding area 102 and the multi-corner equal channel angular extruding area 103 and obtaining a formed magnesium sheet extruded from a magnesium sheet outlet 104, wherein the extrusion speed of the magnesium alloy billet is controlled at 0.5 to 1.5 m/min.

[0041] Furthermore, in the S7, the process temperature at which the magnesium alloy billet is extruded in the forward extruding area 102 is maintained at the first predetermined temperature.

[0042] Furthermore, in the S7, the process temperature at which the magnesium alloy billet is extruded in the multi-corner equal channel angular extruding area 103 is lower than the first predetermined temperature.

[0043] Specifically, in the S7, the process temperature is gradually reduced when the magnesium alloy billet passes through a plurality of corners of the multi-corner equal channel angular extruding area 103 from top to bottom.

[0044] Furthermore, in the S2, the assembling steps of the die apparatus are as follows: firstly, assembling the inner container 1 and the middle lining 3 by interference fit; secondly, assembling the thermal insulation layer on the outer side of the middle lining 3; and finally, assembling the outer container 2 to the outer side of the thermal insulation layer by wire winding.

[0045] Specifically, in the S5, graphite mixed lubricant can be used as the lubricant.

[0046] Specifically, in the S1, the magnesium alloy billet can be magnesium alloy billet AZ31, the size of the magnesium alloy billet is: 500 to 2000 mm in width, 10 to 500 mm in thickness, and the length can be set according to actual process requirements and the size of the die cavity 101. Wherein the magnesium alloy billet is preferably magnesium alloy ingot. Since the requirements for the type of billet in the present disclosure are relatively low, the billet is not limited to cast billets, but can also be extruded billets, forged billets, etc.

[0047] In the method for producing wide magnesium sheets in the embodiments of the present disclosure, the two methods of forward extruding and multi-corner equal channel angular extruding are combined to achieve the industrial production of large-size magnesium alloy products. Taking a magnesium alloy cast billet as the raw billet as an example, the process principle of this method will be described in detail as follows.

[0048] The as-cast microstructure of magnesium alloy includes mostly coarse equiaxed crystals with random orientation. After magnesium alloy cast billet passes through the forward extruding area 102, the grain microstructure is bent and broken, and then re-arranged under stress to form a long crystal zone parallel to the extrusion direction. Due to the relatively high extrusion temperature, the non-basal slip system in the forward extruding area 102 can be activated. Therefore, the main deformation mechanism is intragranular dislocation slip, and partial dynamic recrystallization occurs at the grain boundary, and thus a necklace-like recrystallized microstructure around the original coarse crystals is formed. The grains are refined after the magnesium alloy casting billet is subjected to forward extruding deformation, and the microstructure is composed of large-sized long strip crystals and chain-like distributed fine equiaxed crystals, while forming an extruded fiber texture with basal plane orientation.

[0049] Afterwards, the magnesium alloy cast billet enters the multi-corner equal channel angular extruding area 103 and is subjected to multi-corner equal channel angular extruding operation. In this process, on the one hand, the grains are subjected to severe shear deformation, and the dislocation density in the shear zone increases rapidly, resulting in dislocation tangle and formation of dislocation cells. Further, a small-angle sub-grain boundaries are formed, which continues to absorb dislocations and the angle continues to increase, and small-angle sub-grain boundaries are eventually converted to large-angle grain boundaries. In addition, due to the large stress field between the tangled dislocations, the dislocations will be rearranged and a subcrystalline structure will also be formed, and it gradually transformed into large-angle grain boundaries through grain boundary migration, thereby forming stable recrystallized grains. The recrystallized grains originally formed at the grain boundaries are deforming as they grow, and a new round of recrystallization nucleation and growth will occur after the critical strain value is reached. The texture orientation formed in the forward extruding process can be changed through the shear deformation from the multi-corner equal channel angular extruding, the Schmid factor originally in the hard orientation slip system can be increased, the texture is softened, the basal surface slip is activated, and then the microstructure deformability is enhanced. On the other hand, due to the grain refinement caused by the previous deformation, the plasticity of the alloy has been greatly improved. At this point, the softening mechanism of recrystallization is emerging, which is manifested as a slow decline in the forming force on the macro level. The main deformation mechanism of the billet when it passes through the last few corners is similar. As the deformation continues, dynamic recrystallization proceeds more completely and the structure grains are more fine and uniform by means of the accumulation of strain. After continuous shear deformation in the multi-corner equal channel angular extruding area 103, the magnesium alloy structure can be refined to submicron level (100 nm to 1 μm), and the texture orientation is randomized. The deformation mechanism of magnesium alloys is diversified, therefore, when the number of corners is continuously increased in the future, the energy storage of crystal deformation is reduced, the dynamic recrystallization is slow, and the grain refinement effect is not obvious.

