In some preferred embodiments, an extrusion die 10 for a metallic material includes a die case 20 having a pressure receiving portion 21 with a metallic material pressure receiving surface 22 faced rearward against an extrusion direction, a male die 30 disposed in the die case 20, and a female die 40 disposed in the die case 20. The pressure receiving portion 21 is formed into a convex configuration protruded rearward, and a porthole 24 for introducing the metallic material is provided in an outer periphery of the pressure receiving portion 21. A ratio of a flat state opening area $S_b$ of the porthole inlet portion 24 to a flat state area $S_a$ of the pressure receiving portion 21 is set to 0.15 to 0.80. The extrusion die is configured such that the metallic material pressurized against the metallic material pressure receiving surface 22 is introduced into the die case 20 via the porthole 24 and passes through the extrusion hole 11.
FIG. 5
EXTRUSION DIE FOR METALLIC MATERIAL


CROSS REFERENCE TO RELATED APPLICATIONS


TECHNICAL FIELD

[0003] The present invention relates to an extrusion die for a metallic material used for extruding a metallic material and its related art.

BACKGROUND ART

[0004] An extrusion die used for manufacturing a metallic hollow extruded product, such as, e.g., an aluminum heat exchanging tube for use in a heat exchanger for a car air-conditioner, there being a porthole die as shown in FIG. 44A, a spider die as shown in FIG. 44B, and a bridge die as shown in FIG. 44C.

[0005] In these extrusion dies, a male die 1 and a female die 2 are combined in a state in which the mandrel 1a of the male die 1 is placed in the corresponding die hole 2a of the female die 2 to define a circular extrusion hole by and between the mandrel 1a and the die hole 2a. The extrusion die is configured such that a metallic billet (metallic material) pressed against the billet pressure receiving surface (metallic material pressure receiving surface 1b) of the male die 1 is introduced into the dies 1 and 2 via material introduction portions 1c and then passed through the extrusion hole while being plastically deformed, so that an extruded member having a cross-sectional shape corresponding to the cross-sectional shape of the extrusion hole is formed.

[0006] In such an extrusion die, since large stress due to the pressing of the metallic billet is applied to the billet pressure receiving surface 1b of the male die 1, the stress may cause generation of cracks in the periphery of the pressure receiving portion of the die, which may sometimes make it difficult to attain sufficiently long die life.

[0007] Under the circumstances, an extrusion die for a metallic material as disclosed by the below-listed Patent Documents 1 and 2 has been conventionally proposed. In the die, the billet pressure receiving surface of the male die is formed into a convex shape protruded in a direction opposite to the billet extruding direction (i.e., protruded rearward) so that the pressing force of the metallic billet to be applied to the billet pressure receiving surface can be received by a bridge portion of the male die.


[0010] In the conventional extrusion die disclosed in the aforementioned Patent Documents 1 and 2, since the billet pressure receiving surface is formed into a convex configuration, the bridge portion is still insufficient in strength although the strength of the male die, such as the resistance to pressure against a metallic billet, can be improved to some extent. Therefore, in order to secure sufficient strength of the bridge portion, the size of the male die such as the thickness of the bridge portion has to be increased, which results in not only an increased size and an increased weight but also an increased cost.

[0011] Especially in the case of extruding an extruded article having a complicated configuration using an extrusion die, it is necessary to stably and smoothly introduce the metallic material into the extrusion hole from the material introducing portion of the male die. In the aforementioned conventional extrusion die, however, the metallic material which flows from the material introducing portion of the male die into the space between the male die and the female die is disturbed by the bridge portion of the male die. This prevents smooth introduction of the metallic material, causing deterioration of dimensional accuracy of the extruded article, which in turn makes it difficult to attain high quality.

[0012] The description herein of advantages and disadvantages of various features, embodiments, methods, and apparatus disclosed in other publications is no way intended to limit the present invention. Indeed, certain features of the invention may be capable of overcoming certain disadvantages, while still retaining some or all of the features, embodiments, methods, and apparatus disclosed therein.

[0013] Other objects and advantages of the present invention will be apparent from the following preferred embodiments.

DISCLOSURE OF INVENTION

[0014] The preferred embodiments of the present invention have been developed in view of the above-mentioned and/or other problems in the related art. The preferred embodiments of the present invention can significantly improve upon existing methods and/or apparatuses.

[0015] The present invention was made to solve the aforementioned problems of conventional techniques, and aims to provide an extrusion die for a metallic material capable of obtaining a high quality extruded article while reducing the cost and size of the die and securing sufficient strength and durability of the die.

[0016] The present invention also aims to provide related technologies capable of attaining the aforementioned objectives, such as, e.g., a production method of an extruded article, a production method of an extruded tubular member, a production method of a multi-passage hollow member, a die case for an extrusion die, an extrusion method of a metallic material, and an extruder for a metallic material.

[0017] The present invention provides the following means to attain the aforementioned objects.

[0018] 1] An extrusion die for a metallic material, comprising:

[0019] a die case having a pressure receiving portion with an outer surface functioning as a metallic material pressure receiving surface, the die case being disposed with the metallic material pressure receiving surface faced rearward against an extrusion direction of the metallic material;
[0020] a male die disposed in the die case; and
[0021] a female die disposed in the die case to define an extrusion hole between the male die and the female die,
[0022] wherein the pressure receiving surface is formed into a convex configuration protruded rearward, and a port-hole for introducing the metallic material is provided in an outer periphery of the pressure receiving portion,
[0023] wherein a ratio of an opening area of an inlet portion of the port-hole defined by a plan view as seen from an axial upstream side (a plan state opening area of the inlet portion of the port-hole) to an area of the pressure receiving portion defined by a plan view as seen from the axial upstream side (a plan state area of the pressure receiving portion) is set to 0.15 to 0.80, and
[0024] wherein the extrusion die is configured such that the metallic material pressurized against the metallic material pressure receiving surface is introduced in the die case via the port-hole and passes through the extrusion hole.

[0025] [2] The extrusion die for a metallic material as recited in the aforementioned Item 1, wherein the metallic material pressure receiving portion is constituted by a convex spherical surface of a 1/4 to 9/4 sphere.

[0026] [3] The extrusion die for a metallic material as recited in the aforementioned Item 1 or 2, wherein a plurality of port-holes are formed at regular intervals in a circumferential direction about an axis of the die case.

[0027] [4] The extrusion die for a metallic material as recited in any one of the aforementioned Items 1 to 3, wherein the port-hole is arranged toward the extrusion hole.

[0028] [5] The extrusion die for a metallic material as recited in any one of the aforementioned Items 1 to 4, wherein an inclination of an axis of the port-hole with respect to an axis of the die case is set to 3 to 45°.

[0029] [6] The extrusion die for a metallic material as recited in any one of the aforementioned Items 1 to 5, wherein the extrusion hole is formed into a flat cross-sectional configuration with a width larger than a thickness, and

[0030] wherein the port-holes are formed at positions corresponding to thickness directional both sides of the extrusion die.

[0031] [7] The extrusion die for a metallic material as recited in any one of the aforementioned Items 1 to 6,

[0032] wherein the male die and the female die define a flat circular extrusion with a height (thickness) smaller than a width,

[0033] wherein a portion of the male die corresponding to the extrusion hole is formed into a comb-like configuration having a plurality of passage forming protrusions arranged in a width direction, and

[0034] wherein the extrusion die is configured such that the metallic material passes through the extrusion hole to form a multi-passage hollow member with a plurality of passages arranged in a width direction.

[0035] [8] The extrusion die for a metallic material as recited in any one of the aforementioned Items 1 to 6, wherein the male die and the female die define a circular extrusion hole, and the extrusion die is configured such that the metallic material passes through the extrusion hole to form a tubular member circular in cross-section.

[0036] [9] The extrusion die for a metallic material as recited in any one of the aforementioned Items 1 to 8, wherein the metallic material is an aluminum or its alloy.

[0037] [10] A production method of an extruded article, comprising the step of forming an extruded article using the extrusion die as recited in any one of the aforementioned Items 1 to 9.


[0039] [12] A production method of an extruded tubular member, comprising the step of forming the extruded article using the extrusion die as recited in the aforementioned Item 8.

[0040] [13] A die case for an extrusion die, comprising a pressure receiving portion with an outer surface functioning as a metallic material pressure receiving surface faced rearward against an extrusion direction of the metallic material, the die case being configured to mount a male die and a female die therein,

[0041] wherein the pressure receiving surface is formed into a convex configuration protruded rearward, and a port-hole for introducing the metallic material is provided in an outer periphery of the pressure receiving portion,

[0042] wherein a ratio of an opening area of an inlet portion of the port-hole defined by a plan view as seen from an axial upstream side (a plan state opening area of the inlet portion of the port-hole) to an area of the pressure receiving portion defined by a plan view as seen from the axial upstream side (a plan state area of the pressure receiving portion) is set to 0.15 to 0.80, and

[0043] wherein the die case is configured such that the metallic material pressurized against the metallic material pressure receiving surface is introduced into the die case via the port-hole and passes through the extrusion hole.

[0044] [14] The die case for an extrusion die as recited in the aforementioned Item 13, wherein the metallic material pressure receiving portion is constituted by a convex spherical surface of a 1/4 to 9/4 sphere.

[0045] [15] An extrusion method for a metallic material, comprising the steps of:

[0046] preparing a die case, wherein the die case comprises a pressure receiving portion with an outer surface functioning as a metallic material pressure receiving surface faced rearward against an extrusion direction of the metallic material, a male die mounted in the die case, and a female die mounted in the die case for defining an extrusion hole between the male die and the female die, wherein the pressure receiving surface is formed into a convex configuration protruded rearward, and a port-hole for introducing the metallic material is provided in an outer periphery of the pressure receiving portion, and wherein a ratio of an opening area of an inlet portion of the port-hole defined by a plan view as seen from an axial upstream side (a plan state opening area of the inlet portion of the port-hole) to an area of the pressure receiving portion defined by a plan view as seen from the axial upstream side (a plan state area of the pressure receiving portion) is set to 0.15 to 0.80; and

[0047] introducing the metallic material pressurized against the metallic material pressure receiving surface into the die case via the port-hole to pass through the extrusion hole.

[0048] [16] An extruder for a metallic material equipped with a container and an extrusion die set in the container and configured to supply the metallic material in the container to the extrusion die.
[0049] wherein the extrusion die comprises:
[0050] a die case having a pressure receiving portion with an outer surface functioning as a metallic material pressure receiving surface, the die case being disposed with the metallic material pressure receiving surface faced rearward against an extrusion direction of the metallic material;
[0051] a male die disposed in the die case; and
[0052] a female die disposed in the die case to define an extrusion hole between the male die and the female die,
[0053] wherein the pressure receiving surface is formed into a convex configuration protruded rearward, and a port·
hole for introducing the metallic material is provided in an outer periphery of the pressure receiving portion,
[0054] wherein a ratio of an opening area of an inlet portion of the port·hole defined by a plan view as seen from an axial upstream side (a plan state opening area of the inlet portion of the port·hole) to an area of the pressure receiving portion defined by a plan view as seen from the axial upstream side (a plan state area of the pressure receiving portion) is set to 0.15 to 0.80, and
[0055] wherein the extrusion die is configured such that the metallic material pressurized against the metallic material pressure receiving surface is introduced into the die case via the port·hole and passes through the extrusion hole.
[0056] [17] An extrusion die for a metallic material, comprising:
[0057] a die case having a pressure receiving portion with an outer surface functioning as a metallic material pressure receiving surface, the die case being disposed with the metallic material pressure receiving surface faced rearward against an extrusion direction of the metallic material;
[0058] a male die disposed in the die case; and
[0059] a female die disposed in the die case to define an extrusion hole between the male die and the female die,
[0060] wherein the pressure receiving surface is formed into a convex configuration protruded rearward, a port·hole for introducing the metallic material is provided in an outer periphery of the pressure receiving portion, and an opening area of the inlet portion of the port·hole is set to be larger than a passage cross-sectional area of an inside of the port·hole, and
[0061] wherein the extrusion die is configured such that the metallic material pressurized against the metallic material pressure receiving surface is introduced into the die case via the port·hole and passes through the extrusion hole.
[0062] [18] The extrusion die for a metallic material as recited in the aforementioned Item 17, wherein the port·hole is configured such that a passage cross-sectional area gradually decreases from the inlet portion toward an inside of the port·hole.
[0063] [19] The extrusion die for a metallic material as recited in the aforementioned Item 17 or 18, wherein the port·hole is configured such that a radial length (thickness) of the inlet portion is set to be larger than a thickness of an inside of the port·hole.
[0064] [20] The extrusion die for a metallic material as recited in any one of the aforementioned Items 17 to 19, wherein the port·hole is configured such that a circumferential length (width) of the inlet portion of the port·hole is set to be larger than a width of an inside of the port·hole.
[0065] [21] The extrusion die for a metallic material as recited in any one of the aforementioned Items 17 to 20, wherein a chambered portion is formed at an outer side portion of a peripheral edge of the inlet portion of the port·hole.
[0066] [22] The extrusion die for a metallic material as recited in any one of the aforementioned Items 17 to 21, wherein a chambered portion is formed at an inner side portion of a peripheral edge of the inlet portion of the port·hole.
[0067] [23] The extrusion die for a metallic material as recited in any one of the aforementioned Items 17 to 22, wherein an inclination angle of an outer side surface of an inner peripheral surface of the port·hole to an axis of the extrusion die is set to be larger than an inclination angle of an inner side surface of an inner peripheral surface of the port·hole to an axis of the extrusion die.
[0068] [24] The extrusion die for a metallic material as recited in any one of the aforementioned Items 17 to 23, wherein the metallic material pressure receiving portion is constituted by a convex spherical surface of a 1/6 to 5/6 sphere.
[0069] [25] The extrusion die for a metallic material as recited in any one of the aforementioned Items 17 to 24, wherein a plurality of port·holes are formed at regular intervals in a circumferential direction about an axis of the die case.
[0070] [26] The extrusion die for a metallic material as recited in any one of the aforementioned Items 17 to 25, wherein the extrusion hole is formed into a flat cross-sectional configuration with a width larger than a thickness, and
[0071] wherein the port·holes are formed at positions corresponding to thickness directional both sides of the extrusion die.
[0072] [27] The extrusion die for a metallic material as recited in any one of the aforementioned Items 17 to 26,
[0073] wherein the male die and the female die define a flat circular extrusion hole with a height (thickness) smaller than a width,
[0074] wherein a portion of the male die corresponding to the extrusion hole is formed into a comb-like configuration having a plurality of passage forming protrusions arranged in a width direction, and
[0075] wherein the extrusion die is configured such that the metallic material passes through the extrusion hole to form a multi-passage hollow member with a plurality of passages arranged in a width direction.
[0076] [28] The extrusion die for a metallic material as recited in any one of the aforementioned Items 17 to 26, wherein the male die and the female die define a circular extrusion hole, and wherein the extrusion die is configured such that the metallic material passes through the extrusion hole to form a tubular member circular in cross-section.
[0077] [29] The extrusion die for a metallic material as recited in any one of the aforementioned Items 17 to 28, wherein the metallic material is an aluminum or its alloy.
[0078] [30] The production method of an extruded article, comprising the step of forming the extruded article using the extrusion die as recited in any one of the aforementioned Items 17 to 28.
[0079] [31] The production method of a multi-passage hollow member, comprising the step of forming the multi-passage hollow member using the extrusion die as recited in the aforementioned Item 27.
[0080] [32] A production method of an extruded tubular member, comprising the step of forming the extruded tubular member using the extrusion die as recited in the aforementioned Item 28.
[0081] [33] A die case for an extrusion die, comprising a pressure receiving portion with an outer surface functioning as a metallic material pressure receiving surface faced rear-
ward against an extrusion direction of the metallic material, the die case being configured to mount a male die and a female die therein.

