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Molding device and metal pipe

Abstract

A forming device forms a metal pipe with a flange and includes a forming tool that forms the metal pipe, in which the forming tool includes a first die and a second die facing each other in a first direction in a cross-sectional view, and a third die disposed on at least one side of a metal pipe material in a second direction intersecting the first direction, and at least one of the first die and the second die is divided in the second direction and sandwiches a part of the metal pipe material in the second direction to form a flange portion.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a bypass continuation of International PCT Application No. PCT/JP2022/001126, filed on Jan. 14, 2021, which claims priority to Japanese Patent Application No. 2021-019159, filed on Feb. 9, 2021, which are incorporated by reference herein in their entirety.

BACKGROUND
Technical Field
(1) A certain embodiment of the present invention relates to a forming device and a metal pipe.
Description of Related Art
(2) In the related art, a forming device used for forming a metal pipe is known. For example, the related art discloses a forming device that includes a forming tool including a lower die and an upper die paired with each other, and a fluid supply unit for supplying a fluid into a metal pipe material held between the upper and lower dies.
SUMMARY
(3) A forming device according to an aspect of the present invention is a forming device that forms a metal pipe with a flange and includes a forming tool that forms the metal pipe, in which the forming tool includes a first die and a second die facing each other in a first direction in a cross-sectional view, and a third die disposed on at least one side of a metal pipe material in a second direction intersecting the first direction, and at least one of the first die and the second die is divided in the second direction and sandwiches a part of the metal pipe material in the second direction to form a flange portion.
(4) A metal pipe according to an embodiment of the present invention includes a hollow pipe portion that extends in a longitudinal direction in a cross-sectional view, and a flange portion that protrudes from the pipe portion to at least one side in a transverse direction perpendicular to the longitudinal direction.
(5) In this metal pipe, the flange portion of the pipe portion that protrudes in the transverse direction from a wall portion extending in the longitudinal direction in a cross-sectional view can be formed. Therefore, the strength and the rigidity of the metal pipe can be improved for a load in the longitudinal direction.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a schematic view of a forming device according to an embodiment of the present invention.
(2) FIGS. **2**A and **2**B are cross-sectional views showing a state when a nozzle has sealed a metal pipe material.
(3) FIG. **3** is a schematic perspective view of a metal pipe.
(4) FIG. **4** is a cross-sectional view showing a state of forming by a forming tool.
(5) FIG. **5** is a cross-sectional view showing a state of forming by the forming tool.
(6) FIG. **6** is a cross-sectional view showing a state of forming by the forming tool.
(7) FIG. **7** is a cross-sectional view showing a state of forming by the forming tool.
(8) FIG. **8** is a cross-sectional view showing a state of forming by the forming tool.
(9) FIG. **9** is a cross-sectional view showing a state of forming by the forming tool.

(10) FIG. **10** is a cross-sectional view showing a state of forming by the forming tool.
(11) FIG. **11** is a cross-sectional view showing a state of forming by the forming tool.
(12) FIG. **12** is a cross-sectional view showing a state of forming by the forming tool.
(13) FIG. **13** is a cross-sectional view showing a state of forming by the forming tool.
(14) FIG. **14** is a cross-sectional view showing a state of forming by the forming tool.
(15) FIG. **15** is a cross-sectional view showing a state of forming by the forming tool.
(16) FIG. **16** is a cross-sectional view showing a state of forming by the forming tool.
(17) FIG. **17** is a cross-sectional view showing a state of forming by the forming tool.
(18) FIG. **18** is a cross-sectional view showing a state of forming by the forming tool.
(19) FIG. **19** is a cross-sectional view showing a state of forming by the forming tool.
(20) FIG. **20** is a cross-sectional view showing a state of forming by the forming tool.
(21) FIG. **21** is a cross-sectional view showing a state of forming by the forming tool.
(22) FIG. **22** is a cross-sectional view showing a state of forming by the forming tool.
(23) FIG. **23** is a cross-sectional view showing a state of forming by the forming tool.

DETAILED DESCRIPTION

(24) In the forming device such as the related art described above, there is a case where the metal pipe with a flange is formed by crushing both sides of the metal pipe material in a lateral direction with the upper die and the lower die. In such a forming device, there is a need for further improving a strength and a rigidity of the metal pipe with a flange.

(25) According to an embodiment of the present invention, it is possible to provide a forming device capable of improving the strength and the rigidity of a metal pipe with a flange and a metal pipe capable of improving the strength and the rigidity.

(26) In the forming device, a forming tool includes a first die and a second die facing each other in a first direction in a cross-sectional view, and a third die disposed on at least one side of a metal pipe material in a second direction intersecting the first direction. The first die and the second die can form a shape of a pipe portion in the first direction of a metal pipe. In addition, the third die can form a shape of the pipe portion in the second direction of the metal pipe. Here, at least one of the first die and the second die is divided in the second direction and sandwiches a part of the metal pipe material in the second direction to form a flange portion. Therefore, it is possible to form the flange portion that protrudes in the first direction which is a direction in which the first die and the second die face each other. Accordingly, it is possible to form the flange portion that can secure a strength and a rigidity in accordance with a direction of a load acting on the metal pipe during use. As described above, the strength and the rigidity of the metal pipe with a flange can be improved.

