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Sintered member and electromagnetic coupling

Abstract

A sintered member having an annular shape, includes: a first face facing one side in an axial direction; a second face facing the other side in the axial direction; an inner peripheral face connected to an inner peripheral edge of the first face; and a plurality of tooth groups and a plurality of tooth-missing parts which are alternately disposed along a circumferential direction of the inner peripheral face. The second face includes a plurality of ball grooves arranged in parallel in the circumferential direction. Each tooth group includes a plurality of spline teeth that are continuous in the circumferential direction of the peripheral face. The number of plurality of tooth-missing parts is the same as the plurality of ball grooves. Positions in a radial direction in which the plurality of tooth-missing parts are formed are within ranges in the radial direction in which the ball grooves are formed.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
5142943	12/1991	Hughes	192/93A	F16D 43/215
8444523	12/2012	Jurjanz	N/A	F16H 25/186

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
62-80060	12/1986	JP	N/A
7-158417	12/1994	JP	N/A
2002-178092	12/2001	JP	N/A
2012-167783	12/2011	JP	N/A
2017-133660	12/2016	JP	N/A

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

(1) The present application is based on PCT filing PCT/JP2020/031031, filed Aug. 17, 2020, which claims priority to Japanese Patent Application No. 2019-182666, filed on Oct. 3, 2019, the entire contents of each are incorporated herein by reference.

TECHNICAL FIELD

(2) The present invention relates to a sintered member and an electromagnetic coupling.

BACKGROUND ART

(3) PATENT LITERATURE 1 discloses a drive force transmission device (electromagnetic

coupling) for connecting and disconnecting a propeller shaft and a rear differential of a four-wheel drive vehicle. The driving force transmission device includes a first cam mechanism. The first cam mechanism includes a main cam (first cam), a pilot cam (second cam), and a cam ball interposed between the main cam and the pilot cam.

CITATION LIST

Patent Literature

(4) PATENT LITERATURE 1: Japanese Laid-Open Patent Publication No. 2012-167783

SUMMARY OF THE INVENTION

(5) A sintered member according to the present disclosure is a sintered member having an annular shape. The sintered member includes a first face facing one side in an axial direction; a second face facing the other side in the axial direction; an inner peripheral face connected to an inner peripheral edge of the first face; and a plurality of tooth groups and a plurality of tooth-missing parts which are alternately disposed along a circumferential direction of the inner peripheral face. In the sintered member, the second face includes a plurality of ball grooves arranged in parallel in the circumferential direction. In the sintered member, each tooth group includes a plurality of spline teeth that are continuous in the circumferential direction of the peripheral face. In the sintered member, the number of the plurality of tooth-missing parts is the same as the number of the plurality of ball grooves. In the sintered member, positions in a radial direction in which the plurality of tooth-missing parts are formed are within ranges in the radial direction in which the plurality of ball grooves are formed. In the sintered member, ranges in the circumferential direction in which the plurality of tooth-missing parts are formed overlap ranges in the circumferential direction in which the plurality of ball grooves are formed.

(6) An electromagnetic coupling according to the present disclosure is an electromagnetic coupling including a first cam, a second cam, and a ball interposed between the first cam and the second cam, and

(7) the first cam is composed of the sintered member of the present disclosure.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. **1** is a perspective view showing a first face side of a sintered member according to Embodiments 1, 2.

(2) FIG. **2** is a perspective view showing a second face side of the sintered member according to Embodiments 1, 2.

(3) FIG. **3** is a plan view showing a part of the first face side of the sintered member according to Embodiments 1, 2.

(4) FIG. **4** is a plan view showing a part of the second face side of the sintered member according to Embodiments 1, 2.

(5) FIG. **5** is a cross-sectional view showing a part of the sintered member taken along a V-V cutting line in FIG. **1**.

(6) FIG. **6** is a cross-sectional view showing an electromagnetic coupling according to Embodiment 1.

(7) FIG. **7** is a graph showing Vickers hardness of a sintered member of Sample No. 2, Vickers hardness of a sintered member of Sample No. 101, and Vickers hardness of a sintered member of Sample No. 110 according to Embodiment 2.

(8) FIG. **8**A is a micrograph showing a cross section of a sintered member of Sample No. 1 according to Embodiment 2.

(9) FIG. **8**B is a micrograph showing a cross section of the sintered member of Sample No. 1 according to Embodiment 2.

(10) FIG. **9**A is a micrograph sowing a cross section of a sintered member of Sample No. 2 according to Embodiment 2.
(11) FIG. **9**B is a micrograph sowing a cross section of the sintered member of Sample No. 2 according to Embodiment 2.
(12) FIG. **10** illustrates a method of measuring the maximum stress that acts on spline teeth of a sintered member in an example of analysis.
(13) FIG. **11** is a micrograph showing a cross section of a sintered member of Sample No. 101.
(14) FIG. **12** is a micrograph showing a cross section of a sintered member of Sample No. 102.

DETAILED DESCRIPTION

Problems to be Solved by the Present Disclosure

(15) The first cam included in the cam mechanism of the electromagnetic coupling may be composed of a sintered member. The first cam is mechanically involved with the second cam through the ball, and therefore is desired to have excellent fatigue strength. The first cam having excellent fatigue strength has a long life, which ensures long-term use of the electromagnetic coupling.
(16) Therefore, one object of the present disclosure is to provide a sintered member capable of constituting an electromagnetic coupling usable over a long period of time.
(17) Another object of the present disclosure is to provide an electromagnetic coupling usable over a long period of time.

Effects of the Present Disclosure

(18) The sintered member according to the present disclosure can constitute an electromagnetic coupling usable over a long period of time.
(19) The electromagnetic coupling according to the present disclosure is usable over a long period of time.

