

DESCRIPTION

FIRE-RESISTANT WOOD MEMBER

Field

[0001] The present invention relates to a fire-resistant
5 wood member suitably used as a building structural member,
such as a pillar and a beam, and more specifically to a
fire-resistant wood member with higher fire-resistant
performance of corner parts in the cross section of the
member.

10 Background

[0002] Conventionally, to build a structure with wood
pillars and beams made of wood materials, the wood
materials are covered with a heat-insulating material and
the like as necessary to suppress a rise in temperature by
15 fire heating because the wood materials do not endure fires.
If a fire-resistant wood member, such as a wood pillar and
a wood beam, with its surface layer covered with a heat-
insulating material, such as a gypsum board, and having a
quadrangular cross section is subjected to fire heating,
20 the inside wood portion is heated to a high temperature by
thermal conduction through the heat-insulating material on
the surface layer.

[0003] Specifically, in a fire-resistant wood member
obtained by covering a wood core material 1 serving as a
25 load supporting part with a gypsum board 2 illustrated in
FIG. 7, the amount of heat input by heating F applied from
around by a fire is as follows: the amount of heat input is
larger in four corner parts 3 in a wood pillar having a
quadrangular cross section illustrated in FIG. 7(1) and in
30 two corner parts 3 at the lower end in a wood beam provided
under a floor 4 and having a quadrangular cross section in
FIG. 7(2) than (the amount of heat input per unit area) in
side surfaces 5. As a result, the corner parts 3 are

heated to a higher temperature than the side surfaces 5.
 These corner parts 3 are portions subjected to heating in
 two directions at right angles in a cross-sectional view
 and apt to have a rise in temperature. Thermal degradation
 5 of the corner parts 3 is a weak point in the fire-resistant
 performance, such as the load supporting performance, of
 the wood member. In other words, when the temperature of
 the corner parts 3 exceeds an ignition temperature of wood
 earlier than that of the side surfaces 5, and the corner
 10 parts 3 start to burn, the fire spreads to the inside part
 and the side surfaces 5 the temperature of which has not
 reach the ignition temperature yet. This leads to breakage
 in the cross section of the member by carbonization and
 ashing, thereby reducing the strength of the member. As a
 15 result, the structure may possibly collapse.

[0004] Widely known are various fire-resistant wood
 members designed to secure the fire-resistant performance
 of the corner parts (refer to Patent Literatures 1 to 4,
 for example).

20 Citation List

Patent Literature

[0005] Patent Literature 1: Japanese Patent Application
 Laid-open No. 2012-136939

Patent Literature 2: Japanese Patent No. 4871660

25 Patent Literature 3: Japanese Patent Application
 Laid-open No. 2015-129431

Patent Literature 4: Japanese Patent Application
 Laid-open No. 2015-061969

Summary

30 Technical Problem

[0006] To improve the fire-resistant performance of the
 corner parts, the conventional structures described above
 use a material with higher fire-resistant performance

especially for the parts. Alternatively, the conventional structures cover the whole member with a thickness of heat-resistant covering necessary for the corner parts, resulting in a larger thickness of the covering layer. As
5 a result, the method for manufacturing the fire-resistant wood member is made complicated, and the thickness of the covering layer is made larger, resulting in a higher cost and a larger cross section of the member.

[0007] There is a need for developing a fire-resistant
10 wood member having a smaller cross section with the structural performance equivalent to that of the conventional techniques.

[0008] In view of the above, it is an object of the present invention to provide a fire-resistant wood member
15 having a smaller cross section.

Solution to Problem

[0009] To solve the above-described problem and achieve the object, a fire-resistant wood member according to the present invention is a wood member having fire resistance
20 and including a core material made of a wood material that supports a load, wherein a shape of a cross section of the core material is a polygon, a corner of the polygon is chamfered off, and a chamfering dimension is within a range of 10 to 50 mm.

25 [0010] Moreover, in the above-described fire-resistant wood member according to the present invention, the chamfering dimension is within a range of 20 to 50 mm.

[0011] Moreover, the above-described fire-resistant wood member according to the present invention further includes
30 a reflector that reflects heat and that is provided in a chamfered portion at a corner of the core material.

[0012] Moreover, the above-described fire-resistant wood member according to the present invention further includes

a burning stop layer or a finishing material provided outside the core material.