(27) At least one of the first die and the second die may include a first portion and a second portion that sandwich a part of the metal pipe material in the second direction to form the flange portion. Accordingly, it is possible to form the flange portion that protrudes in the first direction which is a direction in which the first die and the second die face each other.

(28) Both the first die and the second die may have the first portion and the second portion. Accordingly, it is possible to form the flange portions on both sides in the first direction with respect to the pipe portion to improve the strength and the rigidity of the metal pipe.

(29) The first portion and the second portion in the first die, and the first portion and the second portion in the second die may form the flange portions at positions different from each other in the second direction. In this case, it is possible to adjust positions where the strength and the rigidity are increased with the flange portions in the second direction on one side and the other side in the first direction of the pipe portion. In addition, it is also possible to control a deformation behavior of the metal pipe depending on a direction of a load applied to the metal pipe.

(30) The first portion and the second portion may form the flange portion at the same position as one side surface in the second direction of the metal pipe. In this case, it is also possible to control a deformation behavior of the metal pipe depending on a direction of a load applied to the metal pipe in a case where there is a shape limitation such that a position of the flange portion is only at an end

in terms of position.
(31) At least one of the first die and the second die may include a third portion that sandwiches another part of the metal pipe material with the second portion to form another flange portion. In this case, the number of the flange portions can be increased to increase the strength and the rigidity.
(32) The first portion and the second portion may form the flange portion inclined with respect to the first direction. In this case, the rigidity can be increased, and a deformation behavior of a formed body depending on a direction of a load applied to the metal pipe can be controlled in a more preferable direction.
(33) The metal pipe may include a pair of the flange portions protruding from the pipe portion to both sides in the transverse direction. Accordingly, the strength and the rigidity of the metal pipe can be improved.
(34) The pair of flange portions may be formed at positions different from each other in the longitudinal direction. In this case, it is possible to adjust positions where the strength and the rigidity are increased with the flange portions in the longitudinal direction on one side and the other side in the transverse direction of the pipe portion.
(35) The flange portion may be formed at the same position as one side surface in the longitudinal direction of the pipe portion. In this case, the same stress is generated for a load from a target direction (a load such as a bending load), and the shape can be balanced in terms of strength.
(36) A plurality of the flange portions protruding to at least one side in the transverse direction may be formed in the pipe portion at positions different from each other in the longitudinal direction. In this case, the number of the flange portions can be increased to increase the strength and the rigidity.
(37) The flange portion may be inclined with respect to the transverse direction. In this case, even if the rigidity and the strength are inferior to those in a case where the flange portions are in the vertical direction, there is a case where it is more convenient to have a certain inclination angle in joining with ancillary parts, and it is possible to meet design requirements. In addition, there is a possibility that the deformation behavior can be optimized depending on the direction of the load and the inclination of the flange portion.
(38) Hereinafter, a preferred embodiment of the present invention will be described with reference to the drawings. In addition, in the respective drawings, the same portions or corresponding portions are designated by the same reference signs, and duplicated descriptions will not be repeated.
(39) FIG. **1** is a schematic view of a forming device **1** according to the present embodiment. As shown in FIG. **1**, the forming device **1** is a device that forms a metal pipe having a hollow shape by blow forming. In the present embodiment, the forming device **1** is installed on a horizontal plane. The forming device **1** includes a forming tool **2** (forming die), a drive mechanism **3**, a holding unit **4**, a heating unit **5**, a fluid supply unit **6**, a cooling unit **7**, and a control unit **8**. In addition, in the present specification, the metal pipe refers to a hollow article after completion of forming in the forming device **1**, and a metal pipe material **40** refers to a hollow article before completion of forming in the forming device **1**. The metal pipe material **40** is a steel-type pipe material that can be hardened. In addition, in a horizontal direction, a direction in which the metal pipe material **40** extends during forming is sometimes referred to as an “extending direction”, and a direction perpendicular to the extending direction is sometimes referred to as a “lateral direction (second direction)”.
(40) The forming tool **2** is a die for forming the metal pipe material **40** into the metal pipe and includes a lower die **11** (first die) and an upper die **12** (second die) facing each other in a vertical direction (first direction). In addition, the forming tool **2** includes a pair of lateral dies **14**A and **14**B (third dies) facing each other in the lateral direction (refer to FIG. **4**). Detailed shapes and the like of the dies **11**, **12**, **14**A, and **14**B will be described later. The lower die **11** and the upper die **12** are

made of steel blocks. The lower die **11** is fixed to a base stage **13** via a die holder or the like. The upper die **12** is fixed to a slide of the drive mechanism **3** via a die holder or the like.