Description of Embodiments of the Present Disclosure

(20) The first cam included in the conventional electromagnetic coupling is not provided with a tooth-missing part at a peripheral face thereof, and spline teeth are disposed also in a part, in the circumferential direction of the peripheral face, which overlaps a range in which each ball groove is formed. The present inventor has found that, if a load or the like, which is caused in the axial direction of the sintered member of the first cam by the second cam of the electromagnetic coupling, acts on the sintered member through the ball of the electromagnetic coupling, stress may be concentrated on the roots of the spline teeth. The present disclosure is based on the above findings. Firstly, embodiments of the present disclosure are listed and described.
(21) A sintered member according to an aspect of the present disclosure is a sintered member having an annular shape. The sintered member includes a first face facing one side in an axial direction; a second face facing the other side in the axial direction; an inner peripheral face connected to an inner peripheral edge of the first face; and a plurality of tooth groups and a plurality of tooth-missing parts which are alternately disposed along a circumferential direction of the inner peripheral face. In the sintered member, the second face includes a plurality of ball grooves arranged in parallel in the circumferential direction. In the sintered member, each tooth group includes a plurality of spline teeth that are continuous in the circumferential direction of the peripheral face. In the sintered member, the number of the plurality of tooth-missing parts is the same as the number of the plurality of ball grooves. In the sintered member, positions in a radial direction in which the plurality of tooth-missing parts are formed are within ranges in the radial direction in which the plurality of ball grooves are formed. In the sintered member, ranges in the circumferential direction in which the plurality of tooth-missing parts are formed overlap ranges in the circumferential direction in which the plurality of ball grooves are formed.
(22) The sintered member can constitute an electromagnetic coupling usable over a long period of time. The reason is as follows. That is, in the sintered member, the ranges in the circumferential direction in which the plurality of tooth-missing parts are formed overlap the ranges in the

circumferential direction in which the plurality of ball grooves are formed. Therefore, spline teeth are absent in the part, in the circumferential direction of the inner peripheral face, which overlaps the range in which each ball groove is formed. That is, the part, in the circumferential direction of the inner peripheral face, which overlaps the range in which each ball groove is formed is rounded at a bending radius larger than that of the roots of the spline teeth. Therefore, when a first cam of an electromagnetic coupling is composed of the sintered member, even if a load or the like, which is caused in the axial direction of the sintered member by a second cam of the electromagnetic coupling, acts on the sintered member through a ball of the electromagnetic coupling, stress concentration is reduced by the rounded tooth-missing part, whereby stress concentration on the roots of the spline teeth is inhibited. Therefore, the sintered member can inhibit reduction in fatigue strength, and has a long life.

(23) (2) As one exemplary form of the above sintered member, a variation width of Vickers hardness up to a depth of 5.0 mm along a direction orthogonal to a surface of the sintered member may be not larger than 100 HV.

(24) The sintered member has uniform hardness up to 5.0 mm, in the direction orthogonal to the surface of the sintered member, which is the predetermined depth from the surface. A sintered member having non-uniform hardness is easy to be damaged because portions of lesser hardness can be mechanical weak points. Meanwhile, the sintered member having uniform hardness is hardly damaged because it has smaller number of portions to be mechanical weak points.

(25) (3) As one exemplary form of the above sintered member, the sintered member may have a composition containing Ni, Cr, Mo, and C, and a balance of Fe and inevitable impurities, and when a total content of elements contained in the sintered member is 100 mass %, a content of Ni in the sintered member may be larger than 2 mass % and not larger than 6 mass %.

(26) The sintered member has both high hardness and high toughness. This is because the content of Ni is large but is not excessively large.

(27) (4) As one exemplary form of the above sintered member, the content of Cr may be not less than 2 mass % and not larger than 4 mass %, the content of Mo may be not less than 0.2 mass % and not larger than 0.9 mass %, and the content of C may be not less than 0.2 mass % and not larger than 1.0 mass %.

(28) The sintered member has high hardness. This is because the contents of the elements described above satisfy the respective ranges, which will be described later in detail.

(29) (5) As one exemplary form of the above sintered member, the sintered member may have a multiphase structure including a martensitic phase and a retained austenite phase, and an area ratio of the retained austenite phase at an arbitrary cross section of the sintered member may be not lower than 5%.

(30) The sintered member has both high hardness and high toughness. This is because the sintered member includes the martensitic phase having high hardness and the retained austenite phase having high toughness. In particular, the sintered member is excellent in toughness. This is because the area ratio of the retained austenite phase having high toughness is high.

(31) (6) An electromagnetic coupling according to an aspect of the present disclosure is an electromagnetic coupling including a first cam, a second cam, and a ball interposed between the first cam and the second cam, and the first cam is composed of the sintered member according to any one of the above (1) to (5).

(32) The electromagnetic coupling is usable over a long period of time. This is because the first cam is composed of the sintered member which can reduce concentration of stress on the roots of the spline teeth and has a long life, as described above.

Details of Embodiments of the Present Disclosure

(33) Hereinafter, embodiments of the present disclosure will be described in detail. In the drawings, the same reference characters denote the same elements.