[0082] wherein the pressure receiving surface is formed into a convex configuration protruded rearward, a porthole for introducing the metallic material is provided in an outer periphery of the pressure receiving portion, and an opening area of the inlet portion of the porthole is set to be larger than a passage cross-sectional area of an inside of the porthole; and

[0083] wherein the die case is configured such that the metallic material pressurized against the metallic material pressure receiving surface is introduced into the die case via the porthole and passes through the extrusion hole.

[0084] [34] The die case for an extrusion die as recited in the aforementioned Item 33, wherein the metallic material pressure receiving portion is constituted by a convex spherical surface of a 1/2 to 5/4 sphere.

[0085] [35] An extrusion method for a metallic material, comprising the steps of:

[0086] preparing a die case, wherein the die case comprises a pressure receiving portion with an outer surface functioning as a metallic material pressure receiving surface faced rearward against an extrusion direction of the metallic material, a male die mounted in the die case, and a female die mounted in the die case for defining an extrusion hole between the male die and the female die, wherein the pressure receiving surface is formed into a convex configuration protruded rearward, and a porthole for introducing the metallic material is provided in an outer periphery of the pressure receiving portion, and wherein an opening area of the inlet portion of the porthole is set to be larger than a passage cross-sectional area of an inside of the porthole; and

[0087] introducing the metallic material pressurized against the metallic material pressure receiving surface into the die case via the porthole to pass through the extrusion hole.

[0088] [36] An extruder for a metallic material equipped with a container and an extrusion die set in the container and configured to supply the metallic material in the container to the extrusion die,

[0089] wherein the extrusion die comprises:

[0090] a die case having a pressure receiving portion with an outer surface functioning as a metallic material pressure receiving surface, the die case being disposed with the metallic material pressure receiving surface faced rearward against an extrusion direction of the metallic material;

[0091] a male die disposed in the die case; and

[0092] a female die disposed in the die case to define an extrusion hole between the male die and the female die,

[0093] wherein the pressure receiving surface is formed into a convex configuration protruded rearward, and a porthole for introducing the metallic material is provided in an outer periphery of the pressure receiving portion.

[0094] wherein an opening area of the inlet portion of the porthole is set to be larger than a passage cross-sectional area of an inside of the porthole, and

[0095] wherein the extrusion die is configured such that the metallic material pressurized against the metallic material pressure receiving surface is introduced into the die case via the porthole and passes through the extrusion hole.

EFFECTS OF THE INVENTION

[0096] According to the extrusion die for a metallic material as recited in the aforementioned Item [1], since the pressure receiving surface is formed into a convex surface configuration, when the metallic material is pressed against the pressure receiving surface, the pressing force of the metallic material can be received by the pressure receiving surface in a dispersed manner, which can decrease the pressing force in the normal direction at each portion of the pressure receiving surface. As a result, the strength against the pressing force of the metallic material can be increased, which makes it possible to attain sufficient durability. That is, when the metallic material is pressed against the pressure receiving surface formed into a convex surface configuration, the compressing force toward the axis of the pressure receiving portion will be applied to each portion of the pressure receiving surface, which reduces the shearing force to be generated at the die case at the time of the extrusion processing. As a result, at the portion exposed to the hollow portion of the die case where the largest shearing force will be generated, the shearing force to be generated at the portion can be reduced, which in turn can increase the strength of the die against the pressing force of the metallic material.

[0097] Furthermore, in the present invention, the porthole for introducing a material is formed in the pressure receiving portion of the die case covering the male die and the female die. In other words, the front end (downstream side) wall portion of the pressure receiving portion is integrally formed in a circumferentially continued manner. The existence of this continuous peripheral wall can further increase the strength of the die case, which in turn can further increase the strength of the entire extrusion die. Thus, in the extrusion die of this invention, there is no portion weak in strength, such as a conventional bridge portion, and therefore it is not required to increase the size, such as, e.g., the thickness, beyond the necessity for the purpose of increasing the strength, which makes it possible to attain the size and weight reduction as well as the cost reduction.

[0098] Furthermore, in the invention as recited in the aforementioned Item [1], since the ratio of the plan state opening area of the porthole inlet portion to the plan state area of the pressure receiving portion is set to the specific value, the metallic material can be smoothly introduced into the inside of the die from the porthole inlet portion, resulting in decreased extrusion pressure (extrusion load) of the metallic material against the pressure receiving surface. Therefore, extrusion processing can be performed smoothly and efficiently and longer die life can be attained.

[0099] According to the extrusion die for a metallic material as recited in the aforementioned Item [2], the extrusion pressure of the metallic material to the pressure receiving surface can be more assuredly dispersed in a balanced manner, which in turn can make it possible to more assuredly increase the strength against the pressing force of the metallic material. In detail, when the metallic material is pressed against the pressure receiving surface constituted by a specific convex spherical surface, compressing force in the direction toward the center of the pressure receiving portion will be more assuredly applied to each portion of the pressure receiving surface, which more assuredly reduces the shearing force to be generated in the die case at the time of extrusion processing. As a result, at the portion exposed to the hollow portion of the die case where the largest shearing force will be generated, the shearing force to be generated at the portion can be reduced, which in turn can increase the strength of the die against the pressing force of the metallic material.
According to the extrusion die for a metallic material as recited in the aforementioned Item [3], the metallic material can be evenly introduced toward the extrusion hole from the circumferential direction of the die, enabling stable extrusion.

According to the extrusion die for a metallic material as recited in the aforementioned Items [4] and [5], the metallic material can be evenly introduced toward the extrusion hole from the port hole.

According to the extrusion die for a metallic material as recited in the aforementioned Item [6], a flat extruded product can be formed with a high degree of dimensional accuracy.

According to the extrusion die for a metallic material as recited in the aforementioned Item [7], a multi-passage hollow member with a plurality of passages arranged in the width direction can be formed assuredly.

According to the extrusion die for a metallic material as recited in the aforementioned Item [8], a tubular member circular in cross-section can be formed assuredly.

According to the extrusion die for a metallic material as recited in the aforementioned Item [9], an aluminum or aluminum alloy extruded article can be produced.

According to the invention as recited in the aforementioned Item [10], a production method for an extruded article having the same effects as mentioned above can be provided.

According to the invention as recited in the aforementioned Item [11], a production method for a multi-passage hollow member having the same effects as mentioned above can be provided.

According to the invention as recited in the aforementioned Item [12], a production method for an extruded tubular member having the same effects as mentioned above can be provided.

According to the invention as recited in the aforementioned Item [13], a die case for an extrusion die having the same effects as mentioned above can be provided.

According to the invention as recited in the aforementioned Item [14], by the same reasons as mentioned in the aforementioned Item [2], the extrusion pressure of the metallic material to the pressure receiving surface can be more assuredly dispersed in a balanced manner, which in turn can make it possible to more assuredly increase the strength against the extrusion force of the metallic material.

According to the invention as recited in the aforementioned Item [15], an extrusion method for a metallic material having the same effects as mentioned above can be provided.

According to the invention as recited in the aforementioned Item [16], an extruder for a metallic material having the same effects as mentioned above can be provided.

According to the extrusion die for a metallic material as recited in the aforementioned Item [17], since the pressure receiving surface is formed into a convex surface configuration, when the metallic material is pressed against the pressure receiving surface, the pressing force of the metallic material can be received by the pressure receiving surface in a dispersed manner, resulting in reduced extrusion force in the normal direction at each portion of the pressure receiving surface. As a result, the strength against the pressing force of the metallic material can be increased, resulting in sufficient durability. In detail, when the metallic material is pressed against the pressure receiving surface constituted by a specific convex spherical surface, compressing force in the direction toward the center of the pressure receiving portion will be more assuredly applied to each portion of the pressure receiving surface, which more assuredly reduces the shearing force to be generated in the die case at the time of extrusion processing. As a result, at the portion exposed to the hollow portion of the die case where the most large shearing force will be generated, the shearing force to be generated at the portion can be reduced, which in turn can increase the strength of the die against the pressing force of the metallic material.

Furthermore, in the invention as recited in the aforementioned Item [17], the porthole for introducing a material is formed in the pressure receiving portion of the die case covering the male die and the female die. In other words, the front end (downstream side) wall portion of the pressure receiving portion is integrally formed in a circumferentially continued manner. The existence of this continuous peripheral wall can further increase the strength of the die case, which in turn can further increase the strength of the entire extrusion die. Thus, in the die of this invention, there is no portion weak in strength, such as a conventional bridge portion, and therefore it is not required to increase the size, such as, e.g., the thickness, beyond the necessity for the purpose of increasing the strength, which makes it possible to attain the size and weight reduction as well as the cost reduction.

Furthermore, in the invention as recited in the aforementioned Item [17], since the opening area of the inlet portion of the porthole is formed to be larger than the passage cross-sectional area of the inlet portion of the porthole, the metallic material can be smoothly introduced from the inlet portion, resulting in reduced pressing force (extrusion load) to the pressure receiving surface of the metallic material. This in turn enables efficient and smooth extrusion processing.

Furthermore, since the passage cross-sectional area of the inside of the porthole is small, the void gap rate of the die case by the portholes becomes small, which can further increase the strength of the die case, which in turn can further increase the strength of the entire die.

According to the extrusion die for a metallic material as recited in the aforementioned Item [18], since the porthole is configured such that a passage cross-sectional area gradually decreases from the inlet portion toward an inside of the porthole, no sudden change in flow resistance of the metallic material passing through the porthole occurs, which makes it possible to more smoothly pass the metallic material through the porthole.

According to the extrusion die for a metallic material as recited in the aforementioned Items [19] to [23], the aforementioned effects can be obtained more assuredly.

According to the extrusion die for a metallic material as recited in the aforementioned Item [24], the extrusion pressure of the metallic material to the pressure receiving surface can be more assuredly dispersed in a balanced manner, which in turn can make it possible to more assuredly increase the strength against the extrusion force of the metallic material. In detail, when the metallic material is pressed against the pressure receiving surface constituted by a specific convex spherical surface, compressing force in the direction toward the center of the pressure receiving portion will be more assuredly applied to each portion of the pressure receiving surface, which more assuredly reduces the shearing force to be generated in the die case at the time of extrusion processing. As a result, at the portion exposed to the hollow
portion of the die case where the largest shearing force will be generated, the shearing force to be generated at the portion can be reduced, which in turn can increase the strength of the die against the pressing force of the metallic material.

[0120] According to the extrusion die for a metallic material as recited in the aforementioned Item [25], the metallic material can be evenly introduced toward the extrusion holes from the circumferential direction of the die, enabling stable extrusion.

[0121] According to the extrusion die for a metallic material as recited in the aforementioned Item [26], a flat extruded product can be formed with a high degree of dimensional accuracy.

[0122] According to the extrusion die for a metallic material as recited in the aforementioned Item [27], a multi-passage hollow member with a plurality of passages arranged in the width direction can be formed assuredly.

[0123] According to the extrusion die for a metallic material as recited in the aforementioned Item [28], a tubular member circular in cross-section can be formed assuredly.

[0124] According to the extrusion die for a metallic material as recited in the aforementioned Item [29], an aluminum or aluminum alloy extruded article can be produced.

[0125] According to the invention as recited in the aforementioned Item [30], a production method for an extruded article having the same effects as mentioned above can be provided.

[0126] According to the invention as recited in the aforementioned Item [31], a production method for a multi-passage hollow member having the same effects as mentioned above can be provided.

[0127] According to the invention as recited in the aforementioned Item [32], a production method for an extruded tubular member having the same effects as mentioned above can be provided.

[0128] According to the invention as recited in the aforementioned Item [33], a die case for an extrusion die having the same effects as mentioned above can be provided.

[0129] According to the invention as recited in the aforementioned Item [34], by the same reasons as mentioned in the aforementioned Item [24], the extrusion pressure of the metallic material to the pressure receiving surface can be more assuredly dispersed in a balanced manner, which in turn can make it possible to more assuredly increase the strength against the extrusion force of the metallic material.

[0130] According to the invention as recited in the aforementioned Item [35], an extrusion method for a metallic material having the same effects as mentioned above can be provided.

[0131] According to the invention as recited in the aforementioned Item [36], an extruder for a metallic material having the same effects as mentioned above can be provided.

[0132] The above and/or other aspects, features and/or advantages of various embodiments will be further appreciated in view of the following description in conjunction with the accompanying figures. Various embodiments can include and/or exclude different aspects, features and/or advantages where applicable. The descriptions of aspects, features and/or advantages of particular embodiments should not be construed as limiting other embodiments or the claims.