[0013] Moreover, the above-described fire-resistant wood member according to the present invention further includes:
5 a burning stop layer provided outside the core material;
and a finishing material provided outside the burning stop layer.

[0014] Moreover, in the above-described fire-resistant wood member according to the present invention, a hollow
10 part is formed between the chamfered portion at a corner of the core material and the burning stop layer or the finishing layer provided outside the chamfered portion, and the hollow part is provided with at least one of a heat-insulating material and a heat-absorbing material.

15 Advantageous Effects of Invention

[0015] The fire-resistant wood member according to the present invention is a wood member having fire resistance and including a core material made of a wood material that supports a load. The shape of the cross section of the
20 core material is a polygon. A corner of the polygon is chamfered off, and the chamfering dimension is within a range of 10 to 50 mm. Consequently, the fire-resistant wood member can suppress a rise in temperature of the corner serving as a weak point in fire resistance and
25 significantly improve the fire-resistant performance of the corner. Even if the member is made thinner, the fire-resistant wood member can secure the structural performance equal to or higher than that of the conventional techniques. Consequently, the fire-resistant wood member can have a
30 smaller cross section and be manufactured at a lower cost. Use of the fire-resistant wood member as an indoor pillar or beam, for example, can enhance the openness in an indoor space, thereby enabling effective use of the indoor space.

[0016] Another fire-resistant wood member according to the present invention has a chamfering dimension of within a range of 20 to 50 mm. Consequently, the fire-resistant wood member can suppress a rise in temperature of the corner serving as a weak point in fire resistance more reliably and further improve the fire-resistant performance of the corner.

[0017] Another fire-resistant wood member according to the present invention includes a reflector that reflects heat in a chamfered portion at the corner of the core material. Consequently, the fire-resistant wood member can effectively suppress a rise in temperature of the core material through the chamfered portion.

[0018] Another fire-resistant wood member according to the present invention further includes a burning stop layer or a finishing material provided outside the core material. The burning stop layer can suppress transfer of heat to the core material caused by a fire and prevent the core material from being carbonized and burning. The finishing material can add wood feeling to the outside of the core material.

[0019] Another fire-resistant wood member according to the present invention further includes the burning stop layer provided outside the core material and the finishing material provided outside the burning stop layer. The burning stop layer can suppress transfer of heat to the core material caused by a fire and prevent the core material from being carbonized and burning. The finishing material can add wood feeling to the outside of the core material.

[0020] Another fire-resistant wood member according to the present invention has a hollow part formed between the chamfered portion at the corner of the core material and

the burning stop layer or the finishing layer provided outside the chamfered portion. The hollow part is provided with at least one of a heat-insulating material and a heat-absorbing material. Consequently, the fire-resistant wood member can effectively suppress a rise in temperature of the core material caused by transfer of radiant/convective heat through the hollow part.

Brief Description of Drawings

[0021] FIG. 1(1) is a cross-sectional view of an embodiment of a fire-resistant wood member according to the present invention, FIG. 1(2) is an enlarged view of a corner part illustrated in FIG. 1(1), FIG. 1(3) is a cross-sectional view of a comparative example of the present invention, and FIG. 1(4) is an enlarged view of the corner part illustrated in FIG. 1(3).

FIG. 2 is a schematic view of an analytical model performed to verify functions and effects of the present invention.

FIG. 3 is a diagram of temporal changes in the temperature of the corner part of a core material (without a reflector in a chamfered hollow part).

FIG. 4 is a diagram of temporal changes in the temperature of the corner part of the core material (with the reflector in the chamfered hollow part).

FIG. 5 is a diagram of the temperature distribution (without the reflector in the chamfered hollow part) on the surface of the core material (line-symmetrical positions from the corner part to a side surface), FIG. 5(1) illustrates the temperature distribution obtained when 30 minutes have elapsed since the start of heating, and FIG. 5(2) illustrates the temperature distribution obtained when 60 minutes have elapsed.

FIG. 6 is a diagram of the temperature distribution

(with the reflector in the chamfered hollow part) on the surface of the core material (line-symmetrical positions from the corner part to the side surface), FIG. 6(1) illustrates the temperature distribution obtained when 30 minutes have elapsed since the start of heating, and FIG. 6(2) illustrates the temperature distribution obtained when 60 minutes have elapsed.