Embodiment 1

(34) [Sintered Member]
(35) With reference to FIG. **1** through FIG. **5**, a sintered member **1** according to Embodiment 1 will be described. The sintered member **1** is formed in an annular shape (FIG. **1**). The sintered member **1** has a first face **11** (FIG. **1**), a second face **12** (FIG. **2**), and a peripheral face **15** (FIG. **1**). The first face **11** and the second face **12** face opposite sides from each other in the axial direction of the sintered member **1**. The peripheral face **15** is an annular face connected to an inner peripheral edge of the first face **11**. The sintered member **1** of the present embodiment has one feature of satisfying the following requirements (a) and (b). (a) The sintered member **1** has tooth groups **16** and tooth-missing parts **17** (FIG. **1**) alternately disposed along the circumferential direction of the peripheral face **15**, and a plurality of ball grooves **12***a* (FIG. **2**) disposed in parallel along the circumferential direction of the second face **12**. (b) The tooth-missing parts **17** and the ball grooves **12***a* satisfy a specific numerical relationship and a specific positional relationship.
(36) Hereinafter, the respective components will be described in detail.
(37) [Appearance]
(38) The sintered member **1** has a disk shape (FIG. **1**). The sintered member **1** has a hole **19** at the center thereof. The hole **19** penetrates the sintered member **1** along the axial direction of the sintered member **1**. In addition to the hole **19**, the sintered member **1** may have a plurality of through-holes (not shown) penetrating the first face **11** and the second face **12**. These through holes can realize a reduction in weight of the sintered member.
(39) [First Face and Second Face]
(40) The first face **11** is disposed at one side in the axial direction of the sintered member **1** (FIG. **1**). The second face **12** is disposed at the other side in the axial direction of the sintered member **1** (FIG. **2**). That is, the first face **11** and the second face **12** are disposed at opposite sides from each other in the axial direction of the sintered member **1**. Each of the first face **11** and the second face **12** has an annular shape. Each of the first face **11** and the second face **12** is substantially formed as a flat plane. The first face **11** and the second face **12** are substantially orthogonal to the axial direction of the sintered member **1** and are parallel to each other.
(41) [Peripheral Face]
(42) The peripheral face **15** is parallel to the axial direction of the sintered member **1** (FIG. **1**). In the present embodiment, the peripheral face **15** is an inner peripheral face. That is, a peripheral edge, of the peripheral face **15**, at one side in the axial direction of the sintered member **1** is connected to the inner peripheral edge of the first face **11**. Meanwhile, in the present embodiment, a peripheral edge, of the peripheral face **15**, at the other side in the axial direction of the sintered member **1** is not connected to an inner peripheral edge of the second face **12** but is connected to an outer peripheral edge of a third face **13** described later. When the peripheral face **15** is an inner peripheral face as in the present embodiment, the peripheral edge at the other side of the peripheral face **15** may be connected to the inner peripheral edge of the second face **12**. The peripheral face **15** may be an outer peripheral face. When the peripheral face **15** is the outer peripheral face, a peripheral edge at the one side of the peripheral face **15** is connected to an outer peripheral edge of the first face **11**. The peripheral edge at the other side of the peripheral face **15** may be connected to an outer peripheral edge of the second face **12**.
(43) [Others]
(44) (Third Face)
(45) The third face **13** is a face at the one side in the axial direction of the sintered member **1**. The third face **13** forms a step between itself and the first face **11**, and the step has a length along the axial direction of the peripheral face **15**. The third face **13** has an annular shape. Like the first face **11**, the third face **13** is substantially formed as a flat plane. The third face **13** is substantially parallel to the first face **11** and the second face **12**.
(46) [Tooth Group]
(47) Each of tooth groups **16** is a part to be meshed with teeth of a mating gear, and is an

aggregation of a plurality of spline teeth **16***a* arranged in parallel along the circumferential direction of the peripheral face **15** (FIG. **1**). Illustration of the mating gear is omitted. Since the peripheral face **15** of the present embodiment is an inner peripheral face as described above, the tooth group **16** is an inner tooth group. If the peripheral face **15** is an outer peripheral face, the tooth group **16** is an outer tooth group. One tooth group **16** is disposed between two tooth-missing parts **17** adjacent in the circumferential direction. The number of the tooth groups **16** is the same as the number of the tooth-missing parts **17**. In the present embodiment, the number of the tooth groups **16** is 3.
(48) The number of the spline teeth **16***a* in each tooth group **16** is not particularly limited as long as it is not less than 2, and can be selected as appropriate. If the number of the spline teeth **16***a* in each tooth group **16** is large, the number of the spline teeth **16***a* to be meshed with the mating gear is likely to be large. Therefore, a load that acts on each spline tooth **16***a* due to meshing with the mating gear is easily reduced. If the number of the spline teeth **16***a* in each tooth group **16** is small, a length Lb of each tooth-missing part **17** described later is likely to be increased. Therefore, even when a first cam **110** (FIG. **6**) of an electromagnetic coupling **10** is composed of the sintered member **1**, stress concentration on the roots oldie spline teeth **16***a* is easily reduced, as described later in detail. In the present embodiment, the number of the spline teeth **16***a* in each tooth group **16** is 8.
(49) A length La of each tooth group **16** can be selected as appropriate in accordance with the length Lb of the tooth-missing part **17** described later (FIG. **3**). The length La of a tooth group **16** is a length from a spline tooth **16***a* at one end of the tooth group **16** to a spline tooth **16***a* at the other end of the tooth group **16** on a circumference of a pitch circle Cp of the spline teeth **16***a*. In FIG. **3**, the pitch circle Cp is indicated by a broken line. The length La of each tooth group **16** may be different from or equal to the length Lb of the tooth-missing part **17** described later. When the length La of the tooth group **16** is larger than the length Lb of the tooth-missing part **17**, the number of the spline teeth **16***a* in the tooth group **16** is easy to be increased. Therefore, stress that acts on each spline tooth **16***a* is easily reduced. When the length La of the tooth group **16** is smaller than the length Lb of the tooth-missing part **17**, since the length Lb of the tooth-missing part **17** is large, stress concentration on the roots of the spline teeth **16***a* is easily reduced. When the length a of the tooth group **16** is equal to the length Lb of the tooth-missing part **17**, both the effect of easily reducing stress that acts on each spline tooth **16***a* and the effect of easily reducing stress concentration on the roots of the spline teeth **16***a* can be achieved in good balance.
(50) In each tooth group **16**, a tooth thickness Ta of each spline tooth **16***a* and a width Wa of each tooth groove can be selected as appropriate in accordance with the width of each tooth groove and the thickness of each tooth of the mating gear. The tooth thickness Ta of the spline tooth **16***a* is the length of the spline tooth **16***a* on the circumference of the pitch circle Cp. The width Wa of the tooth groove is the length between adjacent spline teeth **16***a* on the circumference of the pitch circle Cp. In each tooth group **16**, each spline tooth **16***a* has equal tooth thickness Ta. In each tooth group **16**, the width Wa of the tooth groove is smaller than the length Lb of the tooth-missing part **17**. In each tooth group **16**, each tooth groove has equal width Wa.
(51) [Tooth-Missing Part]
(52) Each tooth-missing part **17** has no teeth and does not mesh with the teeth of the mating gear (FIG. **1**). The tooth-missing part **17** is formed of a part of the peripheral face **15**. One tooth-missing part **17** is disposed between two tooth groups **16** adjacent in the circumferential direction. That is, the number of the tooth-missing parts **17** is equal to the number of the ball grooves **12***a* described later. In the present embodiment, the number of the tooth-missing parts **17** is 3.
(53) In each tooth-missing part **17**, the number of missing spline teeth **16***a* varies depending on the tooth thickness Ta of the spline tooth **16***a*, the width Wa of the tooth groove, and the length Lb of the tooth-missing part **17** described later (FIG. **3**). The number of the missing spline teeth **16***a* can be grasped by arranging spline teeth **16***a* of a tooth group **16** in parallel in the circumferential direction, instead of forming a tooth-missing part **17**, as indicated by a dashed-and-double-dotted