[0050] After the magnesium alloy casting billet is subjected to forward extruding and multi-corner equal channel angular extruding, the uniform and fine dynamic recrystallization structure completely replaces the coarse equiaxed crystals in the original as-cast state. At the same time, the severe shear deformation makes the orientation factor of the slip system inside the crystal larger, the plasticity as well as the strength of the alloy are greatly improved, and the structure properties tend to be isotropic.

[0051] In summary, as for the method and die apparatus for producing wide magnesium sheets according to the embodiments of the present disclosure, the two methods of forward extruding and multi-corner equal channel angular extruding are combined by providing a forward extruding area and a multi-corner equal channel angular extruding area in the inner container. Because the material strength and production efficiency are improved by the forward extruding, and the material plasticity and the uniformity of the structure are improved by the multi-corner equal channel angular extruding, the technological advantages of the two are fully combined, thereby reducing the pretreatment requirements for the billet, such that wide magnesium alloy medium-thick sheets and thin sheets with high plasticity are directly produced in a single processing stroke, enabling continuous production of magnesium sheets. Therefore, it not only improves the production efficiency, but also improves the yield and the quality of the finished product of magnesium alloy sheets. The size and properties of the produced magnesium alloy sheets can meet the size and plasticity requirements of the subsequent deep processing of the magnesium alloy sheets, thereby providing a guarantee for the subsequent processing and forming; moreover, the magnesium alloy sheets can be used directly for industrial applications.

[0052] In the description of the present disclosure, unless otherwise clearly specified or defined, it should be noted that the terms "connect with" and "connect to" should be understood in a broad sense, for example, it can be a fixed connection or a detachable connection, or an integral connection; it can be mechanically or electrically connected, directly connected or indirectly connected through an intermediary. For those of ordinary skill in the art, the specific meaning of the above terms in the present disclosure can be understood according to the specific situations.

[0053] In the description of the present disclosure, unless otherwise specified, "a number of' means one or more, and "a plurality of' means two or more; the orientation or positional relationship indicated by the terms such as "upper," "lower," "left," "right," "inner," and "outer" is based on the orientation or positional relationship shown in the drawings, the purpose of which is only to facilitate describing the present disclosure and simplify the description, rather than to indicate or imply that the device or element referred to must have a specific orientation, be constructed and operated in a specific orientation, and therefore cannot be construed as a limitation of the present disclosure.

[0054] It should be noted that the embodiments are only for illustrating the technical solutions of the present disclosure, rather than limiting them; although the present disclosure has been described in detail with reference to the foregoing embodiments, those skilled in the art should understand that the technical solutions documented in the preceding embodiments may still be modified, or parts of the technical features thereof can be equivalently substituted; and such modifications or substitutions do not deviate from scope of the technical solutions of the embodiments of the present disclosure.