FIG. 7 is a view of an example of a conventional fire-resistant wood member subjected to fire heating, FIG. 7(1) is a horizontal sectional view of a wood pillar, and FIG. 7(2) is a vertical sectional view of a wood beam.

Description of Embodiments

[0022] Exemplary embodiments of a fire-resistant wood member according to the present invention are described below in greater detail with reference to the accompanying drawings using a wood pillar as an example. The embodiments are not intended to limit the present invention.

[0023] As illustrated in FIGS. 1(1) and 1(2), a fire-resistant wood member 100 according to the present embodiment is a wood pillar including a core material 10 and a burning stop layer 12. The core material 10 is made of a wood material that supports a load. The burning stop layer 12 is provided outside the core material 10. The shape of the cross section of the core material 10 is a square (polygon), and corner parts 14 (corners) of the square are chamfered off. In the following description, the chamfered portion is referred to as a chamfered part 16.

[0024] The chamfering dimension of the chamfered part 16 is a length L illustrated in FIG. 2, and the chamfering angle is 45° . In other words, the shape of the cross section of the chamfered part 16 according to the present embodiment is an isosceles right triangle having the equal length L of two sides. The hypotenuse corresponds to the

surface of the core material 10. The chamfering dimension L is set preferably within a range of 10 to 50 mm to achieve an object of the present invention of suppressing a rise in temperature of the corner parts 14 and more

5 preferably within a range of 20 to 50 mm to suppress a rise in temperature more reliably. The chamfered part 16 can be formed by planing off the corner in the cross section of the core material 10 to form a plane, for example.

[0025] The core material 10 is made of laminated wood
10 (wood material) that supports a load. The core material 10 may be typical laminated wood made of Japanese cedar and Japanese larch, for example. The thickness (distance between the opposite sides) of the core material 10 may be appropriately adjusted depending on the use and may be
15 approximately 450 mm, for example.

[0026] The burning stop layer 12 is a fire-resistant covering layer and is made of a heat-absorbing and/or heat-insulating inorganic material, a non-flammable material unlikely to burn, or a material, such as a fire-resistant
20 sheet and a fire-resistant film, that foams to significantly increase in thickness when receiving heat and acquires a heat-insulating property, for example. The burning stop layer 12 has a function of preventing transfer of heat to the inside core material 10 disposed side by
25 side with the burning stop layer 12 and preventing the core material 10 from being carbonized and burning in a fire. The burning stop layer 12 exerts a function of suppressing conduction of heat to the core material 10. To form the burning stop layer 12 out of an inorganic material, a
30 board-like material, such as a reinforced gypsum board, a gypsum board, and a calcium silicate board (calcium silicate plate), may be used. The thickness of the burning stop layer 12 may be appropriately adjusted depending on

the use. A larger thickness increases the effect of suppressing heat conduction. These boards may be overlapped to have a predetermined thickness. The materials, such as a reinforced gypsum board, a gypsum board, and a calcium silicate board (calcium silicate plate), are suitably used as the burning stop layer 12 because they can be obtained at a significantly low price and have high heat-insulating and heat-absorbing properties. To form the burning stop layer 12 out of a non-flammable material, non-flammable wood may be used, for example. The non-flammable wood is obtained by performing fire-proof treatment of impregnating wood with a chemical agent, such as boric acid. The thickness of the burning stop layer 12 may be appropriately adjusted depending on the use and is preferably approximately 15 to 45 mm, for example, and more preferably approximately 30 mm. If the burning stop layer 12 is made of the material described above, such as a fire-resistant sheet and a fire-resistant film, the thickness of the burning stop layer 12 may be appropriately adjusted depending on the use and is preferably approximately 1 to 12 mm, for example, and more preferably approximately 1.5 to 6 mm.

[0027] The following describes the functions of the fire-resistant wood member 100 having the structure described above.