(41) The drive mechanism **3** is a mechanism that moves at least one of the lower die **11** and the upper die **12**. In FIG. **1**, the drive mechanism **3** has a configuration in which only the upper die **12** is moved. The drive mechanism **3** includes a slide **21** that moves the upper die **12** such that the lower die **11** and the upper die **12** are joined together, and a pull-back cylinder **22** serving as an actuator that generates a force for pulling the slide **21** upward, a main cylinder **23** serving as a drive source that downward-pressurizes the slide **21**, and a drive source **24** that applies a driving force to the main cylinder **23**.

(42) The holding unit **4** is a mechanism that holds the metal pipe material **40** disposed between the lower die **11** and the upper die **12**. The holding unit **4** includes a lower electrode **26** and an upper electrode **27** that hold the metal pipe material **40** on one end side in the extending direction of the forming tool **2**, and a lower electrode **26** and an upper electrode **27** that hold the metal pipe material **40** on the other end side in the extending direction of the forming tool **2**. The lower electrodes **26** and the upper electrodes **27** on both sides in the extending direction hold the metal pipe material **40** by sandwiching vicinities of the end portions of the metal pipe material **40** from the vertical direction. In addition, groove portions having a shape corresponding to an outer peripheral surface of the metal pipe material **40** are formed on an upper surface of the lower electrode **26** and a lower surface of the upper electrode **27**. The lower electrode **26** and the upper electrode **27** are provided with drive mechanisms (not shown) and are movable independently in the vertical direction.

(43) The heating unit **5** heats the metal pipe material **40**. The heating unit **5** is a mechanism that heats the metal pipe material **40** by energizing the metal pipe material **40**. The heating unit **5** heats the metal pipe material **40** in a state in which the metal pipe material **40** is spaced apart from the lower die **11** and the upper die **12** between the lower die **11** and the upper die **12**. The heating unit **5** includes the lower electrodes **26** and the upper electrodes **27** on both sides in the extending direction described above, and a power supply **28** that causes a current to flow through the metal pipe material via the electrodes **26** and **27**. In addition, the heating unit **5** may be disposed in a preceding process of the forming device **1** and may perform heating externally.

(44) The fluid supply unit **6** is a mechanism that supplies a high-pressure fluid into the metal pipe material **40** held between the lower die **11** and the upper die **12**. The fluid supply unit **6** supplies the high-pressure fluid into the metal pipe material **40** that has been brought into a high-temperature state by being heated by the heating unit **5** and expands the metal pipe material **40**. The fluid supply unit **6** is provided on both end sides of the forming tool **2** in the extending direction. The fluid supply unit **6** includes a nozzle **31** that supplies a fluid from an opening portion of an end portion of the metal pipe material **40** to the inside of the metal pipe material **40**, a drive mechanism **32** that moves the nozzle **31** forward and backward with respect to the opening portion of the metal pipe material **40**, and a supply source **33** that supplies the high-pressure fluid into the metal pipe material **40** via the nozzle **31**. The drive mechanism **32** brings the nozzle **31** into close contact with the end portion of the metal pipe material **40** in a state in which a sealing property is secured at the time of supply and exhaust of the fluid (refer to FIGS. **2**A and **2**B) and at other times, separates the nozzle **31** from the end portion of the metal pipe material **40**. In addition, the fluid supply unit **6** may supply a gas such as high-pressure air or an inert gas as the fluid. Additionally, the fluid supply unit **6** may include the heating unit **5** together with the holding unit **4** having a mechanism that moves the metal pipe material **40** in the vertical direction as the same device.

(45) FIG. **2**A is a schematic side view showing a heating and expanding unit **50** in which components of the holding unit **4**, the heating unit **5**, and the fluid supply unit **6** are unitized. FIG. **2**B is a cross-sectional view showing a state when the nozzle **31** has sealed the metal pipe material **40**.

(46) As shown in FIG. **2**A, the heating and expanding unit **50** includes the above-described lower electrode **26** and upper electrode **27**, an electrode mounting unit **51** on which the electrodes **26** and

27 are mounted, the above-described nozzle **31** and drive mechanism **32**, an elevating unit **52**, and a unit base **53**. The electrode mounting unit **51** includes an elevating frame **54** and electrode frames **56** and **57**. The electrode frames **56** and **57** function as a part of a drive mechanism **60** that supports and moves each of the electrodes **26** and **27**. The drive mechanism **32** drives the nozzle **31** and lifts and lowers the nozzle **31** together with the electrode mounting unit **51**. The drive mechanism **32** includes a piston **61** that holds the nozzle **31**, and a cylinder **62** that drives the piston. The elevating unit **52** includes an elevating frame base **64** attached to an upper surface of the unit base **53**, and an elevating actuator **66** that applies an elevating operation to the elevating frame **54** of the electrode mounting unit **51** by the elevating frame base **64**. The elevating frame base **64** includes guide portions **64***a* and **64***b* that guide the elevating operation of the elevating frame **54** with respect to the unit base **53**. The elevating unit **52** functions as a part of the drive mechanism **60** of the holding unit **4**. The heating and expanding unit **50** includes a plurality of the unit bases **53** of which upper surfaces have different inclination angles, and is allowed to collectively change and adjust inclination angles of the lower electrode **26** and the upper electrode **27**, the nozzle **31**, the electrode mounting unit **51**, the drive mechanism **32**, and the elevating unit **52** by replacing the unit bases **53**.