BRIEF DESCRIPTION OF DRAWINGS

[0133] The preferred embodiments of the present invention are shown by way of example, and not limitation, in the accompanying figures, in which:

[0134] FIG. 1 is a perspective view showing an extrusion die according to a first embodiment of the present invention;

[0135] FIG. 2 is an exploded perspective view showing the extrusion die according to the first embodiment;

[0136] FIG. 3 is a rear view (top view) showing the extrusion die according to the first embodiment;

[0137] FIG. 4 is a cutout perspective view showing the extrusion die according to the first embodiment;

[0138] FIG. 5 is a cross-sectional view showing the extrusion die according to the first embodiment;

[0139] FIG. 6 is another cross-sectional view showing the extrusion die according to the first embodiment;

[0140] FIG. 7 is an enlarged cutout perspective view showing the inside of the extrusion die according to the first embodiment;

[0141] FIG. 8 is an explanatory plan view of a plan state area of the pressure receiving portion and a plan state opening area of the porthole inlet portion of the extrusion die according to the first embodiment;

[0142] FIG. 9 is a perspective cutout principal portion of an extruder to which the extrusion die of the first embodiment is applied;

[0143] FIG. 10 is a cross-sectional view showing the extrusion die of the first embodiment and the vicinity thereof in an extruder;

[0144] FIG. 11 is another cross-sectional view showing the extrusion die of the first embodiment and the vicinity thereof in the extruder;

[0145] FIG. 12 is a perspective view showing a multi-passage hollow member extruded with an extruder according to the first embodiment;

[0146] FIG. 13 is an enlarged front cross-sectional view showing the multi-passage hollow member extruded with the extruder of the first embodiment;

[0147] FIG. 14 is a cross-sectional view showing an extrusion die according to a first modification of this invention;

[0148] FIG. 15 is a perspective cutout view showing an extrusion die according to a second modification of this invention;

[0149] FIG. 16 is a cross-sectional view showing the extrusion die according to the second modification of this invention;

[0150] FIG. 17 is a cross-sectional view showing an extrusion die according to a third modification of this invention;

[0151] FIG. 18 is a cross-sectional view showing an extrusion die according to a fourth modification of this invention;

[0152] FIG. 19 is a perspective view showing an extrusion die according to a second embodiment of this invention;

[0153] FIG. 20 is an exploded perspective view showing the extrusion die according to the second embodiment;

[0154] FIG. 21 is a cutout perspective view showing the extrusion die according to the second embodiment;

[0155] FIG. 22 is a cross-sectional view showing the extrusion die according to the second embodiment;

[0156] FIG. 23 is another cross-sectional view showing the extrusion die according to the second embodiment;
FIG. 24 is an enlarged cutout perspective view showing an inside of the extrusion die according to the second embodiment;

FIG. 25 is a cutout perspective view showing a principle portion of an extruder to which the extrusion die according to the second embodiment is applied;

FIG. 26 is a cross-sectional view showing a die according to the second embodiment and the vicinity thereof mounted in an extruder;

FIG. 27 is another cross-sectional view showing a die according to the second embodiment and the vicinity thereof mounted in an extruder;

FIG. 28 is a perspective view showing a multi-passage hollow member extruded with the extruder of the second embodiment;

FIG. 29 is an enlarged front view of the multi-passage hollow member extruded with the extruder of the second embodiment;

FIG. 30 is a perspective view showing an extrusion die according to a third embodiment of this invention;

FIG. 31 is an exploded perspective view showing the extrusion die according to the third embodiment;

FIG. 32 is a cutout perspective view showing the extrusion die according to the third embodiment;

FIG. 33 is a cross-sectional view showing the extrusion die according to the third embodiment;

FIG. 34 is a perspective view showing an extrusion die according to a fourth embodiment of this invention;

FIG. 35 is an exploded perspective view showing the extrusion die according to the fourth embodiment;

FIG. 36 is a cutout perspective view showing the extrusion die according to the fourth embodiment;

FIG. 37 is a cross-sectional view showing the extrusion die according to the fourth embodiment;

FIG. 38 is a cross-sectional view showing a die case of the extrusion die according to the fourth embodiment;

FIG. 39 is a perspective view showing an extrusion die according to a fifth embodiment of this invention;

FIG. 40 is an exploded perspective view showing the extrusion die according to the fifth embodiment;

FIG. 41 is a cutout perspective view showing the extrusion die according to the fifth embodiment;

FIG. 42 is a cross-sectional view showing the extrusion die according to the fifth embodiment;

FIG. 43 is a cross-sectional view showing a die case of the extrusion die according to the fifth embodiment;

FIG. 44A is a perspective exploded view showing a porthole die as a conventional extrusion die;

FIG. 44B is a perspective exploded view showing a spider die as a conventional extrusion die; and

FIG. 44C is a perspective view showing a bridge die as a conventional extrusion die.

BEST MODE FOR CARRYING OUT THE INVENTION

In the following paragraphs, some preferred embodiments of the invention will be described by way of example and not limitation. It should be understood based on this disclosure that various other modifications can be made by those in the art based on these illustrated embodiments.

First Embodiment

FIGS. 1 to 13 are explanatory views showing an extrusion die for a metallic material according to a first embodiment of the present invention.

This extrusion die 10 for a metallic material according to the first embodiment is designed to extrude a multi-passage hollow member (flat multi-passage tube) 60 as shown in FIGS. 12 and 13.

The hollow member 60 is a metal member. In this embodiment, this hollow member 60 constitutes a heat exchanging tube made of aluminum or aluminum alloy.

This hollow member 60 has a flat member having a width larger than the thickness for use in heat exchangers such as, e.g., condensers for air conditioners. The hollow portion 61 of this hollow member 60 extends in the tube length direction and is divided into a plurality of heat exchanging passages 63 by a plurality of partitions 62 arranged in parallel with each other. These passages 63 extend in the tube length direction and are arranged in parallel with each other.

In the following explanation of this embodiment, a direction with which a tube length direction perpendicularly intersects and along which the passages 63 are arranged will be referred to as a "width direction" or a "lateral direction," and a direction with which a tube length direction perpendicularly intersects and with which the width direction perpendicularly intersects will be referred to as a "height direction" (thickness direction) or a "vertical direction." Furthermore, in the following explanation of this embodiment, the "upstream side" with respect to the extrusion direction will be referred to as a "rear side," and the "downstream side" thereof will be referred to as a "front side."

FIGS. 1 to 7 show an extrusion die 10 of this first embodiment. As shown in these figures, the extrusion die 10 of this embodiment is equipped with a die case 20, a male die 30, a female die 40, and a flow control plate 50.

The die case 20 has a hollow structure having a dome-shaped pressure receiving portion 21 provided at the upstream side (rear side) with respect to the extrusion direction of a metallic billet as a metallic material and a base portion 25 provided at the downstream side (front side).

The surface (rear surface) of the pressure receiving portion 21 opposed against the extrusion direction of a metallic billet is formed into a billet pressure receiving surface 22 functioning as a metallic material pressure receiving surface. This billet pressure receiving surface 22 is formed into a convex surface configuration protruded in a direction opposite to the extrusion direction (i.e., in the rear direction). Concretely, this pressure receiving surface 22 is formed into a hemispherical convex configuration. Thus, the pressure receiving surface 22 is formed so as to protrude rearward.

In the peripheral wall center of the pressure receiving portion 21, a male die holding slit 23 communicated with an internal hollow portion (welding chamber 12) is formed along the axis A1 of the die case. This male die holding slit 23 is formed into a flat rectangular cross-sectional configuration corresponding to the cross-sectional configuration of the male die 30. Furthermore, as shown in FIG. 6, at both side portions of the rear end side of the male die holding slit 23, engaging stepped portions 23a and 23b for engaging the male die 30, which will be mentioned later, are formed.
In the peripheral wall of the pressure receiving portion 21, a pair of portholes 24 and 24 are formed at both sides of the axis A1. The inlet portion 24e of each porthole 24 is formed into an approximately trapezoidal configuration as seen from the upstream side of the axial direction.

The pair of portholes 24 and 24 are arranged so that the outlet portions (front end portions) thereof face toward the below-mentioned extrusion hole 11.

As shown in FIG. 5, each porthole 24 is disposed such that the axis A2 thereof approaches the axis A1 of the pressure receiving portion 21 as it advances toward the downstream side and intersects with the axis A1 of the pressure receiving portion 21 in an inclined state. The detail structure of, e.g., the inclination angle α of the axis A2 of the porthole 24 and the area of the porthole 24 will be detailed later.

In this embodiment, it is constituted that the axis A1 of the die case 20 and the axis of the pressure receiving portion 21 coincide with each other.

The base portion 25 is integrally formed to the pressure receiving portion 21, and formed into an annular shape centered on the axis A1. The base portion 25 has a diameter larger than the diameter of the pressure receiving portion 21.

In this invention, the base portion 25 and the pressure receiving portion 21 are not required to be integrally formed, and can be formed separately. Whether both the members 21 and 25 should be integrally formed or separately formed can be arbitrarily selected in consideration of the maintenance performance, etc.

In the base portion 25, a cylindrical female die holding hole 26 is configured by a welding member 12 and corresponding to the cross-sectional shape of the female die 40 is formed. The axis of this female die holding hole 26 is constituted so as to align with the axis A1 of the die case 20.

At the rear end side of the inner peripheral surface of the female die holding hole 26, as shown in FIGS. 4 to 6 for example, an engaging stepped portion 26a for engaging with the female die 40, which will be explained later, via a flow control plate 50 is formed.

The front principle portion of the male die 30 is constituted as a mandrel 31. As shown in FIGS. 6 and 7, the front end portion of the mandrel 31 is configured to form the hollow portion 61 of the hollow member 60 and has a plurality of passage forming protruded portions 33 each corresponding to each passage 63 of the hollow member 60. These plural passage forming protruded portions 33 are arranged in the width direction of the mandrel 31 at certain intervals. The gap formed between the adjacent passage forming protruded portions 33 and 33 is constituted as a partition forming groove 32 for forming the partition 62 of the hollow member 60.

As shown in FIG. 2, at both the width direction sides of the rear end portion of the male die 30, engaging protruded portions 33a and 33a corresponding to the engaging stepped portions 23a and 23a of the male die holding slit 23 of the die case 20 are integrally formed so as to protrude sideways.

The male die 30 is inserted into the male die holding slit 23 of the die case 20 from the side of the billet pressure receiving surface 22 and fixed therein. In this inserted state, the male die 30 is positioned with the engaging protruded portions 33a and 33a of the male die 30 engaged with the engaging stepped portions 23a and 23a. Thus, the mandrel 31 of the male die 30 is held in the mandrel holding slit 23 with the mandrel 31 forwardly protruded from the mandrel holding slit 23 by a certain length.

The basal end surface (rear end surface) of the male die 30 is formed into a partial hemispherical convex surface corresponding to the billet pressure receiving surface 22 of the die case 20. The basal end surface (rear end surface) of the male die 30 and the billet pressure receiving surface 22 cooperatively form a prescribed smooth hemispherical convex surface.

The female die 40 is formed into a cylindrical shape and provided with key protrusions 47 and 47 arranged in parallel with the axis A1 at both sides on the external peripheral surface thereof.

The female die 40 is provided with a die hole (bearing hole 41) corresponding to the mandrel 31 of the male die 30 and opened at the rear end surface side and a relief hole 42 communicated with the die hole 41 and opened at the front end surface side.

The die hole 41 is provided with an inwardly protruded portion along the inner peripheral edge portion so that the outer peripheral portion of the hollow member 60 can be defined. The relief hole 42 is formed into a tapered shape gradually increasing the thickness (height) toward the front end side (downstream side) and opened at the downstream side.

The flow control plate 50 is formed into an annular shape in external periphery corresponding to the cross-sectional shape of the female die holding hole 26 of the die case 20. Corresponding to the die hole 41 of the female die 40, a central through-hole 51 is formed in the center of the flow control plate 50.

The flow control plate 50 has, at both sides of the external peripheral edge portion, key protrusions 57 and 57 corresponding to the key protrusions 47 and 47 of the female die 40 are formed.

As shown in FIGS. 3 to 6, the female die 40 is accommodated and fixed in the female die holding hole 26 of the die case 20 via the flow control plate 50. With this state, the external peripheral surface of one end surface (rear end surface) of the female die 40 is engaged with the engaging stepped portion 26a of the female die holding hole 26 via the external peripheral edge portion of the flow control plate 50, so that the female die 40 and the flow control plate 50 are positioned in the axial direction. Furthermore, the key protrusions 47 and 47 of the female die 40 and the key protrusions 57 and 57 of the flow control plate 50 are engaged with the keyways (not illustrated) formed on the inner peripheral surface of the female die holding hole 26, so that the female die 40 and the flow control plate 50 are positioned in the circumferential direction about the axis.

With this, the mandrel 31 of the male die 30 and the die hole 41 of the female die 40 are disposed corresponding to the central through-hole 51 of the flow control plate 50. In this state, the mandrel 31 of the male die 30 is disposed within the die hole 41 of the female die 40 to form a flat circular extrusion hole 11 between the mandrel 31 and the die hole 41. Furthermore, a plurality of partition forming grooves 32 of the mandrel 31 are arranged in parallel in the width direction in the extrusion hole 11, whereby a cross-sectional shape corresponding to the cross-sectional shape of the hollow member 60 is formed.

In this embodiment, as shown in FIG. 5, each of the portholes 24 and 24 is formed such that the axis A2 of the porthole 24 inclines with respect to the axis A1 of the die case 20. In this embodiment, it is preferable that the inclination angle 0 of the axis A2 of the porthole 24 with respect to the
axis A1 of the die case 20 is set to 3 to 45°, more preferably 10 to 35°, still more preferably 15 to 30°. When the inclination angle θ is set so as to fall within the above specified range, the metallic material flows through the portholes 24 and 24 and the welding chamber 12 in a stable manner, and then smoothly passes through around the entire periphery of the extrusion hole 11 in a balanced manner. As a result, a high quality extrusion molded article (extruded article) excellent in dimensional accuracy can be formed. In other words, if the inclination angle θ is too small, the metallic material passed through the portholes 24 and 24 and the welding chamber 12 cannot be smoothly introduced into the extrusion hole 11, which may sometimes make it difficult to stably obtain a high quality extrusion molded article. To the contrary, if the inclination angle θ is too large, the material flowing direction of the porthole 24 inclines largely, which increases the metallic material extrusion resistance, and therefore it is not preferable.

[0210] In this embodiment, as shown in FIG. 8, when the area of the pressure receiving portion 21 defined by the plan view as seen from the upstream side of the axial direction is defined as “a plan state area Sα of the pressure receiving portion 21,” and the opening area of the porthole inlet portion 24e defined by the plan view as seen from the upstream side of the axial direction is defined as “a plan state opening area Sb of the porthole inlet portion 24e,” the plan state area Sα of the pressure receiving portion 21 is specified by the illustrated left inclination shaded area, while the plan state opening area Sb of the porthole inlet portion 24e is specified by the illustrated right inclination shaded area. In this embodiment, it is required to set the ratio (2xSb/SA) of the plan state opening area (2xSb) of the porthole inlet portions 24e to the plan state area Sα of the pressure receiving portion 21 so as to fall within the range of 0.15 to 0.80. It is preferably set to 0.25 to 0.75, more preferably 0.3 to 0.75. That is, when the area ratio (2xSb/SA) is set within the aforementioned range, the billet as a metallic material can be stably introduced from the porthole inlet portions 24e into the die while keeping sufficient plan state opening area of the porthole inlet portion 24e, which makes it possible to obtain an extruded product with high quality.

[0211] In other words, if the area ratio (2xSb/SA) is too large, the opening area of the die case 20 becomes large, which may cause deterioration of strength of the die case 20. To the contrary, if the area ratio (2xSb/SA) is too small, the introduction amount of a billet into the portholes 24 becomes small, resulting in excessive pressure (extrusion load) of the billet against the die, which may cause difficulty in smooth extrusion.

[0212] In this embodiment, it is preferable that the billet pressure receiving surface 22 of the die case 20 is constituted by a convex spherical surface of a ¼ to ½ sphere. When the billet pressure receiving surface 22 is constituted by the aforementioned specific convex spherical configuration, the pressing force of a metallic billet can be more assuredly received by the billet pressure receiving surface 22 in a well-balanced dispersed manner, resulting in sufficient strength, which in turn can more assuredly extend the die life. That is, when a billet is pressed against the pressure receiving surface 22 having the specific convex spherical configuration, compressing force toward the center of the pressure receiving portion 21 is more assuredly applied to each portion of the pressure receiving surface 22. As a result, the shearing force to be generated at the die case 20 at the time of the extrusion will be assuredly reduced. As a result, the portion of the die case 20 exposed to the hollow portion thereof, which is the portion where the largest shearing force will be generated, can be reduced assurredly. Thus, the strength of the die 10 against the pressing force of the billet can be improved more assuredly. In addition to the above, it also makes it possible to simplify the die configuration, reduce the size and weight, and also attain the cost reduction. In other words, if the billet pressure receiving surface 22 is formed into a configuration constituted by a convex spherical surface of a sphere smaller than a ¼ sphere, such as, for example, a convex spherical surface constituted by a ½ sphere, sufficient strength against the billet pressing force cannot be obtained, which may cause deteriorated die life due to generation of cracks. To the contrary, if the billet pressure receiving surface 22 is formed into a configuration constituted by a convex spherical surface of a sphere exceeding a ½ sphere, such as, for example, a convex spherical surface configuration of a ¾ sphere, the cost may be increased due to the complicated configuration.