FIGS. 1(1) and 1(2) illustrate the present embodiment, and FIGS. 1(3) and 1(4) illustrate a comparative example. The comparative example has a conventional structure not having the chamfered parts 16 at the corner parts 14 of the core material 10. As illustrated in FIGS. 1(4) and 1(2), t_0 and t , are the thicknesses of the burning stop layer 12 according to the comparative example and the present embodiment, respectively, E_0 and E , are the thermal energy

flowing into the corner parts 14 (hatched portions) by heating F applied from around by a fire, and T_0 and T_5 are the temperatures of the corner parts 14 (hatched portions). When the thickness of the burning stop layer 12 satisfies $t_0 = t_s$, the thermal energy flowing into the corner parts 14 satisfies $E_0 > E_5$, and the temperature satisfies $T_0 > T_5$. Consequently, the present embodiment can suppress a rise in temperature of the corner parts 14 compared with the comparative example.

10 [0028] As described above, the fire-resistant wood member 100 has the chamfered parts 16 at the corner parts 14 that receive concentrated thermal energy to be a weak point in fire resistance. With this structure, the fire-resistant wood member 100 can suppress a rise in
15 temperature of the corner parts 14 and significantly improve the fire-resistant performance. Even if the member is made thinner, the fire-resistant wood member 100 can secure the structural performance equal to or higher than that of the conventional techniques. Consequently, the
20 fire-resistant wood member 100 can have a smaller cross section and be manufactured at a lower cost. Use of the fire-resistant wood member 100 as an indoor pillar (or beam), for example, can enhance the openness in an indoor space, thereby enabling effective use of the indoor space.

25 [0029] The chamfered part 16 may be a hollow part (hereinafter, referred to as a chamfered hollow part). In other words, the chamfered hollow part may be an isosceles right triangular space formed between the surface of the core material 10 formed by chamfering off the corner part
30 14 of the core material 10 and the burning stop layer 12 provided outside the core material 10. The chamfered hollow parts may be filled with at least one of a heat-insulating material or a heat-absorbing material. This

structure can effectively suppress a rise in temperature of the core material 10 caused by transfer of radiant/convective heat through the chamfered hollow parts. The material with which the chamfered hollow parts are
5 filled may be the same material as that of the burning stop layer 12, for example.

[0030] As illustrated in FIG. 1(2) or 2, the surfaces of the core material 10 facing the chamfered hollow parts may be provided with reflectors 18 that reflect heat. This
10 structure can effectively suppress a rise in temperature of the core material 10 through the chamfered portions. Besides the surfaces of the core material 10, the surfaces of the burning stop layer 12 facing the chamfered hollow parts may also be provided with the same reflectors 18.
15 This structure can suppress a rise in temperature more effectively.

[0031] The embodiment may further include a finishing material for adding wood feeling to the outside of the burning stop layer 12. Alternatively, the embodiment may
20 include a finishing material for adding wood feeling to the outside of the core material 10 instead of the burning stop layer 12. With the finishing material, the outer surface of the fire-resistant wood member 100 can have an appearance with wood feeling and wood grain. To reduce the
25 cost, a wood material, such as wood and decorative laminated wood, is preferably used as the finishing material. Alternatively, a building finishing material, such as a cloth material, may be used. While the thickness of the finishing material is preferably approximately 3 to
30 30 mm, for example, it may be thinner naturally.

[0032] In the embodiment, the burning stop layer 12 may be two or more burning stop layers having different actions and functions. This structure can also exert the same

functions and effects as those described above.

[0033] Verification of the functions and effects of the present invention

5 The following describes verification of the functions and effects of the present invention.

An examination was carried out by a two-dimensional heat conduction analysis to grasp the chamfering range and the effects thereof quantitatively. As illustrated in FIG. 2, an analysis model was a wood pillar obtained by covering
10 a 20-cm square core material 10 with a heat-insulating material (burning stop layer 12) made of a gypsum board having a total thickness of 30 mm. An analysis parameter was whether a thermal reflector is provided in the chamfering range and on the inner surface of the chamfered
15 hollow part. The chamfering range is as follows: the chamfering angle was 45° , and the length L of the two equal sides of the chamfering range having a planar shape of an isosceles right triangle (isosceles right triangle surrounded by the two sides and the cut surface on the core
20 material 10) was 0, 10, 20, 30, 40, and 50 mm, which serves as a parameter. A parameter for the chamfered hollow part was whether the thermal reflector (hereinafter, referred to as a reflector) was provided. Heating was performed such that the surface of the member was heated for one hour
25 according to the standard heating temperature and time curve defined by ISO834. The latent heat of vaporization at 100°C was considered, when the water content of the gypsum board was 6 wt%, and the water content of the core material is 10 wt%. The reflectance of the reflector was
30 0.04 (corresponding to the reflectance of aluminum foil). Transfer of radiant heat and convective heat in the hollow part was considered. In the present analysis, it is

assumed that the wood material does not burn even if the temperature of the wood material exceeds its ignition temperature.