(47) The nozzle **31** is a cylindrical member into which the end portion of the metal pipe material **40** can be inserted. The nozzle **31** is supported by the drive mechanism **32** such that a center line of the nozzle **31** coincides with a reference line SL**1**. An inner diameter of a supply port **31***a* at an end portion of the nozzle **31** on the side of the metal pipe material **40** substantially coincides with an outer diameter of the metal pipe material **40** after expansion forming. In this state, the nozzle **31** supplies the high-pressure fluid from an internal flow path **63** to the metal pipe material **40**. Examples of the high-pressure fluid include a gas and the like.

(48) Returning to FIG. **1**, the cooling unit **7** is a mechanism for cooling the forming tool **2**. By cooling the forming tool **2**, the cooling unit **7** can rapidly cool the metal pipe material **40** when the expanded metal pipe material **40** has come into contact with a forming surface of the forming tool **2**. The cooling unit **7** includes a flow path **36** formed inside the lower die **11** and the upper die **12**, and a water circulation mechanism **37** that supplies cooling water to the flow path **36** and circulates the cooling water.

(49) The control unit **8** is a device that controls the entire forming device **1**. The control unit **8** controls the drive mechanism **3**, the holding unit **4**, the heating unit **5**, the fluid supply unit **6**, and the cooling unit **7**. The control unit **8** repeatedly performs an operation of forming the metal pipe material **40** with the forming tool **2**.

(50) Specifically, the control unit **8** controls, for example, a transport timing from a transport device such as a robot arm to dispose the metal pipe material **40** between the lower die **11** and the upper die **12** in an open state. Alternatively, the control unit **8** may wait for a worker to manually dispose the metal pipe material **40** between the lower die **11** and the upper die **12**. Additionally, the control unit **8** controls an actuator of the holding unit **4** and the like such that the metal pipe material **40** is supported by the lower electrodes **26** on both sides in the extending direction, and then the upper electrodes **27** are lowered to sandwich the metal pipe material **40**. Additionally, the control unit **8** controls the heating unit **5** to energize and heat the metal pipe material **40**. Accordingly, an axial current flows through the metal pipe material **40**, and an electric resistance of the metal pipe material **40** itself causes the metal pipe material **40** itself to generate heat due to Joule heat.

(51) The control unit **8** controls the drive mechanism **3** to lower the upper die **12** and bring the upper die **12** close to the lower die **11** to close the forming tool **2**. On the other hand, the control unit **8** controls the fluid supply unit **6** to seal the opening portions of both ends of the metal pipe material **40** with the nozzle **31** and supply the fluid. Accordingly, the metal pipe material **40** softened by heating expands and comes into contact with the forming surface of the forming tool **2**. Then, the metal pipe material **40** is formed so as to follow a shape of the forming surface of the forming tool **2**. When the metal pipe material **40** comes into contact with the forming surface, quenching of the metal pipe material **40** is performed by being rapidly cooled with the forming tool

2 cooled by the cooling unit **7**.

(52) A metal pipe **41** formed by the forming device **1** will be described with reference to FIG. **3**. The metal pipe **41** includes a hollow pipe portion **41***a* and flange portions **41***b* and **41***c*. In a cross-sectional view (a state shown in FIG. **7**), the pipe portion **41***a* has a rectangular shape extending in a longitudinal direction and a transverse direction. The flange portions **41***b* and **41***c* are formed by crushing both end portions of the metal pipe material **40**. In the following description, locations that are planned to become the flange portions **41***b* and **41***c* after completion in the metal pipe material **40** are referred to as flange portions **40***b* and **40***c* (refer to FIGS. **5** and **6**).

(53) In the present embodiment, as shown in FIG. **4**, the metal pipe material **40** has a rectangular shape in a cross-sectional view. The metal pipe material **40** is disposed with respect to the forming tool **2** such that the longitudinal direction thereof is parallel to the lateral direction of the forming device **1** and the transverse direction thereof is parallel to the vertical direction of the forming device **1** in a cross-sectional view. Therefore, the metal pipe **41** immediately after completion is also disposed with respect to the forming tool **2** such that the longitudinal direction thereof is parallel to the lateral direction of the forming device **1** and the transverse direction thereof is parallel to the vertical direction of the forming device **1** (refer to FIG. **7**). In the following description, in a case where terms “upper”, “lower”, and “lateral” are used for the metal pipe **41** and the metal pipe material **40**, a posture when the metal pipe **41** and the metal pipe material **40** are disposed in the forming tool **2** is assumed to be a reference.