line in FIG. **3**. At this time, the spline teeth **16***a* are made to have equal thickness Ta and the tooth grooves are made to have equal width Wa. In each tooth-missing part **17**, the number of the missing spline teeth **16***a* may be at least two or more. In this case, the length Lb of the tooth-missing part **17** is likely to be long, and therefore, stress concentration on the roots of the spline teeth **16***a* is easily reduced. However, if the number of the missing spline teeth **16***a* is excessively large, the number of the spline teeth **16***a* is reduced, and stress that acts on each spline tooth **16***a* is easily increased. The number of the missing spline teeth **16***a* is preferably **3** or less, for example, although it depends on the tooth thickness Ta of the spline tooth **16***a*, the width Wa of the tooth groove, and the length Lb of the tooth-missing part **17**. In the present embodiment, the number of the missing spline teeth **16***a* in the tooth-missing part **17** is 2. That is, one tooth-missing part **17** is formed by two spline teeth **16***a* being missed, and the two missing spline teeth **16***a* are counted as one tooth-missing part **17**.
(54) A part, of the peripheral face **15**, in which each tooth-missing part **17** is formed opposes the corresponding ball groove **12***a* as described later (FIG. **5**). That is, the position, in the radial direction, in which each tooth-missing part **17** is formed is within a range, in the radial direction, in which the corresponding ball groove **12***a* is formed, and a range, in the circumferential direction, in which each tooth-missing part **17** is formed and a range, in the circumferential direction, in which the corresponding ball groove **12***a* is formed, overlap each other in the circumferential direction.
(55) The first cam **110** of an electromagnetic coupling **10** may be composed of a sintered member, different from the sintered member **1** of the present embodiment, in which tooth-missing parts **17** are not formed at the peripheral face **15** and spline teeth **16***a* are also formed in parts, in the circumferential direction of the peripheral face **15**, which overlap the ranges in which the ball grooves **12***a* are formed. In this case, a load or the like, which is caused in the axial direction of the sintered member **1** by a second cam **120** of the electromagnetic coupling **10**, acts on the sintered member **1** through a ball **130** of the electromagnetic coupling **10**, and stress is concentrated on the roots of the spline teeth in the parts in the circumferential direction which overlap the ranges in which the ball grooves **12***a* are formed. Meanwhile, in the sintered member **1** of the present embodiment, since the range in the circumferential direction in which each tooth-missing part **17** is formed overlaps the range in the circumferential direction in which the corresponding ball groove **12***a* is formed, roots of spline teeth **16***a*, on which stress will be concentrated, are absent in the parts, in the circumferential direction of the peripheral face **15**, which overlap the ranges in which the ball grooves **12***a* are formed. That is, the parts, in the circumferential direction of the peripheral face **15**, which overlap the ranges in which the corresponding ball grooves **12***a* are formed are rounded at a bending radius larger than that of the roots of the spline teeth **16***a*. Therefore, stress concentration following the action of the load or the like is reduced by the rounded tooth-missing parts **17**, thereby reducing stress concentration on the roots of the spline teeth **16***a*.
(56) The length Lb of each tooth-missing part **17** can be selected as appropriate in accordance with a length Lc of each ball groove **12***a* described later (FIG. **3**). The length Lb of the tooth-missing part **17** is a length between adjacent tooth groups **16** on the circumference of a root circuit Cr. In FIG. **3**, the root circle Cr is indicated by a dashed-and-dotted line. The length Lb of the tooth-missing part **17** is preferably not smaller than 30% and not larger than 70% with respect to the length Lc of the ball groove **12***a* described later. When the length Lb of the tooth-missing part **17** is not smaller than 30% with respect to the length Lc of the ball groove **12***a*, the tooth-missing part **17** has a sufficient length. Therefore, stress concentration on the roots of the spline teeth **16***a* is easily reduced. When the length Lb of the tooth-missing part **17** is not larger than 70% with respect to the length Lc of the ball groove **12***a*, the length of the tooth-missing part **17** is prevented from being excessively long. That is, the length La of the tooth group **16** is prevented from being excessively short. In the present embodiment, the length Lb of the tooth-missing part **17** is smaller than the length Lc of the ball groove **12***a* (FIG. **4**). Each tooth-missing part **17** has equal length Lb. Each tooth-missing part **17** is formed such that the entire length Lb thereof is within a range that overlaps the range in which the corresponding ball groove **12***a* is formed (FIG. **4**). That is, a spline tooth **16***a*