[0213] In this embodiment, the sphere with a ratio, such as, for example, a ½ sphere, a ¾ sphere, or a ¾ sphere, is defined by a partial sphere obtained by cutting a perfect sphere with a plane perpendicular to the axis of the perfect sphere. That is, in this embodiment, an “n/m sphere “n” and “m” are natural numbers, and “n/m” is defined by a partial sphere obtained by cutting a perfect sphere with a plane perpendicular to the axis of the perfect sphere at a position where a distance from a surface of the perfect sphere to an inner position of the perfect sphere on the axis (diameter) is n/m where the length of the axis (diameter) of the perfect sphere is “1.”

[0214] As shown in FIG. 5, in this embodiment, the inner side surface 24a and the outer side surface 24b among the inner periphery of the porthole 24 are arranged approximately in parallel with each other and also approximately in parallel to the axis A2 of the porthole 24. Furthermore, the inner side surface 24a and the outer side surface 24b of the porthole inner periphery are constituted as an inclined surface (tapered surface) inclined to the axis A1 of the die case 20, respectively.

[0215] The extrusion die 10 having the aforementioned structure is set in an extruder as shown in FIGS. 9 to 11. That is, the extrusion die 10 of this embodiment is set in a container 6 with the extrusion die 10 fixed in the die installation hole 5a formed in the center of a plate 5. The extrusion die 10 is fixed by the plate 5 in a direction perpendicular to the extrusion direction and also fixed by a backer (not illustrated) in the extrusion direction.

[0216] A metallic billet (metallic material), such as, e.g., an aluminum billet, inserted in the container 6 is pressed in the right direction (extrusion direction) in FIG. 9 via a dummy block 7. Thereby, the metallic billet is pressed against the billet pressure receiving surface 22 of the die case 20 constituting the extrusion die 10 to be plastically deformed. As a result, the metallic material passes through the pair of portholes 24 and 24 while being plastically deformed and then reaches the welding chamber 12 of the die case 20. Then, the metallic material is forwarded extruded through the extrusion hole 11 into a cross-sectional configuration corresponding to the opening configuration of the extrusion hole 11. Thus, a metallic extruded article (hollow member 60) is manufactured.

[0217] According to the extrusion die 10 of this embodiment, since the billet pressure receiving surface 22 is formed into a convex spherical configuration, when the metallic billet
is pressed against the billet pressure receiving surface 22, the pressing force can be received by the pressure receiving surface 22 in a dispersed manner. Therefore, the pressing force to be applied to each portion of the billet pressure receiving surface 22 in the direction of a normal line can be reduced, thereby increasing the strength against the pressing force of the metallic material, which results in sufficient durability.

[0218] In this embodiment, since the plan state opening area Sb of the porthole inlet portions 24e with respect to the plan state area Sa of the pressure receiving portion 21 is set to a specific value, it becomes possible to smoothly introduce the billet into the inside of the die from the porthole inlet portions 24e. Thus, the pressing force (extrusion load) of the billet against the pressure receiving surface 22 can be decreased appropriately, resulting in efficient and smooth extrusion. Thus, a high-quality extruded product can be manufactured.

[0219] Furthermore, in this embodiment, the portholes 24 for introducing material are formed in the pressure receiving portion 21 covering the male die 30 and the female die 40. In other words, the front end wall portion of the pressure receiving portion 21 and the wall portion of the base portion 25 are formed integrally and continuously in the peripheral direction. The existence of this continued peripheral wall portion can further increase the strength of the die case 20, which in turn can further increase the strength of the entire extrusion die. Thus, there is no portion weak in strength, such as a conventional bridge portion, and therefore it is not required to increase the size, such as, e.g., the thickness, beyond the necessity for the purpose of increasing the strength, which makes it possible to attain the size and weight reduction as well as the cost reduction.

[0220] Furthermore, in this embodiment, the portholes 24 and 24 are formed at positions away from the axis A1 of the pressure receiving portion 21, i.e., the outer periphery of the pressure receiving portion 21, and the axis A2 of each porthole 24 is inclined with respect to the axis A1 of the die case 20 so as to gradually approach the axis A1 of the die case 20 toward the downstream side. Therefore, the metallic material passing through the portholes 24 and 24 can be stably extruded while being smoothly introduced toward the axis A1, i.e., the extrusion hole 11. Furthermore, in this embodiment, since the downstream side end portions (outlets) of the portholes 24 and 24 are facing toward the extrusion hole 11, the metallic material can be more smoothly introduced to the extrusion hole 11.

[0221] Furthermore, in this embodiment, since the portholes 24 and 24 are arranged at both sides of the height direction (thickness direction) of the flat extrusion hole 11, the metallic material can be more smoothly introduced into the extrusion hole 11 in a stable manner. Accordingly, the metallic material is extruded while evenly passing through the entire area of the extrusion hole 11 in a well-balanced manner, to thereby obtain a high-quality extruded hollow member 60.

[0222] Especially like in this embodiment, even in the case of extruding a hollow member 60 having a complicated configuration, such as, e.g., a flat harmonica tube configuration, metallic material can be introduced into the entire region of the extrusion hole 11 in a well-balanced manner, which can assuredly maintain the high quality.

[0223] For reference, in cases where an aluminum heat exchanging tube (hollow member) provided with a plurality of passages 63 each rectangular in cross-section having a height of 0.5 mm and a width of 0.5 mm, in a conventional extrusion die, since the strength was not sufficient, cracks to be generated in the male die 30 became a factor of the die life. On the other hand, in the extrusion die 10 according to the present invention, since the strength is sufficient, no crack will be generated in the die. Therefore, wear of the die becomes a factor of the die life, which can remarkably improve the die life.

[0224] For example, according to experiment results relevant to a die life performed by the present inventors, in the extrusion die according to the present invention, the die life was extended about three times as compared with a conventional one.

[0225] Moreover, in the present invention, since it has sufficient pressure resistance (strength), the extrusion limit speed can be raised considerably. For example, in a conventional extrusion die, the upper limit of the extrusion speed was 60 m/min. On the other hand, in the extrusion die according to the present invention, the upper limit of the extrusion speed can be raised to 150 m/min, i.e., the extrusion limit speed can be raised about 2.5 times, and therefore the productive efficiency can be further improved.

<Modification>

[0226] In the first embodiment, the pressure receiving portion 21 (pressure receiving surface 22) is formed into a hemisphere convex configuration (hemisphere convex surface). However, in the present invention, the configuration of the pressure receiving portion 21 (pressure receiving surface 22) is not limited to the above.

[0227] For example, in the present invention, the pressure receiving surface 22 can be formed into a polyhedral configuration constituted by a number of surfaces. That is, the pressure receiving surface 22 can be formed into, for example, a polyhedral configuration, such as, e.g., a pyramid configuration in which a plurality of side surfaces are arranged in the circumferential direction, or a polyhedral configuration in which a plurality of side surfaces are arranged in the radial direction. In this case, each side surface constituting the pressure receiving surface 22 can be, for example, a flat surface or a curved surface.

[0228] Furthermore, in the present invention, the pressure receiving portion 21 can be formed into a laterally elongated configuration longer in lengthwise direction than in crosswise direction, the lengthwise direction and the crosswise direction being perpendicular to the axial direction. For example, the pressure receiving portion 21 can be formed into a laterally elongated elliptical configuration as seen from the axial upstream side or a laterally elongated oval configuration as seen from the axial upstream side.

[0229] Furthermore, in the present invention, the pressure receiving portion 21 can be formed into a configuration with an axial direction protruded dimension longer than the radial dimension perpendicular to the axial direction, e.g., a semi-elliptical configuration.

[0230] Furthermore, in the aforementioned embodiment, the die case 20 is integrally formed. The present invention, however, is not limited to the above, and the die case 20 can be divided into two or more parts. For example, the die case 20 can be constituted by two members, i.e., a male die case for holding the male die 30 and a female die case for holding the female die 40.

[0231] Furthermore, in the aforementioned embodiment, the male die 30, the female die 40, the flow control plate 50 are
formed separately from the die case 20. The present invention, however, is not limited to the above, and at least one of the male die 30, the female die 40, and the flow control plate 50 can be formed integrally with the die case 20. Furthermore, in the present invention, the flow control plate 50 can be omitted as needed.

[0232] Furthermore, in the aforementioned embodiment, the explanation was directed to the die for extruding a flat multi-passage tubular member. In the present invention, however, the configuration of the extruded product (configuration of the extrusion hole) is not specifically limited. For example, in the present invention, it can be constituted such that a male die is provided with a mandrel round in cross-section and a female die is provided with a die hole round in cross-section so that a circular ring-shaped extrusion hole is defined between the mandrel and the die hole to extrude a round tubular member.

[0233] In the aforementioned embodiment, the explanation was directed to the case in which two portholes 24 are formed at both sides of the axis A1. The present invention, however, is not limited to the above, and allows forming of one porthole 24 or three or more portholes 24.

[0234] Furthermore, in the present invention, the configuration of the porthole inlet portion 24e is not specifically limited. Incises where a plurality of portholes 24 are formed, each porthole inlet portion 24e can be different in configuration or different in plan state opening area of each porthole inlet portion. In summary, it is sufficient that the ratio of the total plan state opening area of the porthole inlet portions 24e to the plan state area of the pressure receiving portion 21 is set so as to fall within the aforementioned range.

[0235] Especially in the case of extruding a tubular member round in cross-section, it is preferable to form three or more portholes 24 at equal circumferential intervals.

[0236] Furthermore, in the present invention, it can be configured such that the opening area of the porthole inlet portion 24e is formed to be larger than the passage cross-sectional area of the inside of the porthole 24.

[0237] That is, in the present invention, for example, like the first modification shown in FIG. 14, it can be configured such that the inclination angle θa of the inner side surface 24a of the porthole inner peripheral surface with respect to the axis A1 of the pressure receiving portion 21 is set to be smaller than the inclination angle θb of the outer side surface 24b of the porthole inner peripheral surface with respect to the axis A1 of the pressure receiving portion 21 so that the thickness (radial direction length) of the porthole inlet portion 24e is larger than the thickness of the inside of the porthole 24. Furthermore, like the second modification shown in FIGS. 15 and 16, when the distance between both side edges in the porthole inner peripheral surface is defined as a "width," the width of the porthole inlet portion 24e can be formed to be larger than the width of the inside of the porthole 24.

[0238] In the present invention, like the third modification shown in FIG. 17, it can be configured such that an outer chamfered portion 24d is formed by cutting the corner portion between the outer side surface 24b of the porthole inner peripheral surface and the outer side surface of the pressure receiving portion 21 (pressure receiving surface 22) so that the opening area of the porthole inlet portion 24e becomes larger than the passage cross-sectional area of the inside of the porthole 24. Alternatively, like the fourth modification shown in FIG. 18, it can be configured such that an inner chamfered portion 24f is formed by cutting the corner portion between the inner side surface 24a of the porthole inner peripheral surface and the outer side surface of the pressure receiving portion 21 (pressure receiving surface 22) so that the opening area of the porthole inlet portion 24e becomes larger than the passage cross-sectional area of the inside of the porthole 24.

[0239] Furthermore, in the aforementioned embodiments, the base portion 25 is provided at the front end portion of the die case 20. In the present invention, however, it is not always to provide the base portion 25.

[0240] Furthermore, in the aforementioned embodiments, the explanation was directed to the case in which only a single extrusion die is set in a container. The present invention, however, is not limited to the above. In the extruder according to the present invention, it can be configured such that two or more extrusion dies are set in a container.

[0241] In the present invention, it is preferable that the rear end face (basal end face) of the male die 30 is formed as a part of the convex surface (spherical surface) corresponding to the billet pressure receiving surface 22 of the pressure receiving portion 21 and that the rear end face of the male die 30 and the billet receiving surface 22 constitute a prescribed smooth convex surface (spherical surface). In the present invention, however, the configuration of the rear end face (basal end face) of the male die 30 is not limited to the above, and can be, for example, formed into the following configuration. That is, in the present invention, in cases where the surface area of the rear end face of the male die 30 is, for example, ½ or less of the surface area of the billet pressure receiving surface 22 of the die 10, the rear end face of the male die 30 can be constituted by a part of a columnar peripheral surface in which the rear end face is circular corresponding to the billet pressure receiving surface 22 in the width direction (longitudinal direction) and straight in the thickness direction (direction perpendicular to the longitudinal direction) because of the following reasons. That is, in cases where the surface area of the rear end face of the male die 30 is small as mentioned above, influence on die life and extrusion load due to the fact that the rear end face of the male die 30 is formed not into a part of a convex surface (spherical surface) but into a part of an external periphery of a circular column is small and the processing cost for the rear end face of the male die 30 can be reduced.

EXAMPLE

<table>
<thead>
<tr>
<th>Porthole area/Pressure receiving portion area</th>
<th>Die life (ton/die)</th>
<th>Die life limiting factor</th>
<th>Extrusion load (×10^8N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example 1</td>
<td>0.1</td>
<td>2.0</td>
<td>Male die wear</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Male die minute cracks</td>
</tr>
<tr>
<td>Example 2</td>
<td>0.15</td>
<td>2.5</td>
<td>Male die wear</td>
</tr>
<tr>
<td>Example 3</td>
<td>0.25</td>
<td>3.0</td>
<td>Male die wear</td>
</tr>
<tr>
<td>Example 4</td>
<td>0.30</td>
<td>3.2</td>
<td>Male die wear</td>
</tr>
<tr>
<td>Example 5</td>
<td>0.40</td>
<td>3.5</td>
<td>Male die wear</td>
</tr>
<tr>
<td>Example 6</td>
<td>0.60</td>
<td>3.7</td>
<td>Male die wear</td>
</tr>
</tbody>
</table>
As shown in Table 1, the extrusion die 10 corresponding to the first embodiment was prepared. The pressure receiving portion 21 of the die case 20 of the die 10 had two portholes 24 formed at both thickness direction sides of the extrusion hole 11. The inclination angle \( \theta \) of the porthole 24 was adjusted to 10°.

The billet pressure receiving surface 22 was formed into a 1/2 spherical configuration (convex spherical configuration) having a radius of 30 mm.

The ratio (2xSb/Sa) of the total plan state opening area Sb of the porthole inlet portions 24e to the plan state area Sa of the pressure receiving portion 21 was set to 0.1 (the area ratio per porthole was set to 0.05).

The male die 30 was adjusted to 2.0 mm in height (thickness) of mandrel 31, 19.2 mm in width of mandrel 31, 1.2 mm in height of passage forming protruded portion 33, 0.6 mm in width of passage forming protruded portion 33, and 0.2 mm in width of partition forming groove 32.

The female die 40 was adjusted to 1.7 mm in height of die hole 41 and 20.0 mm in width of die hole 41.

As shown in FIGS. 9 to 11, the extrusion die 10 was set to an extruder similar to the extruder shown in the first embodiment and extrusion was performed to produce a flat multi-passage tubular member 60 (heat exchanging tubular member) as shown in FIGS. 12 and 13.

The die life (the amount (tons) of material introduced until cracks or wear occurs) and the extrusion load were measured, and the die life limiting factors were investigated. The results are also shown in Table 1.

In Table 1, the “porthole area” denotes the “plan state opening area of the porthole inlet portions 24e,” and the “pressure receiving portion area” denotes the “plan state area of the pressure receiving portion 21.”