Claims

1. A die apparatus for producing wide magnesium sheets, **characterized by** comprising at least an inner container provided with a billet processing cavity, wherein the billet processing cavity comprises a die cavity, a forward extruding area, a multi-corner equal channel angular extruding area and a magnesium sheet outlet which are sequentially connected; wherein the forward extruding area is a tapered structure with a larger top and a smaller bottom, and the multi-corner equal channel angular extruding area has at least two corners.

2. The die apparatus for producing wide magnesium sheets of claim 1, further comprising an outer container, within which the inner container is detachably mounted.

3. The die apparatus for producing wide magnesium sheets of claim 2, wherein a middle lining is disposed between the outer container and the inner container, and a plurality of heating tubes are embedded in the middle lining and are uniformly arranged on a periphery of the inner container in a ring shape.

4. The die apparatus for producing wide magnesium sheets of claim 3, wherein a thermal insulation layer is provided between the outer container and the middle lining.

5. The die apparatus for producing wide magnesium sheets of claim 1, wherein the inner container is provided with a plurality of lubricant flowing holes along a circumference of the die cavity, an upper end of the lubricant flowing hole passes through an upper surface of the inner container to communicate with the outside, and a lower end of the lubricant flowing hole communicates with the die cavity.

6. A method for producing wide magnesium sheets, comprising at least the following steps:

   mounting a die apparatus onto a main engine so that an indenter on the main engine corresponds to a die cavity of the die apparatus, wherein the die apparatus is the die apparatus for producing wide magnesium sheets of any one of claims 1-5;
   preheating the die apparatus to a first predetermined temperature and maintaining the first predetermined temperature;
   preheating a magnesium alloy billet to a second predetermined temperature;
   placing the magnesium alloy billet into the die cavity of the die apparatus; and
   starting the main engine to allow the indenter to apply pressure to the magnesium alloy billet in the die cavity, and sequentially extruding the magnesium alloy billet in the forward extruding area and the multi-corner equal channel angular extruding area and obtaining a formed magnesium sheet from a magnesium sheet outlet.

7. The method for producing wide magnesium sheets of claim 6, wherein a process temperature at which the magnesium alloy billet is extruded in the forward extruding area is maintained at the first predetermined temperature, and a process temperature at which the magnesium alloy billet is extruded in the multi-corner equal channel angular extruding area is lower than the first predetermined temperature.

8. The method for producing wide magnesium sheets of claim 7, wherein the process temperature is gradually reduced when the magnesium alloy billet passes through a plurality of corners of the multi-corner equal channel angular extruding area from top to bottom.

9. The method for producing wide magnesium sheets of claim 6, further comprising:

injecting lubricant into the lubricant flowing holes of the die apparatus before staring the main engine.

10. The method for producing wide magnesium sheets of claim 6, wherein the die apparatus is preheated to the first predetermined temperature by heating tubes, the first predetermined temperature is 200°C to 400°C, and the second predetermined temperature is 250°C to 400°C.