(54) Next, a configuration of the forming tool **2** will be described in detail with reference to FIG. **4**. The lower die **11** is fixed to a base member **150** provided on the base stage **13** (refer to FIG. **1**). The lower die **11** includes a first portion **11**A and a second portion **11**B that are divided in the lateral direction and form a flange portion **41***b* by sandwiching a part of a lower wall portion of the metal pipe material **40** in the lateral direction. The first portion **11**A and the second portion **11**B each include a pipe portion forming surface **11***a* that extends parallel to the lateral direction at an upper end portion and a flange portion forming surface **11***b* that extends parallel to the vertical direction on an inner side in the lateral direction. The pipe portion forming surface **11***a* is a forming surface for forming a lower wall portion of the metal pipe **41**. The flange portion forming surface **11***b* is a forming surface for forming the flange portion **41***b* on a lower side of the metal pipe **41**. The first portion **11**A and the second portion **11**B can reciprocate in the lateral direction.

(55) The upper die **12** is fixed to a base member **151** provided on the slide **21** (refer to FIG. **1**). The upper die **12** includes a first portion **12**A and a second portion **12**B that are divided in the lateral direction and form a flange portion **41***c* by sandwiching a part of an upper wall portion of the metal pipe material **40** in the lateral direction. The first portion **12**A and the second portion **12**B include a pipe portion forming surface **12***a* that extends parallel to the lateral direction at a lower end portion and a flange portion forming surface **12***b* that extends parallel to the vertical direction on an inner side in the lateral direction. The pipe portion forming surface **12***a* is a forming surface for forming an upper wall portion of the metal pipe **41**. The flange portion forming surface **12***b* is a forming surface for forming the flange portion **41***c* on an upper side of the metal pipe **41**. The first portion **12**A and the second portion **12**B can reciprocate in the lateral direction. In addition, the first portion **12**A and the second portion **12**B can reciprocate in the vertical direction as the base member **151** reciprocates in the vertical direction together with the slide **21** (refer to FIG. **1**).

(56) The die **14**A on a lateral side is disposed on one side of the metal pipe material **40** in the lateral direction. The die **14**B on a lateral side is disposed on the other side of the metal pipe material **40** in the lateral direction. The die **14**A is disposed between the pipe portion forming surface **11***a* of the first portion **11**A and the pipe portion forming surface **12***a* of the first portion **12**A in the vertical direction. The die **14**B is disposed between the pipe portion forming surface **11***a* of the second portion **11**B and the pipe portion forming surface **12***a* of the second portion **12**B in the vertical direction. The dies **14**A and **14**B each have a pipe portion forming surface **14***a* that extends parallel to the vertical direction on an inner side in the lateral direction. The dies **14**A and **14**B can

reciprocate in the lateral direction and reciprocate in the vertical direction. Lower surfaces of the dies **14**A and **14**B come into surface contact with the pipe portion forming surface **11***a* of the lower die **11**. Upper surfaces of the dies **14**A and **14**B come into surface contact with the pipe portion forming surface **12***a* of the upper die **12**.

(57) The lateral movements of the respective portions **11**A, **11**B, **12**A, and **12**B and the dies **14**A and **14**B are performed simultaneously or at different timings. The lateral movements of the respective portions **11**A, **11**B, **12**A, and **12**B and the dies **14**A and **14**B may be performed by individually providing a drive source for each member. Alternatively, a wedge mechanism may be provided such that the respective portions **11**A, **11**B, **12**A, and **12**B and the dies **14**A and **14**B are closed in the lateral direction as the slide **21** lowers the upper die **12**. In this case, a spring mechanism may be provided such that the respective portions **11**A, **11**B, **12**A, and **12**B and the dies **14**A and **14**B open in the lateral direction when the slide **21** raises the upper die **12**.

(58) Next, a procedure for forming with the forming tool **2** will be described. First, as shown in FIG. **4**, the metal pipe material **40** is set in an internal space of the forming tool **2**. As shown in FIG. **4**, in an initial forming state, the respective dies **11**, **12**, **14**A, and **14**B are disposed at positions separated from the metal pipe material **40**. The control unit **8** lowers the upper die **12** from the state shown in FIG. **4** to a position separated from the metal pipe material **40**, and heats the metal pipe material **40** in this state.

(59) Next, as shown in FIG. **5**, the control unit **8** lowers the die **12**, the dies **14**A and **14**B, and the metal pipe material **40** downward. In this case, the pipe portion forming surface **12***a* of the die **12** comes into contact with the upper wall portion of the metal pipe material **40**, the pipe portion forming surface **11***a* of the die **11** comes into contact with the lower wall portion of the metal pipe material **40**, and the pipe portion forming surfaces **14***a* of the dies **14**A and **14**B come into contact with side wall portions of the metal pipe material **40**. In addition, the control unit **8** controls the fluid supply unit **6** to supply the fluid into the metal pipe material **40** to perform blow forming (primary blowing). The portions of the flange portions **40***b* and **40***c* of the metal pipe material **40** on both sides in the vertical direction expand so as to enter between a pair of the flange portion forming surfaces **11***b* of the die **11** and enter between a pair of the flange portion forming surfaces **12***b* of the die **12**. In this case, the side wall portions on both sides of the metal pipe material **40** come into contact with the pipe portion forming surfaces **14***a* of the dies **14**A and **14**B, so that further outward deformation in the lateral direction is restricted.