Example 1

<table>
<thead>
<tr>
<th>Porthole area/Pressure receiving portion area</th>
<th>Die life (ton/die)</th>
<th>Die life limiting factor</th>
<th>Extrusion load ( x \times 10^4 \text{N} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example 7</td>
<td>0.65</td>
<td>3.8</td>
<td>Male die wear</td>
</tr>
<tr>
<td>Example 8</td>
<td>0.75</td>
<td>3.8</td>
<td>Male die wear</td>
</tr>
<tr>
<td>Example 9</td>
<td>0.80</td>
<td>2.5</td>
<td>Male die wear, Case minute cracks</td>
</tr>
<tr>
<td>Comparative Example 1</td>
<td>—</td>
<td>0.7</td>
<td>Male die cracks</td>
</tr>
</tbody>
</table>

Example 2

As shown in Table 1, the ratio (2xSb/Sa) of the total plan state opening area Sb of the porthole inlet portions 24e to the plan state area Sa of the pressure receiving portion 21 was set to 0.15 (the area ratio per porthole was set to 0.075).

An extrusion die 10 having the same structure other than the above was prepared, and extrusion was performed in the same manner as mentioned above to evaluate in the same manner as mentioned above.

Example 3

As shown in Table 1, the ratio (2xSb/Sa) of the total plan state opening area Sb of the porthole inlet portions 24e to the plan state area Sa of the pressure receiving portion 21 was set to 0.25 (the area ratio per porthole was set to 0.125).

An extrusion die 10 having the same structure other than the above was prepared, and extrusion was performed in the same manner as mentioned above to evaluate in the same manner as mentioned above.

Example 4

As shown in Table 1, the ratio (2xSb/Sa) of the total plan state opening area Sb of the porthole inlet portions 24e to the plan state area Sa of the pressure receiving portion 21 was set to 0.30 (the area ratio per porthole was set to 0.15).

An extrusion die 10 having the same structure other than the above was prepared, and extrusion was performed in the same manner as mentioned above to evaluate in the same manner as mentioned above.

Example 5

As shown in Table 1, the ratio (2xSb/Sa) of the total plan state opening area Sb of the porthole inlet portions 24e to the plan state area Sa of the pressure receiving portion 21 was set to 0.40 (the area ratio per porthole was set to 0.20).

An extrusion die 10 having the same structure other than the above was prepared, and extrusion was performed in the same manner as mentioned above to evaluate in the same manner as mentioned above.

Example 6

As shown in Table 1, the ratio (2xSb/Sa) of the total plan state opening area Sb of the porthole inlet portions 24e to the plan state area Sa of the pressure receiving portion 21 was set to 0.60 (the area ratio per porthole was set to 0.30).

An extrusion die 10 having the same structure other than the above was prepared, and extrusion was performed in the same manner as mentioned above to evaluate in the same manner as mentioned above.

Example 7

As shown in Table 1, the ratio (2xSb/Sa) of the total plan state opening area Sb of the porthole inlet portions 24e to the plan state area Sa of the pressure receiving portion 21 was set to 0.65 (the area ratio per porthole was set to 0.325).

An extrusion die 10 having the same structure other than the above was prepared, and extrusion was performed in the same manner as mentioned above to evaluate in the same manner as mentioned above.

Example 8

As shown in Table 1, the ratio (2xSb/Sa) of the total plan state opening area Sb of the porthole inlet portions 24e to the plan state area Sa of the pressure receiving portion 21 was set to 0.75 (the area ratio per porthole was set to 0.375).

An extrusion die 10 having the same structure other than the above was prepared, and extrusion was performed in the same manner as mentioned above to evaluate in the same manner as mentioned above.

Example 9

As shown in Table 1, the ratio (2xSb/Sa) of the total plan state opening area Sb of the porthole inlet portions 24e to the plan state area Sa of the pressure receiving portion 21 was set to 0.80 (the area ratio per porthole was set to 0.40).
An extrusion die 10 having the same structure other than the above was prepared, and extrusion was performed in the same manner as mentioned above to evaluate in the same manner as mentioned above.

Comparative Example 1

As shown in Table 1, a bridge-type extrusion die 30 mm in radius and height (length in the extrusion direction) in 50 mm in which the pressure receiving portion was finished into a flat surface perpendicular to the extrusion direction was prepared. The other structure was the same as that of the aforementioned examples.

This extrusion die was set to an extruder in the same manner as mentioned above to produce an extruded product, and evaluated in the same manner as mentioned above.

<Evaluation>

As shown in Table 1, in Comparative Example 1, cracks of the male die were a life limiting factor, and the die life was short.

On the other hand, in Examples 1 to 9, a longer die life was secured as compared with Comparative Example 1.

Among other things, in Example 2 to 8 in which the area ratio (2xSk/Sa) was adjusted to 0.15 to 0.75, the wear of the male die 30 was the life limiting factor, and was sufficiently long in die life. The dies of Examples 3 to 8 in which the area ratio (2xSk/Sa) was adjusted to 0.25 to 0.75, especially the dies of Examples 4 to 8 in which it was adjusted to 0.30 to 0.75, were further longer in die life.

In the dies of Examples 1 and 9, although minute cracks of the male die 30 and minute cracks of the die case 20 were life limiting factors, the wear of the male die 30 was the main life limiting factor, which could secure certain die life. The life was at least longer than that of Comparative Example 1.

Example 10

As shown in Table 2, an extrusion die 10 corresponding to the first embodiment (see FIGS. 1 to 8) was prepared. The pressure receiving portion 21 of the die 10 had two portholes 24 formed at both thickness direction sides of the extrusion hole 11. The inclination angle θ of the porthole 24 was adjusted to 10°.

The billet pressure receiving surface 22 was constituted by a ½ convex spherical surface (convex spherical configuration) having a radius of 45.4 mm. The diameter of this pressure receiving portion 21 was adjusted to 60 mm.

The ratio (2xSk/Sa) of the total plan state opening area Sk of the porthole inlet portions 24a to the plan state area Sa of the pressure receiving portion 21 was set to 0.30 (the area ratio per porthole was set to 0.15).

Table 2

<table>
<thead>
<tr>
<th>Spherical size of the billet pressure receiving surface</th>
<th>Die life (ton/die)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example 10 ½</td>
<td>1.2</td>
</tr>
<tr>
<td>Example 11 ¼</td>
<td>2.0</td>
</tr>
<tr>
<td>Example 12 ½</td>
<td>2.6</td>
</tr>
<tr>
<td>Example 13 ½</td>
<td>3.2</td>
</tr>
<tr>
<td>Example 14 ¼</td>
<td>3.2</td>
</tr>
<tr>
<td>Example 15 ½</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Example 11

An extrusion die 10 similar to the extrusion die of Example 10 except that the billet pressure receiving surface 22 was constituted by a ½ convex spherical surface and the spherical radius was set to 40.3 mm as shown in Table 2 was prepared. The extrusion die 10 was set to an extruder similar to the extruder shown in the first example, and extrusion was performed to produce a flat multi-passage tubular member 60 (heat exchanging tubular member).

Example 12

An extrusion die 10 similar to the extrusion die of Example 10 except that the billet pressure receiving surface 22 was constituted by a ½ convex spherical surface and the spherical radius was set to 32.0 mm as shown in Table 2 was prepared. The extrusion die 10 was set to an extruder similar to the extruder shown in the first example, and extrusion was performed to produce a flat multi-passage tubular member 60 (heat exchanging tubular member).

Example 13

An extrusion die 10 similar to the extrusion die of Example 10 except that the billet pressure receiving surface 22 was constituted by a ½ convex spherical surface and the spherical radius was set to 20.0 mm as shown in Table 2 was prepared. The extrusion die 10 was set to an extruder similar to the extruder shown in the first example, and extrusion was performed to produce a flat multi-passage tubular member 60 (heat exchanging tubular member).

Example 14

An extrusion die 10 similar to the extrusion die of Example 10 except that the billet pressure receiving surface 22 was constituted by a ½ convex spherical surface and the spherical radius was set to 40.3 mm as shown in Table 2 was prepared. The extrusion die 10 was set to an extruder similar to the extruder shown in the first example, and extrusion was performed to produce a flat multi-passage tubular member 60 (heat exchanging tubular member).

Example 15

An extrusion die 10 similar to the extrusion die of Example 10 except that the billet pressure receiving surface 22 was constituted by a ½ convex spherical surface and the spherical radius was set to 40.3 mm as shown in Table 2 was prepared. The extrusion die 10 was set to an extruder similar to the extruder shown in the first example, and extrusion was performed to produce a flat multi-passage tubular member 60 (heat exchanging tubular member).
performed to produce a flat multi-passage tubular member 60 (heat exchanging tubular member).

<Evaluation>

[0285] In the die (Example 10) with a large spherical radius of the billet pressure receiving surface 22 and a relatively smaller protruded amount thereof, the die life was slightly shortened.

[0286] In the die (Example 15) with a small spherical radius of the billet pressure receiving surface 22 and a relatively larger protruded amount thereof, although long die life can be secured, it is considered to be slightly difficult to process the billet pressure receiving surface 22.

[0287] On the other hand, in the dies (Examples 11 to 14) in which the billet pressure receiving surface 22 was formed into an appropriate convex surface configuration, i.e., a ½ to ¾ spherical convex surface, the die life could be extended and that the die production cost could be reduced. Among other things, in the die (Example 13) with a ½ spherical surface, sufficient die life could be secured and that the die production cost could be reduced, which was excellent in result.

[0288] Compared with the die of Example 13, in the die (Example 14) in which the billet pressure receiving surface 22 was formed into a ¾ spherical surface, the die production cost was slightly increased, which was slightly deteriorated in result among Examples 11 to 14.

Second Embodiment

[0289] FIGS. 19 to 29 are explanatory views showing an extrusion die for metallic material according to a second embodiment of the present invention.

[0290] This extrusion die 10 for metallic material according to the second embodiment is designed to extrude a multi-passage hollow member (flat multi-passage tube) 60 as shown in FIGS. 28 and 29.

[0291] The hollow member 60 is a metal member. In this second embodiment, this hollow member 60 constitutes a heat exchanging tube made of aluminum or aluminum alloy.

[0292] This hollow member 60 is a flat member having a width larger than the thickness for use in heat exchangers, such as, e.g., condensers for car air-conditioners. The hollow portion 61 of this hollow member 60 extends in the tube length direction and is divided into a plurality of heat exchanging passages 63 by a plurality of partitions 62 arranged in parallel with each other. These passages 63 extend in the tube length direction and are arranged in parallel with each other.

[0293] In the following explanation of this second embodiment, a direction with which a tube length direction perpendicularly intersects and along which the passages 63 are arranged will be referred to as a “width direction” or a “lateral direction,” and a direction with which a tube length direction perpendicularly intersects and with which the width direction perpendicularly intersects will be referred to as a “height direction (thickness direction)” or a “vertical direction.” Furthermore, in the following explanation of this second embodiment, the “upstream side” with respect to the extrusion direction will be referred to as a “rear side,” and the “downstream side” thereof will be referred to as a “front side.”

[0294] FIGS. 19 to 24 show an extrusion die 10 of this second embodiment. As shown in these figures, the extrusion die 10 of this second embodiment is equipped with a die case 20, a male die 30, a female die 40, and a flow control plate 50.

[0295] The die case 20 has a hollow structure having a dome-shaped pressure receiving portion 21 provided at the upstream side (rear side) with respect to the extrusion direction of a metallic billet as a metallic material and a base portion 25 provided at the downstream side (front side).

[0296] The surface (rear surface) of the pressure receiving portion 21 opposed against the extrusion direction of a metallic billet is formed into a billet pressure receiving surface 22 functioning as a metallic material pressure receiving surface. This billet pressure receiving surface 22 is formed into a convex configuration protruded in a direction opposite to the extrusion direction (i.e., in the rear direction). Concretely, this pressure receiving surface 22 is formed into a hemispherical convex configuration. Thus, the pressure receiving surface 22 is formed so as to protrude rearward.

[0297] In the peripheral wall center of the pressure receiving portion 21, a male die holding slit 23 communicated with an internal hollow portion (welding chamber 12) is formed along the axis A1 of the die case 20. This male die holding slit 23 is formed into a flat rectangular cross-sectional configuration corresponding to the cross-sectional configuration of the male die 30. Furthermore, as shown in FIG. 23, at both side portions of the rear end side of the male die holding slit 23, engaging stepped portions 23a and 23a for engaging the male die 30, which will be mentioned later, are formed.

[0298] In the peripheral wall of the pressure receiving portion 21, a pair of portholes 24 and 24 are formed at both sides of the axis A1. The inlet portion 24e of each porthole 24 is formed into an approximately trapezoidal configuration as seen from the upstream side of the axial direction.

[0299] As shown in FIG. 22, each porthole 24 is disposed such that the axis A2 thereof approaches the axis A1 of the pressure receiving portion 21 as it advances toward the downstream side and intersects with the axis A1 of the pressure receiving portion 21 in an inclined state. The detail structure of, e.g., the inclination angle θ of the axis A2 of the porthole 24 will be explained later.

[0300] Furthermore, each porthole 24 is formed such that the passage cross-sectional area gradually decreases from the inlet portion 24e toward the inner portion, so that the opening area of the inlet portion 24e is larger than the passage cross-sectional area of the inner portion. In the second embodiment, the porthole 24 is formed such that the inclination angle θa of the inner surface 24a of the inner peripheral surface with respect to the axis A1 is set to be smaller than the inclination angle θb of the outer side surface 24b with respect to the axis A1 (i.e., θa<θb).

[0301] The pair of portholes 24 and 24 are arranged so that the outlet portions (front end portions) thereof face toward the below-mentioned extrusion hole 11.

[0302] In this second embodiment, it is constituted such that the axis A1 of the die case 20 and the axis of the pressure receiving portion 21 coincide with each other.

[0303] The base portion 25 is integrally formed to the pressure receiving portion 21, and formed into an annular shape centered on the axis A1. The base portion 25 has a diameter larger than the diameter of the pressure receiving portion 21.

[0304] In this invention, the base portion 25 and the pressure receiving portion 21 are not required to be formed integrally, and can be formed separately. Whether both the members 21 and 25 should be integrally formed or separately formed can be arbitrarily selected in consideration of the maintenance performance, etc.
[0315] As shown in FIG. 20, the flow control plate 50 has, at its both sides of the external peripheral edge portion, key protrusions 57 and 58 corresponding to the key protrusions 47 and 48 of the female die 40 are formed.

[0316] As shown in FIGS. 21 to 23, the female die 40 is accommodated and fixed in the female die holding hole 26 of the die case 20 via the flow control plate 50. With this state, the external peripheral surface of one end surface (rear end surface) of the female die 40 is engaged with the engaging stepped portion 26a of the female die holding hole 26 via the external peripheral edge portion of the flow control plate 50, so that the female die 40 and the flow control plate 50 are positioned in the axial direction. Furthermore, the key protrusions 47 and 48 of the female die 40, and the key protrusions 57 and 58 of the flow control plate 50 are engaged with the keyways (not illustrated) formed on the internal peripheral surface of the female die holding hole 26, so that the female die 40 and the flow control plate 50 are positioned in the axial rotational direction.