[0034] FIGS. 3 and 4 illustrate temporal changes in the temperature of the corner part formed by chamfering. FIGS. 5 and 6 illustrate the temperature distribution on the surface of the core material when 30 minutes have elapsed and when 60 minutes have elapsed since the start of heating.

[0035] Effectiveness and the effective range of chamfering

As illustrated in FIGS. 3 to 6, chamfering on a quadrangular cross section (chamfering: 0 mm) suppresses a rise in temperature of the corner part. Disposing the reflector on the inner surface of the hollow part is also effective. The chamfering range increases as the length L of the two equal sides increases in the isosceles right triangular plane. As illustrated in FIGS. 5 and 6, however, it is assumed that the effects of chamfering do not significantly change if the length L of the two equal sides is equal to or larger than 50 mm (chamfering: equal to or larger than 50 mm). It is readily assumed that this tendency does not significantly depend on the size of the cross section of the member. By contrast, it is undeniable that enlargement of the chamfering range in the core material degrades the structural member cross-section performance (axial rigidity and flexural rigidity). Considering these factors, the length L of one side of chamfering is preferably equal to or smaller than 50 mm regardless of the dimensions of the cross section of the member.

[0036] Heat characteristics of the chamfered hollow part (portion surrounded by the heat-insulating material and the core material)

In the present analysis, as illustrated in the temperature distribution chart of 60 minutes in FIG. 5(2), the temperature of the surface formed by chamfering was higher than that of the corner part (portion indicated by G 5 in the figure). This phenomenon was not found in the temperature distribution chart of 60 minutes in FIG. 6(2). Consequently, the phenomenon was supposed to occur because the supply of thermal energy by transfer of radiant/convective heat exceeded the supply through the 10 heat-insulating material.

[0037] Measures for suppressing a rise in temperature of the core material through the chamfered hollow part

By comparing FIG. 5 with FIG. 6, it is found that disposing the reflector on the surface of the core material 15 facing the chamfered hollow part is effective. In the present analysis example, the reflector was disposed on only the surface of the core material facing the hollow part. Alternatively, the reflector may be disposed on the surface of the heat-insulating material facing the hollow 20 part besides the surface of the core material. This structure further increases the effectiveness.

[0038] In addition to disposing the reflector, filling the chamfered hollow part with a heat-insulating material or a heat-absorbing material is supposed to be an effective 25 way to suppress a rise in temperature caused by transfer of radiant/convective heat. Examples of the effective heat-insulating material with which the chamfered hollow part is filled include, but are not limited to, a bulk or felt of inorganic fibers, such as heat-resistant rock wool, a bulk 30 or felt of highly heat-resistant biosoluble fibers, etc. Examples of the effective heat-absorbing material with which the chamfered hollow part is filled include, but are not limited to, mortar or wettable gypsum containing a

large amount of free water (moisture that evaporates at 100°C) or chemisorbed water, a packing material obtained by sealing super absorbent polymers containing water or hydrogel with a moisture-impermeable sheet (e.g., PET
5 aluminum paper), an aqueous adhesive, such as a vinyl acetate adhesive, etc.

[0039] While the member having a quadrangular cross section has been described, for example, chamfering off the corner parts 14 is also effective for a wood member having
10 a triangular cross section or a pentagonal cross section and other polygonal cross sections having more sides and angles. Also in this case, the present invention can exert the same functions and effects as those for the quadrangular cross section. In other words, forming a
15 space between the burning stop layer 12 covering the surface of the core material 10 and the core material 10 and filling the space with a heat-insulating material or a heat-absorbing material are effective in suppressing a rise in temperature of the corner parts 14 of the core material
20 and improving the fire-resistant performance.