at each end of the tooth group **16** is located at a position that overlaps an end part of the range in which the ball groove **12***a* is formed.
(57) In FIG. **4**, the tooth-missing part **17** opposing the ball groove **12***a* and the spline tooth **16***a* at each end of the tooth group **16** are indicated by a broken line.
(58) The length Lb of the tooth-missing part **17** indicates the formation range in the circumferential direction of the tooth-missing part **17**, and the length Lc of the ball groove **12***a* indicates the formation range in the circumferential direction of the ball groove **12***a* (FIG. **4**).
(59) That is, as shown in FIG. **4**, the formation range (length Lb) in the circumferential direction of the tooth-missing part **17** and the formation range (length Lc) in the circumferential direction of the ball groove **12***a*, overlap each other.
(60) In FIG. **4**, the center of the range of the length Lb of the tooth-missing part **17** and the center of the range of the length Lc of the ball groove **12***a* are substantially aligned with each other. However, the center of the range of the length Lb of the tooth-missing part **17** and the center of the range of the length Lc of the ball groove **12***a* may be shifted from each other.
(61) In FIG. **4**, the entire range of the length Lb of the tooth-missing part **17** is included in the range of the length Lc of the ball groove **12***a*, and the entire range of the length Lb of the tooth-missing part **17** overlaps the range of the length Lc of the ball groove **12***a*. However, a part of the range of the length Lb of the tooth-missing part **17** may overlap the range of the length Lc of the ball groove **12***a*.
(62) The length Lb of the tooth-missing part **17** may be larger than the length Lc of the ball groove **12***a* as long as a part or the entirety of the length Lb of the tooth-missing part **17** overlaps a part or the entirety of the length Lc of the ball groove **12***a*.
(63) In the present embodiment, the position, in the radial direction, of the tooth-missing part **17** at the outer peripheral edge is shifted toward the outer peripheral edge side of the ball groove **12***a* when the tooth-missing part **17** is viewed in a plan. The position of the tooth-missing part **17** at the outer peripheral edge may be shifted toward the inner peripheral edge side of the ball groove **12***a*. The outer peripheral edge of the tooth-missing part **17** may be disposed right in the middle between the outer peripheral edge and the inner peripheral edge of the ball groove **12***a*. It is considered that, when the position of the tooth-missing part **17** at the outer peripheral edge is shifted toward the inner peripheral edge side of the ball groove **12***a*, stress concentration following the action of the load or the like is easily reduced in the tooth-missing part **17**, and stress concentration on the roots of the spline teeth **16***a* is easily reduced.
(64) As described above, the position in the radial direction at which each tooth-missing part **17** is formed is within the range in the radial direction in which the corresponding ball groove **12***a* is formed.
(65) [Ball Groove]
(66) In each ball groove **12***a*, a ball **130** (FIG. **6**) which is a component of the electromagnetic coupling **10** is disposed (FIG. **2**). The ball grooves **12***a* are arranged in parallel along the circumferential direction of the second face **12**. As for the ball grooves **12***a* adjacent in the circumferential direction, the ball grooves **12***a* may be formed at intervals in the circumferential direction as in the present embodiment or may be successively formed in the circumferential direction substantially without intervals, although it depends on the number of the ball grooves **12***a* and the length Lc of each ball groove **12***a*. Being successively formed in the circumferential direction substantially without intervals means, for example, being successively formed such that the ball grooves **12***a* adjacent in the circumferential direction are connected via the end portions thereof. In the present embodiment, the second face **12** is interposed between the ball grooves **12***a* adjacent in the circumferential direction. The circumferential intervals of the ball grooves **12***a* adjacent in the circumferential direction are equal intervals.
(67) The number of the ball grooves **12***a* is not particularly limited as long as it is not smaller than 2, and can be appropriately selected. The number of the ball grooves **12***a* is 3 to 9, for example. In