[0317] With this, the mandrel 31 of the male die 30 and the die hole 41 of the female die 40 are disposed corresponding to the central through-hole 51 of the flow control plate 50. In this state, the mandrel 31 of the male die 30 is disposed within the die hole 41 of the female die 40 to form a flat circular extrusion hole 11 between the mandrel 31 and the die hole 41. Furthermore, a plurality of partition forming grooves 32 of the mandrel 31 are arranged in parallel in the width direction in the extrusion hole 11, whereby a cross-sectional shape corresponding to the cross-sectional shape of the hollow member 60 is formed.

[0318] In this second embodiment, as shown in FIG. 22, it is preferable that the angle difference (θb-θa) between the inclination angle θb of the outer side surface 24b and the inclination angle θa of the inner side surface 24a is set to 3 to 37°, more preferably 5 to 25°. When the angle difference (θb-θa) is set so as to fall within the above specified range, the opening area of the porthole inlet portion 24c can be kept sufficiently large, which makes it possible to stably introduce a billet as a metallic material into the inside of the die. As a result, a high quality extruded product can be formed.

[0319] In other words, if the angle difference (θb-θa) is too large, the passage cross-sectional area of the inside portion of the porthole 24 becomes extremely small as compared with that of the inlet portion 24c, causing sudden pressure changes when the billet passes through the porthole 24, which may sometimes make it difficult to stably introduce the billet into the die. To the contrary, if the angle difference (θb-θa) is too small, the opening area of the inlet portion 24c cannot be kept large enough, causing excessively large pressure (extrusion load) of the billet against the die, which may sometimes make it difficult to smoothly perform the extrusion processing. It is not preferable to keep the opening area of the inlet portion 24c large with the aforementioned angle difference (θb-θa) kept small, because the porthole 24 itself becomes large, increasing the void ratio in the die by the portholes 24, which causes deteriorated die strength.

[0320] As will be explained with reference to the third embodiment to the fifth embodiment, in the present invention, it is possible to increase the opening area of the inlet portion 24c by setting the angle difference (θb-θa) to 0°.

[0321] Furthermore, in the second embodiment, it is preferable to set the inclination angle θa of the inner side surface 24a of the porthole 24 to 3 to 30°, more preferably 5 to 25°. The inclination angle θb of the outer side surface 24b is
preferably set to 10 to 40°, more preferably 20 to 30°. That is, in cases where the inclination angle \( \theta \) of the inner side surface \( 24a \) is excessively large or the inclination angle \( \theta b \) of the outer side surface \( 24b \) is excessively small, a sufficient opening area of the inlet portion \( 24e \) cannot be secured, causing excessively large extrusion load of the billet, which may sometimes make it difficult to perform smooth extrusion processing. In cases where the inclination angle \( \theta a \) of the inner side surface \( 24a \) is excessively small or the inclination angle \( \theta b \) of the outer side surface \( 24b \) is excessively large, the passage cross-sectional area of the porthole \( 24 \) may sometimes become excessively small as compared with the inlet portion \( 24e \) of the porthole \( 24 \), which may make it difficult to pass the billet in a stable manner.

[0322] As explained above, each of the portholes \( 24 \) and \( 24 \) is formed such that the axis \( A2 \) inclines with respect to the axis \( A1 \) of the die case \( 20 \). In this second embodiment, it is preferable that the inclination angle \( \theta \) of the axis \( A2 \) of the porthole \( 24 \) with respect to the axis \( A1 \) of the die case \( 20 \) is set to 3 to 45°, more preferably 10 to 35°, still more preferably 15 to 30°. When the inclination angle \( \theta \) is set so as to fall within the above specified range, the metallic material flows through the portholes \( 24 \) and \( 24 \) and the welding chamber \( 12 \) in a stable manner, and then smoothly passes through around the entire periphery of the extrusion hole \( 11 \) in a balanced manner. As a result, a high quality extruded product excellent in dimensional accuracy can be formed. In other words, if the inclination angle \( \theta \) is too small, the metallic material passed through the portholes \( 24 \) and \( 24 \) and the welding chamber \( 12 \) cannot be smoothly introduced into the extrusion hole \( 11 \), which may sometimes make it difficult to stably obtain a high quality extruded product. To the contrary, if the inclination angle \( \theta \) is too large, the material flowing direction of the porthole \( 24 \) inclines largely, which increases the metallic material extrusion resistance, and therefore it is not preferable.

[0323] In this second embodiment, it is preferable that the billet pressure receiving surface \( 22 \) of the die case \( 20 \) is constituted by a convex spherical surface of a \( \frac{1}{3} \) sphere to a \( \frac{1}{2} \) sphere. When the billet pressure receiving surface \( 22 \) is constituted by the aforementioned specific convex spherical configuration, the pressing force of a metallic billet can be more assuredly received by the billet pressure receiving surface \( 22 \) in a well-balanced dispersed manner, resulting in sufficient strength, which in turn can more assuredly extend the die life. That is, when a billet is pressed against the pressure receiving surface \( 22 \) having the specific convex spherical configuration, compressing force toward the center of the pressure receiving portion \( 21 \) is more assuredly applied to each portion of the pressure receiving surface \( 21 \). As a result, the shearing force generated at the die case \( 20 \) at the time of the extrusion will be assuredly reduced. As a result, the portion of the die case \( 20 \) exposed to the hollow portion thereof, which is the portion where the largest shearing force will be generated, can be reduced assuredly. Thus, the strength of the die \( 10 \) against the pressing force of the billet can be improved more assuredly. In addition to the above, it also makes it possible to simplify the die configuration, reduce the size and weight, and also attain the cost reduction. In other words, if the billet pressure receiving surface \( 22 \) is formed into a configuration constituted by a convex spherical surface of a sphere smaller than a \( \frac{1}{3} \) sphere, such as, e.g., a convex spherical surface constituted by a \( \frac{1}{2} \) sphere, sufficient strength against the billet pressing force cannot be obtained, which may cause deteriorated die life due to generation of cracks. To the contrary, if the billet pressure receiving surface \( 22 \) is formed into a configuration constituted by a convex spherical surface of a sphere exceeding a \( \frac{1}{3} \) sphere, such as, e.g., a convex spherical surface configuration of a \( \frac{1}{3} \) sphere, the cost may be increased due to the complicated configuration.

[0324] In this embodiment, the sphere with a ratio, such as, e.g., a \( \frac{1}{3} \) sphere, a \( \frac{1}{2} \) sphere, or a \( \frac{1}{4} \) sphere, is defined by a partial sphere obtained by cutting a perfect sphere with a plane perpendicular to the axis of the perfect sphere. That is, in this embodiment, an "\( n/m \) sphere ("m" and "n" are natural numbers, and \( n\leq m \)" is defined by a partial sphere obtained by cutting a perfect sphere with a plane perpendicular to the axis of the perfect sphere at a position where a distance from a surface of the perfect sphere to an inner position of the perfect sphere on the axis (diameter) is \( n/m \) where the length of the axis (diameter) of the perfect sphere is "1."

[0325] The extrusion die \( 10 \) having the aforementioned structure is set in an extruder as shown in FIGS. 25 to 27. That is, the extrusion die \( 10 \) of this embodiment is set to a container \( 6 \) with the extrusion die \( 10 \) fixed in the die installation hole \( 5a \) formed in the center of a plate \( 5 \). The extrusion die \( 10 \) is fixed by the plate \( 5 \) in a direction perpendicular to the extrusion direction and also fixed by a backer (not illustrated) in the extrusion direction.

[0326] A metallic billet (metallic material), such as, e.g., an aluminum billet, inserted in the container \( 6 \) is pressed in the right direction (extrusion direction) in FIG. 25 via a dummy block \( 7 \). Thereby, the metallic billet is pressed against the billet pressure receiving surface \( 22 \) of the die case \( 20 \) constituting the extrusion die \( 10 \) to be plastically deformed. As a result, the metallic material passes through the pair of portholes \( 24 \) and \( 24 \) while being plastically deformed and then reaches the welding chamber \( 12 \) of the die case \( 20 \). Then, the metallic material is forwardly extruded through the extrusion hole \( 11 \) into a cross-sectional configuration corresponding to the opening configuration of the extrusion hole \( 11 \). Thus, a metallic extruded article (hollow member \( 60 \) is manufactured.

[0327] According to the extrusion die \( 10 \) of this second embodiment, since the billet pressure receiving surface \( 22 \) is formed into a convex spherical configuration, when the metallic billet is pressed against the billet pressure receiving surface \( 22 \), the pressing force can be received by the pressure receiving surface \( 22 \) in a dispersed manner. Therefore, the pressing force to be applied to each portion of the billet pressure receiving surface \( 22 \) in the direction of a normal line can be reduced, thereby increasing the strength against the pressing force of the metallic material, which results in sufficient durability.

[0328] Furthermore, in the second embodiment, since the porthole \( 24 \) is formed such that the opening area of the inlet portion \( 24e \) is larger than the passage cross-sectional area of the inside of the porthole \( 24 \), it is possible to smoothly introduce a billet from the inlet portion \( 24e \), resulting in appropriately reduced pressing force (extrusion load) against the pressure receiving surface \( 22 \) of the billet. As a result, the extrusion processing can be smoothly performed efficiently, which in turn can produce a high quality extruded product.

[0329] Especially in the second embodiment, since the porthole \( 24 \) is formed so as to gradually decrease from the inlet portion \( 24e \) toward the inside, no sudden change in flow resistance of the billet passing through the portholes \( 24 \)
occurs, which makes it possible to more smoothly pass the billet through the portholes 24, resulting in more effective extrusion processing.

Furthermore, since the passage cross-sectional area of the inside of the porthole 24 is small, the volume (size) of the porthole 24 can be kept relatively small, resulting in a small void rate of the die case 20 by the portholes 24, which can sufficiently increase the strength of the die case 20. This in turn can sufficiently increase the strength of the entire die.

Furthermore, in this second embodiment, the portholes 24 for introducing material are formed in the pressure receiving portion 21 covering the male die 30 and the female die 40. In other words, the front end wall portion of the pressure receiving portion 21 and the wall portion of the base portion 25 are formed integrally and continuously in the peripheral direction. The existence of this continued peripheral wall portion can further increase the strength of the die case 20, which in turn can further increase the strength of the entire extrusion die. Thus, there is no portion weak in strength, such as a conventional bridge portion, and therefore it is not required to increase the size, such as, e.g., the thickness, beyond the necessity for the purpose of increasing the strength, which makes it possible to attain the size and weight reduction as well as the cost reduction.

Furthermore, in this second embodiment, the portholes 24 and 24 are formed at positions away from the axis A1 of the pressure receiving portion 21, i.e., the outer periphery of the pressure receiving portion 21, and the axis A2 of each porthole 24 is inclined with respect to the axis A1 of the die case 20 so as to gradually approach the axis A1 of the die case 20 toward the downstream side. Therefore, the metallic material passing through the portholes 24 and 24 can be stably extruded while being smoothly introduced toward the axis A1, i.e., the extrusion hole 11. Furthermore, in this second embodiment, since the downstream side end portions (outlets) of the portholes 24 and 24 are faced toward the extrusion hole 11, the metallic material can be more smoothly introduced to the extrusion hole 11.

Furthermore, in this second embodiment, since the portholes 24 and 24 are arranged at both sides of the height direction (thickness direction) of the flat extrusion hole 11, the metallic material can be more smoothly introduced into the extrusion hole 11 in a stable manner. Accordingly, the metallic material is extruded while evenly passing through the entire area of the extrusion hole 11 in a well-balanced manner, to thereby obtain a high quality extruded hollow member 60.

Especially like in this second embodiment, even in the case of extruding a hollow member 60, having a complicated configuration, such as, e.g., a flat monolith tube configuration, a metallic material can be introduced into the entire region of the extrusion hole 11 in a well-balanced manner, which can assuredly maintain the high quality.

For reference, in cases where an aluminum heat exchanging tube (hollow member) provided with a plurality of passages 63 each rectangular in cross-section having a height of 0.5 mm and a width of 0.5 mm, in a conventional extrusion die, since the strength was not sufficient, cracks generated in the male die 30 became a factor of the die life. On the other hand, in the extrusion die 10 according to the present invention, since the strength is sufficient, no crack will be generated in the die. Therefore, the wear of the die becomes a factor of the die life, which can remarkably improve the die life.

For example, according to experiment results relevant to a die life performed by the present inventors, in the extrusion die according to the present invention, the die life was extended about three times as compared with a conventional one.

Moreover, in the present invention, since it has sufficient pressure resistance (strength), the extrusion limit speed can be raised considerably. For example, in a conventional extrusion die, the upper limit of the extrusion speed was 60 m/min. On the other hand, in the extrusion die according to the present invention, the upper limit of the extrusion speed can be raised to 150 m/min, i.e., the extrusion limit speed can be raised about 2.5 times, and therefore the productive efficiency can be further improved.

Third Embodiment

FIGS. 30 to 33 show an extrusion die 10 according to a third embodiment of this invention. As shown in these figures, this extrusion die 10 according to the third embodiment is different from the extrusion die 10 according to the second embodiment in the configuration (structure) of the porthole 24.

That is, in the extrusion die 10 according to the third embodiment, at both peripheral sides of the pressure receiving portion 21, a pair of portholes 24 and 24 are formed corresponding to thickness both sides of the flat extrusion hole 11. Each porthole 24 is formed into an approximately trapezoidal configuration as seen from the upstream side in the axial direction. This porthole 24 has an inlet portion 24e formed into a flat elongated configuration large in peripheral direction size (width) and small in radial direction size (thickness).

As shown in FIGS. 32 and 33, this porthole 24 is formed into an approximately fan shape with a width of the inlet portion 24e larger than that of the inside thereof. In detail, the width of the porthole 24 gradually decreases from the inlet portion 24e toward the inside, and the opening area of the inlet portion 24e is larger than the passage cross-sectional area of the inside of the porthole 24.

In the third embodiment, the inner side surface 24a of the inner peripheral surface of the porthole 24 and the outer side surface 24b thereof are arranged approximately in parallel with each other. The inclination angle θa of the inner side surface 24a with respect to the axis A1 and the inclination angle θb of the outer side surface 24b with respect to the axis A1 are approximately equal.

As shown in FIG. 33, when the cross angle (width directional opening angle) between both side edges 24e and 24e of the inner peripheral surface of the porthole 24 is defined as “θw,” it is preferable that the opening angle of 8θw is set to 5 to 45°, more preferably 10 to 40°. When the opening angle of 8θw is set within the aforementioned range, the billet as a metallic material can be stably extruded from the inlet portion 24e of the porthole 24 into the inside thereof while keeping the opening area of the porthole inlet portion 24e sufficiently large. As a result, a high quality extruded product can be obtained.

In other words, if the aforementioned opening angle 8θw is excessively large, the passage cross-sectional area of the porthole 24 becomes extremely small as compared with the passage cross-sectional area of the inlet portion 24e of the porthole 24, causing sudden pressure changes when the billet passes through the porthole 24, which may sometimes make it difficult to stably introduce the billet into the die. To the
contrary, if the aforementioned opening angle $\theta_0$ is too small, the opening area of the inlet portion $24e$ cannot be secured, causing excessively large pressure (extrusion load) of the billet against the die, which in turn may sometime make it difficult to smoothly perform the extrusion processing. If the opening area of the inlet portion $24e$ is kept large while keeping the aforementioned opening angle $\theta_0$ small, the porthole itself becomes large. This increases the void rate of the die by the portholes $24$, resulting in deteriorated die strength. Therefore, it is not preferable.