(60) Next, as shown in FIG. **6**, the control unit **8** further lowers the die **12** and the dies **14**A and **14**B downward. Accordingly, the portions **11**A and **11**B of the die **11** come into contact with the dies **14**A and **14**B in the vertical direction, and the portions **12**A and **12**B of the die **12** come into contact with the dies **14**A and **14**B in the vertical direction.

(61) Next, as shown in FIG. **7**, the control unit **8** moves the portions **11**A and **11**B inward in the lateral direction and moves the portions **12**A and **12**B inward in the lateral direction. Accordingly, the flange portion forming surfaces **11***b* of the portions **11**A and **11**B sandwich and crush the flange portion **40***b* of the metal pipe material **40**. The flange portion forming surfaces **12***b* of the portions **12**A and **12**B sandwich and crush the flange portion **40***c* of the metal pipe material **40**. Accordingly, the flange portions **41***b* and **41***c* of the metal pipe **41** are formed. In addition, the control unit **8** controls the fluid supply unit **6** to supply the fluid into the pipe portion **40***a* of the metal pipe material **40** to perform blow forming (secondary blowing). Accordingly, the pipe portion **41***a* of the metal pipe **41** is formed. As described above, the metal pipe **41** is completed.

(62) Next, operations and effects of the forming device **1** according to the present embodiment will be described.

(63) In the forming device **1**, the forming tool **2** includes the lower die **11** and the upper die **12** facing each other in the vertical direction and includes the dies **14**A and **14**B disposed on both sides of the metal pipe material **40** in the lateral direction intersecting the vertical direction in a cross-sectional view. The die **11** and the die **12** can form a shape of the pipe portion **41***a* in the vertical

direction of the metal pipe **41**. In addition, the dies **14**A and **14**B can form a shape of the pipe portion **41***a* in the lateral direction of the metal pipe **41**. Here, the die **11** and the die **12** include the first portions **11**A and **12**A and the second portions **11**B and **12**B that are divided in the lateral direction and form the flange portions **41***b* and **41***c* by sandwiching a part of the metal pipe material **40** in the lateral direction. Therefore, it is possible to form the flange portions **41***b* and **41***c* that protrude in the vertical direction which is a direction in which the die **11** and the die **12** face each other. Accordingly, it is possible to form the flange portions **41***b* and **41***c* which can secure a strength and a rigidity in accordance with a direction of a load acting on the metal pipe **41** during use. As described above, the strength and the rigidity of the metal pipe **41** with a flange can be improved.

(64) Specifically, the metal pipe **41** according to the present embodiment includes the hollow pipe portion **41***a* that extends in the longitudinal direction and the flange portion **41***b* and **41***c* that protrude from the pipe portion **41***a* to both sides in the transverse direction perpendicular to the longitudinal direction in a cross-sectional view.

(65) In the metal pipe **41**, the flange portions **41***b* and **41***c* of the pipe portion **41***a* that protrude in the transverse direction from a wall portion (wall portion forming a long side) extending in the longitudinal direction in a cross-sectional view can be formed. Since the metal pipe **41** is sometimes used in a vehicle frame, there is a possibility that a load acts on the long side of the metal pipe **41**. When there is no flange portion on the long side, the metal pipe is easily deformed. However, by forming the flange portion, it is possible to improve the strength and the rigidity without being easily deformed. In addition, since the flange portion is formed along the longitudinal direction, the strength and the rigidity of the metal pipe **41** can be improved for a load in the longitudinal direction.

(66) Both the lower die **11** and the upper die **12** may include the first portions **11**A and **12**A and the second portions **11**B and **12**B. Accordingly, the flange portions **41***b* and **41***c* can be formed on both sides in the vertical direction with respect to the pipe portion **41***a* to improve the strength and the rigidity of the metal pipe **41**.

(67) The metal pipe **41** may include a pair of the flange portions **41***b* and **41***c* protruding from the pipe portion **41***a* to both sides in the transverse direction. Accordingly, the strength and the rigidity of the metal pipe **41** can be improved.

(68) The present invention is not limited to the above-described embodiment.

(69) For example, the forming device **1** as shown in FIGS. **8** to **11** may be adopted. In addition, the metal pipe **41** shown in FIG. **11** may be formed thereby. Specifically, in the forming device **1** shown in FIGS. **8** to **11**, the first portion **11**A and the second portion **11**B in the lower die **11** and the first portion **12**A and the second portion **12**B in the upper die **12** form the flange portions **41***b* and **41***c* at positions different from each other in the lateral direction. Accordingly, as shown in FIG. **11**, a pair of the flange portions **41***b* and **41***c* are formed at positions different from each other in the longitudinal direction. In this case, it is possible to adjust positions where the strength and the rigidity are increased with the flange portions **41***b* and **41***c* in the lateral direction (longitudinal direction) on one side and the other side in the vertical direction (transverse direction) of the pipe portion **41***a*. In addition, it is also possible to control a deformation behavior of the metal pipe depending on a direction of a load applied to the metal pipe.