the present embodiment, the number of the ball grooves **12***a* is 3.
(68) The length Lc of the ball groove **12***a* can be selected as appropriate in accordance with the number of the ball grooves **12***a*, the interval between the ball grooves **12***a* adjacent in the circumferential direction, and the like. The length Lc of the ball groove **12***a* is the maximum length along the circumferential direction as shown in FIG. **5**. In the present embodiment, the length Lc of the ball groove **12***a* is larger than the length Lb of the tooth-missing part **17** described above.
(69) The shape of each ball groove **12***a* is not particularly limited and can be selected as appropriate. The depths of the ball grooves **12***a* are not uniform and are different from each other. When the first cam **110** (FIG. **6**) of the electromagnetic coupling **10** is composed of the sintered member **1**, the different depths allow the interval between the first cam **110** and the second cam **120** opposing through the ball **130** to be reduced and increased, which will be described later in detail. The widths of openings of the ball grooves **12***a* may be uniform or different from each other (FIG. **2**). The depth and the opening width of each ball groove **12***a* may satisfy the following relationships. That is, the opening width at the deepest part of the ball groove **12***a* is broadest. The opening width at the shallowest part of the ball groove **12***a* may be equal to the opening width at the deepest part, or may be narrowest.
(70) In the present embodiment, each ball groove **12***a* has an arc shape (FIG. **2**, FIG. **4**). In the present embodiment, the ball groove **12***a* is sloped such that the depth thereof is gradually reduced from the center toward the both ends in the circumferential direction. That is, the depth of the ball groove **12***a* is largest at the center in the circumferential direction and is smallest at the both ends in the circumferential direction. The opening width of the ball groove **12***a* is gradually reduced from the center toward the both ends in the circumferential direction. That is, the opening width of the ball groove **12***a* is largest at the center in the circumferential direction and is smallest at the both ends in the circumferential direction.
(71) Depending on the shape of the ball groove **12***a*, the ball groove **12***a* may be sloped such that the depth thereof is reduced from one end toward the other end in the circumferential direction. In this case, the opening width of the ball groove **12***a* may be reduced from the one end toward the other end in the circumferential direction. The opening width of the ball groove **12***a* may be uniform in the circumferential direction.
(72) [Composition]
(73) The sintered member **1** is formed of a plurality of iron-based particles being bonded to each other. The "iron-based" means pure iron or iron-based alloys. For example, an iron-based alloy contains: one or more types of additive elements selected from the group consisting of Cu (copper), C (carbon), Ni (nickel), Mo (molybdenum), Mn (manganese), and Cr (chromium); and a balance of Fe (iron) and impurities. Specific examples of the iron-based alloy include stainless steel, Fe—C-based alloy, Fe—Cu—Ni—Mo-based alloy, Fe—Ni—Mo—Mn-based alloy, Fe—Cu-based alloy, Fe—Cu—C-based alloy, Fe—Cu—Mo-based alloy, Fe—Ni—Mo—Cu—C-based alloy, Fe—Ni—Cu-based alloy, Fe—Ni—Mo—C-based alloy, Fe—Ni—Cr-based alloy, Fe—Ni—Mo—Cr-based alloy, Fe—Ni—Cr—Mo—C-based alloy, Fe—Cr-based alloy, Fe—Mo—Cr-based alloy, Fe—Cr—C-based alloy, Fe—Ni—C-based alloy, and Fe—Mo—Mn—Cr—C-based alloy. Among these iron-based alloys, a specific Fe—Ni—Cr—Mo—C-based alloy is preferable. A sintered member **1** formed of the specific Fe—Ni—Cr—Mo—C-based alloy will be described later for Embodiment 2.
(74) The composition of the sintered member **1** can be confirmed through component analysis using an inductively coupled plasma optical emission spectrometry (ICP-OES).
(75) [Manufacturing Method]
(76) The sintered member **1** of the present embodiment can be manufactured by a manufacturing method including a process of preparing a powder compacted body, and a process of sintering the powder compacted body. Hereinafter, these processes are described in order.
(77) [Preparation Process]
(78) This process prepares a powder compacted body having a plurality of teeth groups, a plurality

of tooth-missing parts, and a plurality of ball grooves. The plurality of teeth groups, the plurality of tooth-missing parts, and the plurality of ball grooves included in the powder compacted body correspond to the plurality of tooth groups **16**, the plurality of tooth-missing parts **17**, and the plurality of ball grooves **12***a* included in the sintered member **1** described above. The sintered member **1** is manufactured by sintering the powder compacted body prepared in this process. That is, the powder compacted body corresponds to the member **1** which has not yet been sintered. The powder compacted body is obtained through pressure molding of prepared material powder. The material powder can be selected as appropriate so as to satisfy the aforementioned composition of the sintered member **1**. For the pressure molding of the material powder, a mold capable of performing "near net shape" is used, for example. The near net shape is a technique of finishing an item in a shape very close to its final (net) shape. Through this pressure molding, the powder compacted body including the plurality of teeth groups, the plurality of tooth-missing parts, and the plurality of ball grooves is obtained. The powder compacted body can also be prepared by manufacturing a disk-like powder compacted body, and forming a plurality of teeth groups, a plurality of tooth-missing parts, and a plurality of ball grooves in the powder compacted body through cutting work.
(79) [Sintering Process]
(80) This process sinters the powder compacted body. The aforementioned sintered member **1** in which the particles of the material powder are bonded can be obtained by sintering the powder compacted body. An appropriate sintering furnace can be used for sintering of the powder compacted body. If rapid cooling is required at a cooling step in the sintering process, a continuous sintering furnace is preferred for sintering of the powder compacted body. The continuous sintering furnace includes a sintering furnace, and a rapid cooling chamber connected downstream of the sintering furnace.
(81) Sintering conditions can be selected as appropriate in accordance with the composition of the material powder. A sintering temperature is, for example, not lower than 1050° C. and not higher than 1400° C., and furthermore, not lower than 1100° C. and not higher than 1300° C. A sintering time is, for example, not shorter than 10 minutes and not longer than 150 minutes, and furthermore, not shorter than 15 minutes and not longer than 60 minutes. As the sintering conditions, known conditions are applicable.
(82) A cooling rate at the cooling step in the sintering process can be selected as appropriate. The sintered member **1** may be rapidly cooled by increasing the cooling rate, or may be slowly cooled without increasing the cooling rate. Rapid cooling can dispense with a process of heat treatment described later. If rapid cooling is not performed, the process of heat treatment described later may be performed.
(83) In the case of rapid cooling, the cooling rate may be not lower than 1° C./sec. When the cooling rate is not lower than 1° C./sec, the sintered member **1** is rapidly cooled. This allows a martensitic phase to be easily formed, whereby the sintered member **1** having high hardness can be manufactured. Moreover, rapid cooling allows the sintered member **1**, in which a variation width of Vickers hardness from the surface to a predetermined depth is small, to be easily manufactured. Specifically, the sintered member **1** in which the variation width of Vickers hardness is 50 HV or smaller is manufactured. The cooling rate is more preferably not lower than 2° C./sec, and particularly preferably not lower than 5° C./sec. For example, an upper limit of the cooling rate is 1000° C./sec, furthermore, 500° C./sec, and, particularly, 200° C./sec. As for a cooling method, spraying a cooling gas to the sintered member **1** may be adopted. As for the type of the cooling gas, an inactive gas such as nitrogen gas or argon gas may be adopted.
(84) [Other Processes]
(85) In addition to the above processes, the sintered member manufacturing method may include at least one of a process of heat treatment and a process of finishing treatment.
(86) (Process of Heat Treatment)