[0040] As described above, the fire-resistant wood member according to the present invention is a wood member having fire resistance and including a core material made of a wood material that supports a load. The shape of the
25 cross section of the core material is a polygon. Corners of the polygon are chamfered off, and the chamfering dimension is within a range of 10 to 50 mm. Consequently, the fire-resistant wood member can suppress a rise in temperature of the corners serving as a weak point in fire
30 resistance and significantly improve the fire-resistant performance of the corners. Even if the member is made thinner, the fire-resistant wood member can secure the structural performance equal to or higher than that of the

conventional techniques. Consequently, the fire-resistant wood member can have a smaller cross section and be manufactured at a lower cost. Use of the fire-resistant wood member as an indoor pillar or beam, for example, can
5 enhance the openness in an indoor space, thereby enabling effective use of the indoor space.

[0041] Another fire-resistant wood member according to the present invention has a chamfering dimension of within a range of 20 to 50 mm. Consequently, the fire-resistant
10 wood member can suppress a rise in temperature of the corners serving as a weak point in fire resistance more reliably and further improve the fire-resistant performance of the corners.

[0042] Another fire-resistant wood member according to
15 the present invention includes the reflectors that reflect heat in the chamfered portions at the corners of the core material. Consequently, the fire-resistant wood member can effectively suppress a rise in temperature of the core material through the chamfered portions.

20 [0043] Another fire-resistant wood member according to the present invention further includes the burning stop layer or the finishing material provided outside the core material. The burning stop layer can suppress transfer of heat to the core material caused by a fire and prevent the
25 core material from being carbonized and burning. The finishing material can add wood feeling to the outside of the core material.

[0044] Another fire-resistant wood member according to the present invention further includes the burning stop
30 layer provided outside the core material and the finishing material provided outside the burning stop layer. The burning stop layer can suppress transfer of heat to the core material caused by a fire and prevent the core

material from being carbonized and burning. The finishing material can add wood feeling to the outside of the core material.

[0045] Another fire-resistant wood member according to 5 the present invention has hollow parts each formed between the chamfered portion at the corner of the core material and the burning stop layer or the finishing layer provided outside the chamfered portion. The hollow part is provided with at least one of a heat-insulating material and a heat- 10 absorbing material. Consequently, the fire-resistant wood member can effectively suppress a rise in temperature of the core material caused by transfer of radiant/convective heat through the hollow parts.

Industrial Applicability

15 [0046] As described above, the fire-resistant wood member according to the present invention is suitably used as a building structural member and especially can have a smaller cross section and be manufactured at a lower cost.

Reference Signs List

20 [0047] 10 core material
12 burning stop layer
14 corner part (corner)
16 chamfered part
18 reflector
25 L chamfering dimension
100 fire-resistant wood member

CLAIMS

1. A fire-resistant wood member that is a wood member having fire resistance and including a core material made of a wood material that supports a load, wherein
5 a shape of a cross section of the core material is a polygon,
a corner of the polygon is chamfered off,
a cross section of the chamfered corner is an isosceles right triangle having an equal length L of two
10 sides,
a hypotenuse of the isosceles right triangle corresponds to a surface of the core material, and
the length L that is a chamfering dimension is set to be within a range of 10 to 50 mm for suppressing rise in
15 temperature of the corner regardless of a dimension of the cross section of the core material.
2. The fire-resistant wood member according to claim 1, wherein the chamfering dimension is within a range of 20 to
20 50 mm.
3. The fire-resistant wood member according to claim 1 or 2, further comprising a reflector that reflects heat and that is provided in a chamfered portion at a corner of the
25 core material.
4. The fire-resistant wood member according to any one of claims 1 to 3, further comprising a burning stop layer or a finishing material provided outside the core material.
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5. The fire-resistant wood member according to any one of claims 1 to 3, further comprising: a burning stop layer provided outside the core material; and a finishing

material provided outside the burning stop layer.

6. The fire-resistant wood member according to claim 4 or 5, wherein a hollow part is formed between the chamfered portion at a corner of the core material and the burning stop layer or the finishing material provided outside the chamfered portion, and the hollow part is provided with at least one of a heat-insulating material and a heat-absorbing material.

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7. A method of designing a fire-resistant wood member that is a wood member having fire resistance and including a core material made of a wood material that supports a load, a shape of a cross section of the core material being a polygon, the method comprising:

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setting a corner of the polygon to be chamfered off;

setting a cross section of the chamfered corner to be an isosceles right triangle having an equal length L of two sides; and

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designing the length L that is a chamfering dimension to be within a range of 10 to 50 mm for suppressing rise in temperature of the corner regardless of a dimension of the cross section of the core material.