(70) As shown in FIGS. **8** to **11**, in the lateral direction, the first portion **11**A is larger than the second portion **11**B. Therefore, as shown in FIG. **11**, the lower flange portion **41***b* is formed at a position closer to the die **14**B side in the lateral direction (longitudinal direction) with respect to the pipe portion **41***a*. The upper flange portion **41***c* is formed at a position closer to the die **14**A side in the lateral direction (longitudinal direction) with respect to the pipe portion **41***a*. The operation of the forming device **1** in FIGS. **8** to **11** is the same as the operation in FIGS. **4** to **7**.

(71) In addition, the forming device **1** as shown in FIGS. **12** to **15** may be adopted. In addition, the metal pipe **41** shown in FIG. **15** may be formed thereby. Specifically, in the forming device **1**

shown in FIGS. **12** to **15**, the first portions **11**A and **12**A and the second portions **11**B and **12**B may form the flange portions **41***b* and **41***c* at the same position as one side surface **41***d* in the lateral direction (longitudinal direction) of the metal pipe **41** (refer to FIG. **15**). In this case, it is also possible to control a deformation behavior of the metal pipe depending on a direction of a load applied to the metal pipe in a case where there is a shape limitation such that a position of the flange portion is only at an end in terms of position. In addition, the same stress is generated for a load from a target direction (a load such as a bending load), and the shape can be balanced in terms of strength.

(72) As shown in FIGS. **12** to **15**, in the lateral direction, the first portions **11**A and **12**A are smaller than the second portions **11**B and **12**B. Therefore, as shown in FIG. **15**, the flange portions **41***b* and **41***c* on both sides are formed at positions closer to the die **14**A side in the lateral direction (longitudinal direction) with respect to the pipe portion **41***a*. Then, the flange portions **41***b* and **41***c* protrude in the vertical direction such that one side surface **41***d* in the lateral direction (longitudinal direction) of the pipe portion **41***a* extends in the vertical direction (transverse direction) as it is. The operation of the forming device **1** in FIGS. **12** to **15** is the same as the operation in FIGS. **4** to **7**. The die **14**A may be integrally formed with the upper die **12**A, or conversely, the die **14**A may be integrally formed with the lower die **11**A.

(73) In addition, the forming device **1** as shown in FIGS. **16** to **19** may be adopted. In addition, the metal pipe **41** shown in FIG. **19** may be formed thereby. Specifically, in the forming device **1** shown in FIGS. **16** to **19**, the lower die **11** and the upper die **12** may include third portions **11**C and **12**C that form another flange portions **41***b* and **41***c* by sandwiching another part of the metal pipe material **40** with the second portions **11**B and **12**B. In this case, as shown in FIG. **19**, in the pipe portion **41***a*, a plurality of (here, two each) flange portions **41***b* and **41***c* protruding to both sides in the vertical direction (transverse direction) may be formed at positions different from each other in the lateral direction (longitudinal direction). In this case, the number of the flange portions **41***b* and **41***c* can be increased to increase the strength and the rigidity.

(74) As shown in FIGS. **16** to **19**, in the lateral direction, the lower die **11** is divided into three parts, and the upper die **12** is divided into three parts. The first portions **11**A and **12**A are smaller than the second portions **11**B and **12**B. Therefore, as shown in FIG. **19**, the flange portions **41***b* and **41***c* relating to one set are formed at positions closer to the die **14**A side in the lateral direction (longitudinal direction) with respect to the pipe portion **41***a*. Then, the flange portions **41***b* and **41***c* relating to one set protrude in the vertical direction such that one side surface **41***d* in the lateral direction (longitudinal direction) of the pipe portion **41***a* extends in the vertical direction (transverse direction) as it is. Further, the flange portions **41***b* and **41***c* relating to the other set are formed at positions closer to the die **14**B side in the lateral direction (longitudinal direction) with respect to the pipe portion **41***a*. Then, the flange portions **41***b* and **41***c* relating to the other set protrude in the vertical direction such that the other side surface **41***e* in the lateral direction (longitudinal direction) of the pipe portion **41***a* extends in the vertical direction (transverse direction) as it is. The operation of the forming device **1** in FIGS. **16** to **19** is the same as the operation in FIGS. **4** to **7**. The dies **14**A and **14**B may be integrally formed with the upper dies **12**A and **12**C, or conversely, the dies **14**A and **14**B may be integrally formed with the lower dies **11**A and **11**C.