(87) Examples of heat treatment include quenching treatment, tempering treatment, and the like. The quenching treatment and the tempering treatment improve mechanical characteristics, in particular, hardness and strength, of the sintered member **1**. The quenching treatment may be carburizing quenching treatment. Known conditions are applicable to the quenching treatment (carburizing quenching treatment) and the tempering treatment.
(88) (Process of Finishing Treatment)
(89) This process adjusts the dimensions of the sintered member **1** to design dimensions. Examples of finishing treatment include sizing, polishing of the surface of the sintered member **1**, and the like. In particular, polishing can easily reduce the surface roughness of the sintered member **1**.
(90) [Applications]
(91) The sintered member **1** according to the present embodiment can be preferably used as a cam component constituting a cam mechanism of an electromagnetic coupling, for example. With reference to FIG. **6**, an example of an electromagnetic coupling according to the present embodiment will be described. The electromagnetic coupling **10** performs connection and disconnection of a propeller shaft and a rear differential gear of an automobile, for example.
(92) The electromagnetic coupling **10** is provided with a cam mechanism including a first cam **110**, a second cam **120**, and a ball **130**. FIG. **6** shows only the cam mechanism, for convenience of description. In addition to these components, the electromagnetic coupling **10** includes an electromagnetic coil, an armature, a first clutch, a second clutch, etc., which are not shown in FIG. **6**. FIG. **6** is a cross-sectional view showing a state where the cam mechanism is cut at the same position as in the cross-sectional view shown in FIG. **5**.
(93) The first cam **110** is composed of the aforementioned sintered member **1**. That is, the first cam **110** includes a plurality of tooth groups **16** and a plurality of tooth-missing parts **17**. A second face **12** includes a plurality of ball grooves **12***a*. A first face **11** of the first cam **110** is located at a side opposite to the second cam **120** side, and the second face **12** of the first cam **110** is located at the second cam **120** side. The second cam **120** includes a ball groove **121** in which the ball **130** is disposed. The ball **130** is interposed between the ball groove **12***a* of the first cam **110** and the ball groove **121** of the second cam **120**.
(94) The distance between the first cam **110** and the second cam **120** is increased (not shown) and reduced as shown in FIG. **6**, depending on presence/absence of current application to the electromagnetic coil.
(95) When a current is applied to the electromagnetic coil, the second cam **120** rotates through the armature, the second clutch, and the like. The ball **130** moves from the deepest part to the shallowest part of the ball groove **12***a* of the first cam **110** while being dragged by the ball groove **121** of the second cam **120**. This movement of the ball **130** causes the first cam **110** to be pushed toward the first face **11** side through the ball **130**. Then, the first cam **110** moves apart from the second cam **120**, and the distance between the first cam **110** and the second cam **120** is increased. When the distance is increased, the propeller shaft and the rear differential gear are connected to each other through the first clutch and the like.
(96) Meanwhile, when the current applied to the electromagnetic coil is shut off, rotation of the second cam **120** during current application is canceled. The second cam **120** rotates in a direction opposite to the direction during current application. Then, the ball **130** moves from the shallowest part to the deepest part of the ball groove **12***a* of the first cam **110** while being dragged by the ball groove **121** of the second cam **120**. This movement of the ball **130** cancels the pressing force toward the first face **11** of the first cam **110** through the ball **130**. The first cam **110** approaches the second cam **120** side, and the distance between the first cam **110** and the second cam **120** is reduced. When the distance is reduced, connection of the propeller shaft and the rear differential gear through the first clutch and the like is disconnected.
Advantageous Effects
(97) The sintered member **1** according to the present embodiment can constitute the

electromagnetic coupling **10** usable over a long period of time. In the sintered member **1** of the present embodiment, since the range in the circumferential direction in which each tooth-missing part **17** is formed overlaps the range in the circumferential direction in which the corresponding ball groove **12***a* is formed, roots of spline teeth **16***a*, on which stress will be concentrated, are absent in the parts, in the circumferential direction of the peripheral face **15**, which overlap the ranges in which the ball grooves **12***a* are formed. That is, the parts, in the circumferential direction of the peripheral face **15**, which overlap the ranges in which the corresponding ball grooves **12***a* are formed are rounded at a bending radius larger than that of the roots of the spline teeth **16***a*. Therefore, in the case where the first cam **110** of the electromagnetic coupling **10** is composed of the sintered member **1** of the present embodiment, if a load or like, which is caused in the axial direction of the sintered member **1** by the second cam **120** of the electromagnetic coupling **10**, acts on the sintered member **1** through the ball **130** of the electromagnetic coupling **10**, stress concentration is reduced by the rounded tooth-missing parts **17**, thereby inhibiting stress concentration on the roots of the spline teeth **16***a*. Therefore, the sintered member **1** of the present embodiment can inhibit reduction in fatigue strength, and has a long life. Meanwhile, the electromagnetic coupling **10** of the present embodiment is usable over a long period of time because the first cam **110** is composed of the sintered member **1** which can reduce stress concentration on the roots of the spline teeth **16***a* and therefore has a long life.
Embodiment 2
(98) [Sintered Member]
(99) With reference to FIG. **1** to FIG. **5**, FIG. **7**, FIG. **8**A, FIG. **8**B, FIG. **9**A, and FIG. **9**B, a sintered member **1** according to Embodiment 2 will be described. The sintered member **1** of Embodiment 2 is different from the sintered member **1** of Embodiment 1 mainly in that it has specific composition, structure, and characteristics. The sintered member **1** of Embodiment 2 has the same appearance as the sintered member **1** of Embodiment 1. The following description will be focused mainly on the difference from Embodiment 1. Description of the same components as those in Embodiment 1 will be omitted.
(100) [Composition]
(101) The sintered member **1** has a composition containing Ni, Cr Mo, C, and the balance of Fe and inevitable impurities.
(102) (Ni)
(103) Ni increases toughness of the sintered member **1**. Ni can improve hardenability during the process of manufacturing the sintered member **1**, and therefore also contributes to an increase in hardness of the sintered member **1**. Hereinafter, the process of manufacturing the sintered member **1** is sometimes referred to simply as “manufacturing process”. The content of Ni is preferably larger than 2 mass % and not larger than 6 mass %. When the content of Ni is larger than 2 mass %, the sintered member **1** has excellent toughness. This is because the content of Ni is large. Since the content of Ni is large, part of Ni is alloyed with Fe while the remaining Ni is not alloyed but remains as pure Ni. The pure Ni contributes to improvement of toughness. When the content of Ni is not larger than 6 mass %, the sintered member **1** has excellent hardness. Because the content of Ni is not excessively large, reduction in hardness can be inhibited. Therefore, when the content of Ni satisfies the above range, the sintered member **1** has both high hardness and high toughness. The content of Ni is more preferably not less than 2.5 mass % and not larger than 5.5 mass %, and particularly preferably not less than 3 mass %, and not larger than 5 mass %. The content of Ni is the amount of Ni contained in the sintered member **1** when the total amount of the elements contained in the sintered member **1** is 100 mass %. The same applies to Cr, Mo, and C described below.
(104) (Cr)
(105) Cr increases hardness of the sintered member **1**. This is because Cr can increase hardenability during the manufacturing process. The content of Cr is preferably not less than 2 mass % and not