[0344] In this third embodiment, since the other structure is essentially the same as that of the second embodiment, the cumulative explanation will be omitted by allotting the same reference numeral to the same or corresponding portion.

[0345] This extrusion die $10$ according to the third embodiment is also set to the same extruder shown in FIGS. 25 to 27 used in the second embodiment to perform the extrusion.

[0346] In this third embodiment too, the same functions and effects as in the second embodiment can be attained.

Fourth Embodiment

[0347] FIGS. 34 to 38 show an extrusion die $10$ according to a fourth embodiment of this invention. As shown in these figures, the extrusion die $10$ of this fourth embodiment is different from the extrusion dies $10$ of the second and third embodiments in the configuration (structure) of the porthole $24$.

[0348] In this extrusion die $10$ of the fourth embodiment, at both sides of the peripheral wall of the pressure receiving portion $21$, a pair of portholes $24$ and $24$ are formed so as to be located at thickness both sides of the flat extrusion hole $11$. The inlet portion $24e$ of this porthole $24$ is formed into an approximately trapezoidal configuration as seen from the upstream side of the axial direction, in the same manner as in the second embodiment.

[0349] Furthermore, in this porthole $24$, an outer chamfered portion $242$ is formed by cutting out the corner portion between the outer side surface $24b$ of the inner peripheral surface and the pressure receiving surface $22$.

[0350] When the inclination angle of the outer chamfered portion $242$ with respect to the axis $A1$ is defined as "$\theta_2$" as shown in FIG. 38, it is preferable to set the inclination angle $\theta_2$ to 25 to 50°, more preferably to 30 to 45°.

[0351] When the ratio of the length $L_2$ of the chamfered portion to the length $L_2$ of the outer side surface $24b$ of the porthole inner peripheral surface before forming the outer chamfered portion $242$ is defined as the chamfered ratio of the outer chamfered portion $242$, the chamfered ratio $(L_2/L_2)$ is preferably set to 0.2 to 0.9, more preferably set to 0.4 to 0.8.

[0352] That is, when the inclination angle $\theta_2$ of the outer chamfered portion $242$ and the chamfered ratio $(L_2/L_2)$ are set so as to fall within the aforementioned ranges, the extrusion load can be suppressed by the increased opening area of the porthole inlet portion $24e$, and therefore a billet can be stably introduced into the inside of the die from the inlet portion $24e$ of the porthole $24$.

[0353] In this fourth embodiment, in the state before forming the outer chamfered portion $242$ on the outer side surface $24b$ of the inner peripheral surface of the porthole $24$, the inner side surface $24a$ of the inner peripheral surface of the porthole $24$ and the outer side surface $24b$ thereof are arranged approximately in parallel with each other, so that the inclination angle $\theta a$ of the inner side surface $24a$ with respect to the axis $A1$ and the inclination angle $\theta b$ of the outer side surface $24b$ with respect to the axis $A1$ are approximately the same.

[0354] In this fourth embodiment, the other structure is substantially the same as that of the second and third embodiments. Also, in this extrusion die $10$ of the fourth embodiment, the extrusion can be performed in the same manner as mentioned above, and the same functions and effects can be attained.

Fifth Embodiment

[0355] FIGS. 39 to 43 show an extrusion die $10$ according to a fifth embodiment of this invention. As shown in these figures, in this extrusion die $10$ of the fifth embodiment, at both sides of the peripheral wall of the pressure receiving portion $21$, a pair of portholes $24$ and $24$ are formed. Furthermore, in this porthole $24$, an inner chamfered portion $241$ is formed by cutting out the corner portion between the inner side surface $24a$ of the inner peripheral surface and the pressure receiving surface $22$.

[0356] When the inclination angle of the inner chamfered portion $241$ with respect to the axis $A1$ is defined as "$\theta_1$" as shown in FIG. 43, it is preferable to set the inclination angle $\theta_1$ to $-10$ to $+10^\circ$, more preferably $-3$ to $+5^\circ$.

[0357] When the ratio of the length $L_1$ of the chamfered portion to the length $L_1$ of the inner side surface $24a$ of the porthole inner peripheral surface before forming the inner chamfered portion $241$ is defined as the chamfered ratio of the outer chamfered portion $241$, the chamfered ratio $(L_1/L_1)$ is preferably set to 0.2 to 0.9, more preferably set to 0.4 to 0.8.

[0358] That is, when the inclination angle $\theta_1$ of the inner chamfered portion $241$ and the chamfered ratio $(L_1/L_1)$ are set so as to fall within the aforementioned ranges, the extrusion load can be suppressed by the increased opening area of the porthole inlet portion $24e$, and therefore a billet can be stably introduced into the inside of the die from the inlet portion $24e$ of the porthole $24$.

[0359] In this fifth embodiment, in the state before forming the inner chamfered portion $241$ on the inner side surface $24a$ of the inner peripheral surface of the porthole $24$, the inner side surface $24a$ of the inner peripheral surface of the porthole $24$ and the outer side surface $24b$ thereof are arranged approximately in parallel with each other, so that the inclination angle $\theta a$ of the inner side surface $24a$ with respect to the axis $A1$ and the inclination angle $\theta b$ of the outer side surface $24b$ with respect to the axis $A1$ are approximately the same.

[0360] In this fifth embodiment, the other structure is substantially the same as that of the second and third embodiments. Also, in this extrusion die $10$ of the fifth embodiment, the extrusion can be performed in the same manner as mentioned above, and the same functions and effects can be attained.

<Modification>

[0361] In the second to fifth embodiments, the pressure receiving portion $21$ (pressure receiving surface $22$) is formed into a hemisphere convex configuration (hemisphere convex surface). However, in the present invention, the configuration of the pressure receiving portion $21$ (pressure receiving surface $22$) is not limited to the above.

[0362] For example, in the present invention, the pressure receiving surface $22$ can be formed into a polyhedral configu-
ration constituted by a number of side surfaces. That is, the pressure receiving surface 22 can be formed into, for example, a polyhedral configuration, such as, e.g., a pyramid configuration in which a plurality of side surfaces are arranged in the circumferential direction, or a polyhedral configuration in which a plurality of side surfaces are arranged in the radial direction. In this case, each side surface constituting the pressure receiving surface 22 can be, for example, a flat surface or a curved surface.

Furthermore, in the present invention, the pressure receiving portion 21 can be formed into a laterally elongated configuration longer in the lengthwise direction than in the crosswise direction, the lengthwise direction and the crosswise direction being perpendicular to the axial direction. For example, the pressure receiving portion 21 can be formed into a laterally elongated elliptical configuration as seen from the axial upstream side or a laterally elongated oval configuration as seen from the axial upstream side.

Furthermore, in the present invention, the pressure receiving portion 21 can be formed into a configuration with an axial directional dimension longer than the radial directional dimension perpendicular to the axial direction, e.g., a semi-elliptical configuration.

Furthermore, in the aforementioned second to fifth embodiments, the die case 20 is integrally formed. The present invention, however, is not limited to the above, and the die case 20 can be divided into two or more parts. For example, the die case 20 can be constituted by two members, i.e., a male die case for holding the male die 30 and a female die case for holding the female die 40.

Furthermore, in the aforementioned second to fifth embodiments, the male die 30, the female die 40, the flow control plate 50 are formed separately from the die case 20. The present invention, however, is not limited to the above, and at least one of the male die 30, the female die 40, and the flow control plate 50 is integrally formed together with the die case 20. Furthermore, in the present invention, the flow control plate 50 can be omitted as needed.

Furthermore, in the aforementioned second to fifth embodiments, the explanation was directed to the die for extruding a flat multi-passage tubular member. In the present invention, however, the configuration of the extruded product (configuration hole) is not specifically limited. For example, in the present invention, it can be constituted such that a male die is provided with a mandrel round in cross-section and a female die is provided with a die hole round in cross-section so that a circular ring shaped extrusion hole is formed between the mandrel and the die hole to extrude a round tubular member.

In the aforementioned second to fifth embodiments, the explanation was directed to the case in which only a single extrusion die is set in a container. The present invention, however, is not limited to the above. In the extruder according to the present invention, it can be configured such that two or more extrusion dies are set in a container.

Furthermore, in the present invention, it can be configured such that both the outer chamfered portion 242 and the inner chamfered portion 241 are formed so that the opening area of the orifice inlet portion 24c is larger than the passage cross-sectional area of the inside of the orifice 24.

Furthermore, in the present invention, like the aforementioned second to fifth embodiments, it is preferable that the rear end face (basal end face) of the male die 30 is formed as a part of the convex surface (spherical surface) corresponding to the billet pressure receiving surface 22 of the pressure receiving portion 21 and that the rear end face of the male die 30 and the billet receiving surface 22 constitute a prescribed smooth convex surface (spherical surface). In the present invention, however, the configuration of the rear end face (basal end face) of the male die 30 is not limited to the above, and can be, for example, formed into the following configuration. That is, in the present invention, in cases where the surface area of the rear end face of the male die 30 is, for example, 1/3 or less of the surface area of the billet pressure receiving surface 22 of the die 10, the rear end face of the male die 30 can be constituted by a part of a columnar external peripheral surface in which the rear end face is circular corresponding to the billet pressure receiving surface 22 in the width direction (longitudinal direction) and straight in the thickness direction (direction perpendicular to the longitudinal direction) because of the following reasons. That is, in cases where the surface area of the rear end face of the male die 30 is small as mentioned above, influence on die life and extrusion load due to the fact that the rear end face of the male die 30 is formed not into a part of a convex surface (spherical surface) but into a part of an external periphery of a circular column is small and the processing cost for the rear end face of the male die 30 can be reduced.

Example

<table>
<thead>
<tr>
<th>TABLE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enlarged direction of the orifice inlet portion</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Example 16</td>
</tr>
<tr>
<td>Example 17</td>
</tr>
<tr>
<td>Example 18</td>
</tr>
<tr>
<td>Example 19</td>
</tr>
<tr>
<td>Reference Example</td>
</tr>
<tr>
<td>Comparative Example 2</td>
</tr>
</tbody>
</table>
Example 1

[0375] As shown in Table 3, an extrusion die 10 corresponding to the second embodiment (see FIGS. 19 to 23) was prepared. The pressure receiving portion 21 of the die case 20 of the die 10 had two portholes 24 formed at both thickness direction sides of the extrusion hole 11. In each porthole 24, the inclination angle \( \theta_a \) of the inner side surface 24a was adjusted to 10°, and the inclination angle \( \theta_b \) of the outer side surface 24b was adjusted to 25°. Accordingly, this porthole inlet portion 24e is enlarged in the thickness direction. Furthermore, the width dimension of each porthole 24 is set to be constant from the inlet portion 24e toward the inside of the die.

[0376] Furthermore, the ratio \((2 \times S_b/S_a)\) of the total plan state opening area \(S_b\) of the porthole inlet portions 24e to the plan state area \(S_a\) of the pressure receiving portion 21 was set to 0.70 (the area ration per porthole 24 was 0.35).

[0377] The billet pressure receiving surface 22 was formed into a \(1/2\) spherical configuration (convex spherical configuration) having a radius of 30 mm. The male die 30 was adjusted to 2.0 mm in height of mandrel 31, 19.2 mm in width of mandrel 31, 1.2 mm in height of passage forming protruded portion 33, 0.6 mm in width of passage forming protruded portion 33, and 0.2 mm in width of partition forming groove 32.

[0378] The female die 40 was adjusted to 1.7 mm in height of die wall 41 and 20.0 mm in width of die wall 41.

[0379] As shown in FIGS. 25 to 27, the extrusion die 10 was set to an extruder similar to the extruder shown in the second embodiment and extrusion was performed to produce a flat multi-passage tubular member 60 (heat exchanging tubular member) as shown in FIGS. 28 and 29.

[0380] Then, the die life (the amount (tons) of material introduced until cracks or wear occurred) and the extrusion load were measured, and the die life limiting factors were also investigated. The results are also shown in Table 3.

Example 17

[0381] As shown in Table 3, an extrusion die 10 corresponding to the third embodiment (see FIGS. 30 to 33) was prepared. That is, the porthole 24 of the pressure receiving portion 21 was formed such that the width thereof gradually decreased from the inlet portion 24e toward the inside thereof. The width direction opening angle \( \theta_a \) was set to 15°. Accordingly, this porthole inlet portion 24e was enlarged in the width direction. The inner side surface 24a of the porthole inner peripheral surface and the outer side surface 24b thereof were set to 10° in inclination angle \( \theta_a \) and \( \theta_b \) and arranged in parallel with each other.

[0382] Furthermore, the ratio \((2 \times S_b/S_a)\) of the total plan state opening area \(S_b\) of the porthole inlet portions 24e to the plan state area 21 of the pressure receiving portion 21 was set to 0.60 (the area ratio per porthole 24 was 0.30).

[0383] An extrusion die 10 same as that of Example 16 other than the aforementioned structure was prepared, and evaluated in the same manner as mentioned above by performing extrusion processing.

Example 18

[0384] As shown in Table 3, an extrusion die 10 corresponding to the fourth embodiment (see FIGS. 34 to 38) was prepared. That is, the inner side surface 24a and outer side surface 24b of the porthole inner peripheral surface of the pressure receiving portion 21 were set to 10° in inclination angles \( \theta_a \) and \( \theta_b \), and arranged in parallel with each other. Furthermore, at the outer side of the inlet portion 24e of the porthole 24, a chamfered portion 241 was formed. This outer chamfered portion 241 was set to 45° in inclination angle and 5 mm in length, and the chamfered rate (L/1L) of this chamfered portion 241 was 0.23/1. Therefore, the porthole inlet portion 24e was enlarged in the thickness direction.

[0385] Furthermore, the width dimension of the porthole 24 was set to be constant from the inlet portion 24e toward the inside of the die.

[0386] Furthermore, the ratio \((2 \times S_b/S_a)\) of the total plan state opening area \(S_b\) of the porthole inlet portions 24e to the plan state area 21 of the pressure receiving portion 21 was set to 0.76 (the area ratio per porthole 24 was 0.38).

[0387] An extrusion die 10 same as that of Example 16 other than the aforementioned structure was prepared, and evaluated in the same manner as mentioned above by performing extrusion processing.

Example 19

[0388] As shown in Table 3, an extrusion die 10 corresponding to the fifth embodiment (see FIGS. 39 to 43) was prepared. That is, the inner side surface 24a and outer side surface 24b of the porthole inner peripheral surface of the pressure receiving portion 21 was set to 10° in inclination angles \( \theta_a \) and \( \theta_b \), and arranged in parallel with each other. Furthermore, at the inner side of the inlet portion 24e of the porthole 24, a chamfered portion 241 was formed. This inner chamfered portion 241 was set to 0° in inclination angle (parallel to the axis A1) and 10 mm in length L1, and the chamfered rate (L1/La) of this chamfered portion 241 was 0.35/1. Therefore, the porthole inlet portion 24e was enlarged in the thickness direction.

[0389] Furthermore, the width dimension of the porthole 24 was set to be constant from the inlet portion 24e toward the inside of the die.