(75) In addition, the forming device **1** as shown in FIGS. **20** to **23** may be adopted. In addition, the metal pipe **41** shown in FIG. **23** may be formed thereby. Specifically, in the forming device **1** shown in FIGS. **20** to **23**, the first portions **11**A and **12**A and the second portions **11**B and **12**B form the flange portions **41***b* and **41***c* that are inclined with respect to the vertical direction. In this case, as shown in FIG. **23**, the flange portions **41***b* and **41***c* protrude so as to be inclined with respect to the transverse direction. In this case, the rigidity can be increased, and a deformation behavior of a formed body depending on a direction of a load applied to the metal pipe can be controlled in a more preferable direction. Further, even if the rigidity and the strength are inferior to those in a case

where the flange portions are in the vertical direction, there is a case where it is more convenient to have a certain inclination angle in joining with ancillary parts, and it is possible to meet design requirements. In addition, there is a possibility that the deformation behavior can be optimized depending on the direction of the load and the inclination of the flange portion.

(76) As shown in FIG. **20**, the flange portion forming surfaces **11***b* of the first portion **11**A and the second portion **11**B extend in a state of being inclined with respect to the vertical direction. In addition, the flange portion forming surfaces **12***b* of the first portion **12**A and the second portion **12**B extend in a state of being inclined with respect to the vertical direction. Therefore, as shown in FIG. **23**, the flange portions **41***b* and **41***c* on both sides protrude so as to be inclined with respect to upper and lower side surfaces of the pipe portion **41***a*. The operation of the forming device **1** in FIGS. **20** to **23** is the same as the operation in FIGS. **4** to **7**.

(77) In the above-described embodiment, the description has been made by using the die adopted in the forming device for STAF as an example. However, the type of the forming device in which the die according to the embodiment of the present invention is adopted is not particularly limited, and may be any type of the forming device that supplies a fluid to expand the metal pipe material.

(78) A facing direction between the first die and the second die does not have to be the vertical direction and may be the horizontal direction.

(79) In addition, the configuration of the forming device shown in each drawing is merely an example, and may be appropriately changed without departing from the concept of the invention of the present application. For example, an operation timing and a contact state of each die may be appropriately changed. For example, in the above-described example, the dies **14**A and **14**B are in contact with the dies **11** and **12** so as to be sandwiched therebetween in a completely closed state, but in the meantime, the dies **14**A and **14**B may be in any contact state with respect to the dies **11** and **12**.

(80) It should be understood that the invention is not limited to the above-described embodiment, but may be modified into various forms on the basis of the spirit of the invention. Additionally, the modifications are included in the scope of the invention.

Claims

1. A forming device that forms a metal pipe with at least one flange portion, the forming device comprising: a forming tool that forms the metal pipe, wherein the forming tool includes a first die and a second die facing each other in a first direction in a cross-sectional view, and a third die disposed on at least one side of a metal pipe material in a second direction intersecting the first direction, at least one of the first die and the second die is divided in the second direction and sandwiches a part of the metal pipe material in the second direction to form the at least one flange portion, at least one of the first die and the second die includes a first portion and a second portion which sandwich the part of the metal pipe material in the second direction to form the at least one flange portion, and the first portion and the second portion are configured to move in the second direction to form the at least one flange portion.

2. The forming device according to claim 1, wherein both the first die and the second die have the first portion and the second portion.

3. The forming device according to claim 2, wherein the at least one flange portion is two flange portions, and the first portion and the second portion in the first die, and the first portion and the second portion in the second die form the two flange portions at positions different from each other in the second direction.

4. The forming device according to claim 1, wherein the first portion and the second portion form the at least one flange portion at a same position as one side surface in the second direction of the metal pipe material.

5. The forming device according to claim 1, wherein at least one of the first die and the second die

includes a third portion that sandwiches another part of the metal pipe material with the second portion to form another flange portion.

6. The forming device according to claim 1, wherein the first portion and the second portion form the at least one flange portion inclined with respect to the first direction.

7. The forming device according to claim 1, further comprising: a holding unit that holds the metal pipe material disposed between the first die and the second die, wherein the holding unit includes a first lower electrode and a first upper electrode that hold the metal pipe material on one end side in an extending direction of the forming tool, and a second lower electrode and a second upper electrode that hold the metal pipe material on the other end side in the extending direction of the forming tool.

8. The forming device according to claim 7, wherein groove portions having a shape corresponding to an outer peripheral surface of the metal pipe material are formed on an upper surface of the first lower electrode, a lower surface of the first upper electrode, an upper surface of the second lower electrode, and a lower surface of the second upper electrode.

9. The forming device according to claim 1, further comprising: a heating unit that heats the metal pipe material by energizing the metal pipe material, wherein the heating unit heats the metal pipe material in a state in which the metal pipe material is spaced apart from the first die and the second die between the first die and the second die.

10. The forming device according to claim 1, further comprising: a fluid supply unit that supplies a high-pressure fluid into the metal pipe material held between the first die and the second die, wherein the fluid supply unit includes a nozzle and a drive mechanism that moves the nozzle forward and backward with respect to an opening portion of the metal pipe material, and the drive mechanism brings the nozzle into close contact with an end portion of the metal pipe material at a time of supply of the fluid.