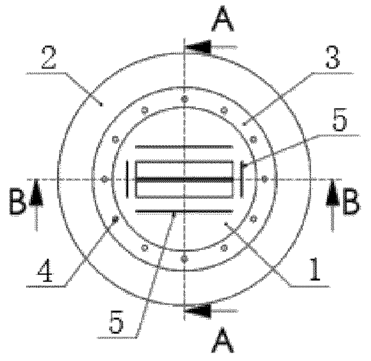

Fig. 1

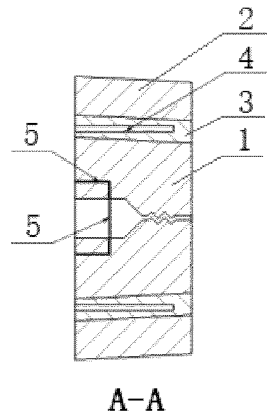

Fig. 2

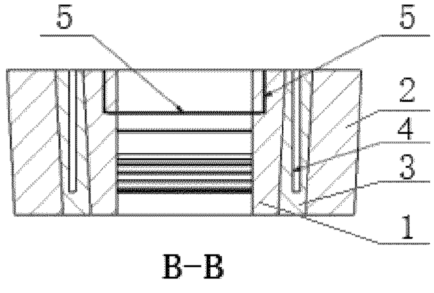

Fig. 3

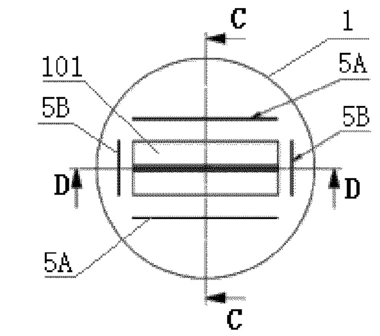

Fig. 4

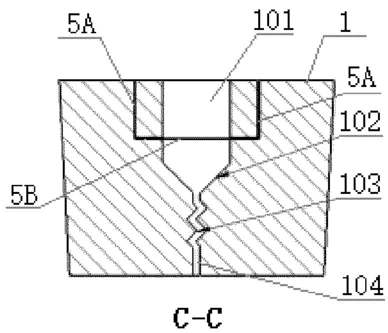

Fig. 5

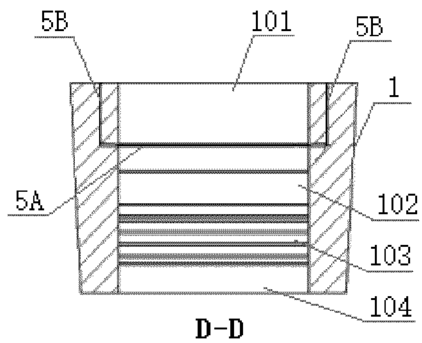

Fig. 6

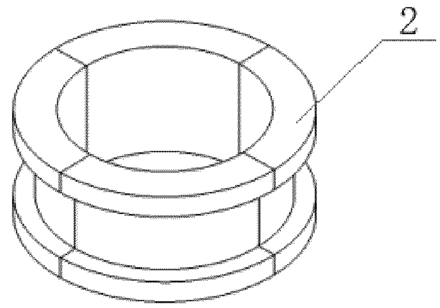

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2019/101914

A. CLASSIFICATION OF SUBJECT MATTER

B21C 25/02(2006.01)i; B21C 23/02(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B21C

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)

CNABS; CNKI; VEN; CNTXT; EPTXT; WOTXT; USTXT: 镁板, 内筒, 外筒, 挤压, 拐角, 模具, magnesium, sleeve, corner, mould, press

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 109513762 A (TSINGHUA UNIVERSITY) 26 March 2019 (2019-03-26) description, paragraphs [0040]-[0075], and figures 1-7	1-10
X	CN 206083461 U (HUNAN UNIVERSITY OF SCIENCE AND TECHNOLOGY) 12 April 2017 (2017-04-12) description, paragraphs [0023]-[0037], and figures 3 and 4	1, 5
Y	CN 206083461 U (HUNAN UNIVERSITY OF SCIENCE AND TECHNOLOGY) 12 April 2017 (2017-04-12) description, paragraphs [0023]-[0037], and figures 3 and 4	2-4, 6-10
Y	CN 105032964 A (TAIYUAN UNIVERSITY OF TECHNOLOGY) 11 November 2015 (2015-11-11) description, paragraphs [0017]-[0022], and figure 1	2-4, 6-10
A	JP 2008194749 A (MIZUNUMA, S.) 28 August 2008 (2008-08-28) entire document	1-10

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
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- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 October 2019	**15 November 2019**

Name and mailing address of the ISA/CN

China National Intellectual Property Administration
No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088
China

Facsimile No. **(86-10)62019451**

Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2019/101914

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 109513762 A	26 March 2019	None	
CN 206083461 U	12 April 2017	None	
CN 105032964 A	11 November 2015	CN 105032964 B	23 November 2016
JP 2008194749 A	28 August 2008	None	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 201811469436X **[0001]**