[0390] Furthermore, the ratio \((2 \times S_b/S_a)\) of the total plan state opening area \(S_b\) of the porthole inlet portions 24e to the plan state area 21 of the pressure receiving portion 21 was set to 0.60 (the area ratio per porthole 24 was 0.30).

[0391] An extrusion die 10 same as that of Example 16 other than the aforementioned structure was prepared, and evaluated in the same manner as mentioned above by performing extrusion processing.

Reference Example

[0392] As shown in Table 3, the pressure receiving portion 21 was formed into a semispherical configuration having a radius of 30 mm and a height (axial length) 15 mm.

[0393] The inner side surface and outer side surface of the porthole inner peripheral surface of the pressure receiving portion 21 were set to 10° in inclination angles \( \theta_a \) and \( \theta_b \), and arranged in parallel with each other, and the width dimension of the porthole 24 was set to be constant from the inlet portion 24e toward the inside of the die. Accordingly, the porthole inlet portion 24e was not enlarged.

[0394] Furthermore, the ratio \((2 \times S_b/S_a)\) of the total plan state opening area \(S_b\) of the porthole inlet portions 24e to the plan state area 21 of the pressure receiving portion 21 was set to 0.30 (the area ratio per porthole 24 was 0.15).
[0395] An extrusion die 10 same as that of Example 16 other than the aforementioned structure was prepared, and evaluated in the same manner as mentioned above by performing extrusion processing.

Comparative Example 2

[0396] As shown in Table 3, a bridge-type extrusion die having a radius of 30 mm and a height (extrusion direction length) of 50 mm in which the pressure receiving surface was finished into a flat surface perpendicularly intersecting with the extrusion direction was prepared. The inclination angle of the metallic material introduction direction was essentially set to 0°. The other structure was the same as the aforementioned embodiments.

[0397] This extrusion die 10 was set to an extruder in the same manner as mentioned above to produce an extruded product, and evaluated in the same manner as mentioned above.

<Evaluation>

[0398] As shown in Table 3, in Examples 16 to 19, wear of the male die 30 was a life limiting factor, and they had a sufficiently long die life. Furthermore, in these Examples, the extrusion load was relatively low, and therefore extrusion could perform smoothly.

[0399] On the other hand, in Comparative Example 2, generation of cracks in the male die was a life limiting factor. The die life was short and the extrusion load was large.

[0400] In Reference Example, wear of the male die was a life limiting factor and the die life was relatively long. However, the extrusion load was larger than that of Examples 16 to 19.

<table>
<thead>
<tr>
<th>Example</th>
<th>Spherical size of billet</th>
<th>Die life</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pressure receiving surface</td>
<td>(ton/die)</td>
</tr>
<tr>
<td>Example 20</td>
<td>⅓</td>
<td>1.7</td>
</tr>
<tr>
<td>Example 21</td>
<td>⅓</td>
<td>3.0</td>
</tr>
<tr>
<td>Example 22</td>
<td>⅓</td>
<td>3.6</td>
</tr>
<tr>
<td>Example 23</td>
<td>⅓</td>
<td>4.0</td>
</tr>
<tr>
<td>Example 24</td>
<td>⅓</td>
<td>4.0</td>
</tr>
<tr>
<td>Example 25</td>
<td>⅓</td>
<td>3.8</td>
</tr>
</tbody>
</table>

Example 20

[0401] As shown in Table 4, an extrusion die 10 corresponding to the second example (see FIGS. 19 to 24) was prepared. The pressure receiving portion 21 of the die case 20 of the die 10 had two portholes 24 formed at both thickness direction sides of the extrusion hole 11. In each porthole 24, the inclination angle θa of the inner surface 24a was adjusted to 10°, and the inclination angle θb of the outer side surface 24b was adjusted to 25°. Furthermore, the width dimension of each porthole 24 is set to be constant from the inlet portion 24e toward the inside of the die.

[0402] Furthermore, the ratio (2×Sb/Sa) of the plan state opening area Sb of the porthole inlet portions 24e to the plan state area Sa of the pressure receiving portion 21 was set to 0.70 (the area ration per porthole 24 was 0.35).

[0403] The billet pressure receiving surface 22 was formed into a ⅔ convex spherical surface (convex spherical configuration) having a radius of 45.4 mm. The male die 30 was adjusted to 60 mm in diameter.

Example 21

[0404] The male die 30 adjusted to 2.0 mm in height (thickness) of mandrel 31, 19.2 mm in width of mandrel 31, 1.2 mm in height of passage forming protruded portion 33, 0.6 mm in width of passage forming protruded portion 33, and 0.2 mm in width of partition forming groove 32, was used.

[0405] The female die 40 adjusted to 1.7 mm in height of die hole 41 and 20.0 mm in width of die hole 41 was used.

[0406] As shown in FIGS. 25 to 27, the extrusion die 10 was set to an extruder similar to the extruder shown in the second embodiment and extrusion was performed to produce a flat multi-passage tubular member 60 (heat exchanging tubular member) as shown in FIGS. 28 and 29.

[0407] Then, the die life (ton/die) was measured. The result is shown in Table 4.

Example 22

[0408] As shown in Table 4, an extrusion die 10 similar to the extrusion die of Example 20 except that the billet pressure receiving surface 22 was constituted by a convex spherical surface of a ⅔ sphere and the spherical diameter was set to 40.3 mm was prepared and set to an extruder similar to the extruder as mentioned above. A flat multi-passage hollow member 60 was produced by performing extrusion in the same manner as mentioned above.

Example 23

[0409] As shown in Table 4, an extrusion die 10 similar to the extrusion die of Example 20 except that the billet pressure receiving surface 22 was constituted by a convex spherical surface of a ⅔ sphere and the spherical diameter was set to 32.0 mm was prepared and set to an extruder similar to the extruder as mentioned above. A flat multi-passage hollow member 60 was produced by performing extrusion in the same manner as mentioned above.

Example 24

[0410] As shown in Table 4, an extrusion die 10 similar to the extrusion die of Example 14 except that the billet pressure receiving surface 22 was constituted by a convex spherical surface of a ⅔ sphere and the spherical diameter was set to 30.0 mm was prepared and set to an extruder similar to the extruder as mentioned above. A flat multi-passage hollow member 60 was produced by performing extrusion in the same manner as mentioned above.

Example 25

[0411] As shown in Table 4, an extrusion die 10 similar to the extrusion die of Example 20 except that the billet pressure receiving surface 22 was constituted by a convex spherical surface of a ⅔ sphere and the spherical diameter was set to 32.0 mm was prepared and set to an extruder similar to the extruder as mentioned above. A flat multi-passage hollow member 60 was produced by performing extrusion in the same manner as mentioned above.

[0412] As shown in Table 4, an extrusion die 10 similar to the extrusion die of Example 20 except that the billet pressure receiving surface 22 was constituted by a convex spherical surface of a ⅔ sphere and the spherical diameter was set to 40.3 mm was prepared and set to an extruder similar to the extruder as mentioned above. A flat multi-passage hollow
member 60 was produced by performing extrusion in the same manner as mentioned above.

<Evaluations>

[0413] As shown in Table 4, in the die in which the spherical radius of the billet pressure receiving surface 22 was large and the protruded amount was relatively small (Example 20), the die life was slightly shortened.

[0414] In the die in which the spherical radius of the billet pressure receiving surface 22 was small and the protruded amount was relatively large (Example 25), although the die life could be kept long, it seems to be slightly difficult to perform the processing of the billet pressure receiving surface 22.

[0415] On the other hand, in the die in which the billet pressure receiving surface 22 was formed into an appropriate convex surface configuration, i.e., a convex spherical surface of a 1/4 to 1/8 sphere (Examples 21 to 24), the die life could be extended and the die production cost could be reduced. Among other things, in the die in which the billet pressure receiving surface 22 was formed into a convex spherical surface of a 1/8 sphere (Example 23), the die production cost could be kept low while keeping sufficiently long die life, which was an excellent result.

[0416] Comparing with the die according to Example 23, in the die in which the billet pressure receiving surface 22 was formed into a convex spherical surface of a 1/4 sphere (Example 24), the die production cost was increased, which was an inferior result among Examples 21 to 24.

[0417] It should be understood that the terms and expressions used herein are used for explanation and have no intention to be used to construe in a limited manner, do not eliminate any equivalents of features shown and mentioned herein, and allow various modifications falling within the claimed scope of the present invention.

[0418] While the present invention may be embodied in many different forms, a number of illustrative embodiments are described herein with the understanding, that the present disclosure is to be considered as providing examples of the principles of the invention and such examples are not intended to limit the invention to preferred embodiments described herein and/or illustrated herein.

[0419] While illustrative embodiments of the invention have been described herein, the present invention is not limited to the various preferred embodiments described herein, but includes any and all embodiments having equivalent elements, modifications, omissions, combinations (e.g., of aspects across various embodiments), adaptations and/or alterations as would be appreciated by those in the art based on the present disclosure. The limitations in the claims are to be interpreted broadly based on the language employed in the claims and not limited to examples described in the present specification or during the prosecution of the application, which examples are to be construed as non-exclusive. For example, in the present disclosure, the term “preferably” is non-exclusive and means “preferably, but not limited to.” In this disclosure and during the prosecution of this application, means-plus-function or step-plus-function limitations will only be employed where for a specific claim limitation all of the following conditions are present in that limitation: a) “means for” or “step for” is expressly recited; b) a corresponding function is expressly recited; and c) structure, material or acts that support that structure are not recited. In this disclosure and during the prosecution of this application, the terminology “present invention” or “invention” may be used as a reference to one or more aspect within the present disclosure. The language present invention or invention should not be improperly interpreted as an identification of criticality, should not be improperly interpreted as applying across all aspects or embodiments (i.e., it should be understood that the present invention has a number of aspects and embodiments), and should not be improperly interpreted as limiting the scope of the application or claims. In this disclosure and during the prosecution of this application, the terminology “embodiment” can be used to describe any aspect, feature, process or step, any combination thereof, and/or any portion thereof, etc. In some examples, various embodiments may include overlapping features. In this disclosure and during the prosecution of this case, the following abbreviated terminology may be employed: “e.g.” which means “for example;” and “NB” which means “note well.”

INDUSTRIAL APPLICABILITY

[0420] The extrusion die for a metallic material according to the present invention can be applied to manufacture an extruded product such as a hollow tube, for example, a heat exchanging tube for use in car air conditioners, evaporators, or household hot-water supply equipments.

1. An extrusion die for a metallic material, comprising: a die case having a pressure receiving portion with an outer surface functioning as a metallic material pressure receiving surface, the die case being disposed with the metallic material pressure receiving surface faced rearward against an extrusion direction of the metallic material; a male die disposed in the die case; and a female die disposed in the die case to define an extrusion hole between the male die and the female die, wherein the pressure receiving surface is formed into a convex configuration protruded rearward, and a porthole for introducing the metallic material is provided in an outer periphery of the pressure receiving portion, wherein a ratio of an opening area of an inlet portion of the porthole defined by a plan view as seen from an axial upstream side (a plan state area of the pressure receiving portion) to an area of the pressure receiving portion defined by a plan view as seen from the axial downstream side (a plan state area of the pressure receiving portion) is set to 0.15 to 0.80, and wherein the extrusion die is configured such that the metallic material pressurized against the metallic material pressure receiving surface is introduced in the die case through the porthole and passes through the extrusion hole.

2. The extrusion die for a metallic material as recited in claim 1, wherein the porthole is configured such that the opening area of the inlet portion is larger than a passage cross-sectional area of an inside of the porthole.

3. The extrusion die for a metallic material as recited in claim 1, wherein the porthole is configured such that a passage cross-sectional area gradually decreases from the inlet portion toward an inside of the porthole.

4. The extrusion die for a metallic material as recited in claim 1, wherein the porthole is configured such that a radial length (thickness) of the inlet portion is set to be larger than a thickness of an inside of the porthole.

5. The extrusion die for a metallic material as recited in claim 1, wherein the porthole is configured such that a cir-
cumferential length (width) of the inlet portion is set to be larger than a width of an inside of the porthole.

6. The extrusion die for a metallic material as recited in claim 1, wherein the metallic material pressure receiving portion is constituted by a convex spherical surface of a ½ to ³⁄₈ sphere.

7. The extrusion die for a metallic material as recited in claim 1, wherein a plurality of portholes are formed at regular intervals in a circumferential direction about an axis of the die case.

8. The extrusion die for a metallic material as recited in claim 1, wherein the porthole is arranged toward the extrusion hole.

9. The extrusion die for a metallic material as recited in claim 1, wherein an inclination of an axis of the porthole with respect to an axis of the die case is set to 3 to 45°.

10. The extrusion die for a metallic material as recited in claim 1, wherein the extrusion hole is formed into a flat cross-sectional configuration with a width larger than a thickness, and wherein the portholes are formed at positions corresponding to thickness directional both sides of the extrusion die.

11. The extrusion die for a metallic material as recited in claim 1, wherein the male die and the female die define a flat circular extrusion hole with a height (thickness) smaller than a width, wherein a portion of the male die corresponding to the extrusion hole is formed into a comb-like configuration having a plurality of passage forming protrusions arranged in a width direction, and wherein the extrusion die is configured such that the metallic material passes through the extrusion hole to form a multi-passage hollow member with a plurality of passages arranged in a width direction.

12. The extrusion die for a metallic material as recited in claim 1, wherein the male die and the female die define a circular extrusion hole, and the extrusion die is configured such that the metallic material passes through the extrusion hole to form a tubular member circular in cross-section.

13. A die case for an extrusion die, comprising a pressure receiving portion with an outer surface functioning as a metallic material pressure receiving surface faced rearward against an extrusion direction of the metallic material, the die case being configured to mount a male die and a female die therein.

wherein the pressure receiving surface is formed into a convex configuration protruded rearward, and a porthole for introducing the metallic material is provided in an outer periphery of the pressure receiving portion, wherein a ratio of an opening area of an inlet portion of the porthole defined by a plan view as seen from an axial upstream side (a plan state opening area of the inlet portion of the porthole) to an area of the pressure receiving portion defined by a plan view as seen from the axial upstream side (a plan state area of the pressure receiving portion) is set to 0.15 to 0.80, and wherein the die case is configured such that the metallic material pressurized against the metallic material pressure receiving surface is introduced into the die case via the porthole and passes through the extrusion hole.

14. The die case for an extrusion die as recited in claim 13, wherein the metallic material pressure receiving portion is constituted by a convex spherical surface of a ½ to ³⁄₈ sphere.

15. An extrusion method for a metallic material, comprising the steps of:

preparing a die case, wherein the die case comprises a pressure receiving portion with an outer surface functioning as a metallic material pressure receiving surface faced rearward against an extrusion direction of the metallic material, a male die mounted in the die case, and a female die mounted in the die case for defining an extrusion hole between the male die and the female die, wherein the pressure receiving surface is formed into a convex configuration protruded rearward, and a porthole for introducing the metallic material is provided in an outer periphery of the pressure receiving portion, and wherein a ratio of an opening area of an inlet portion of the porthole defined by a plan view as seen from an axial upstream side (a plan state opening area of the inlet portion of the porthole) to an area of the pressure receiving portion defined by a plan view as seen from the axial upstream side (a plan state area of the pressure receiving portion) is set to 0.15 to 0.80; and introducing the metallic material pressurized against the metallic material pressure receiving surface into the die case via the porthole to pass through the extrusion hole.

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