larger than 4 mass %, for example. When the content of Cr is not less than 2 mass %, the sintered member **1** has excellent hardness. When the content of Cr is not larger than 4 mass %, reduction in toughness of the sintered member **1** can be inhibited. The content of Cr is more preferably not less than 2.2 mass % and not larger than 3.8 mass %, and particularly preferably not less than 2.5 mass % and not larger than 3.5 mass %.
(106) (Mo)
(107) Mo increases hardness of the sintered member **1**. This is because Mo can increase hardenability during the manufacturing process. The content of Mo is preferably not less than 0.2 mass % and not larger than 0.9 mass %, for example. When the content of Mo is not less than 0.2 mass %, the sintered member **1** has excellent hardness. When the content of Mo is not larger than 0.9 mass %, reduction in toughness of the sintered member **1** can be inhibited. The content of Mo is more preferably not less than 0.3 mass % and not larger than 0.8 mass %, and particularly preferably not less than 0.4 mass % and not larger than 0.7 mass %.
(108) (C)
(109) C increases hardness of the sintered member **1**. C easily causes an Fe—C liquid phase to appear during the manufacturing process. The Fe—C liquid phase easily rounds off edges of voids. Therefore, the sintered member **1** has less acute-angle edges of voids that will cause reduction in hardness. Therefore, hardness of the sintered member **1** is easily increased. The content of C is preferably not less than 0.2 mass % and not larger than 1.0 mass %, for example. When the content of C is not less than 0.2 mass %, the sintered member **1** has high hardness. This is because the Fe—C liquid phase is sufficiently generated during the manufacturing process, and effectively rounds off the edges of the voids. When the content of C is not larger than 1.0 mass %, the sintered member **1** has excellent dimensional accuracy. This is because the Fe—C liquid phase is easily prevented from being excessively generated during the manufacturing process. The content of C is more preferably not less than 0.3 mass % and not larger than 0.95 mass %, and particularly preferably not less than 0.4 mass % and not larger than 0.9 mass %.
(110) [Structure]
(111) As for the structure of the sintered member **1**, a multiphase structure including a martensitic phase and a retained austenite phase is preferable (FIG. **8**A, FIG. **8**B, FIG. **9**A, FIG. **9**B). Each of FIG. **8**A, FIG. **8**B, FIG. **9**A, and FIG. **9**B is a micrograph of a cross section of the sintered member **1**, as described later in detail. In each micrograph, a white part indicated ahead of each arrow is the retained austenite phase, and a part surrounding the retained austenite phase is the martensitic phase. The martensitic phase causes the sintered member **1** to have high hardness. The retained austenite phase causes the sintered member **1** to have high toughness.
(112) The area ratio of the retained austenite phase is preferably not lower than 5%, for example. In this case, since the area ratio of the retained austenite phase having high toughness is high, the sintered member **1** has excellent toughness. The area ratio of the retained austenite phase is preferably not higher than 50%, for example. In this case, the area ratio of the retained austenite phase is not excessively high. That is, the area ratio of the martensitic phase is more likely to be high. Therefore, the sintered member **1** has high hardness and high toughness. The area ratio of the retained austenite phase is more preferably not lower than 10% and not higher than 45%, and particularly preferably not lower than 15% and not higher than 40%. The area ratio of the retained austenite phase is a ratio of the total area of the retained austenite phase with respect to the whole area of the micrograph at the cross section of the sintered member **1**, which will be described later in detail.
(113) [Characteristics]
(114) (Hardness)
(115) The sintered member **1** preferably has high hardness. The sintered member **1** preferably has high Vickers hardness, and a small variation width of the Vickers hardness (circles shown in the graph of FIG. **7**). The graph of FIG. **7** will be described later in detail. The Vickers hardness of the

sintered member **1** is preferably not lower than 615 HV. The variation width of the Vickers hardness of the sintered member **1** is preferably not larger than 100 HV. This sintered member **1** has high and uniform hardness from the surface to the predetermined depth. That is, this sintered member **1** has less parts to be mechanical weak points as compared to a sintered member having uneven hardness, and therefore is hardly damaged. The sintered member **1**, having the small variation width of the Vickers hardness, is obtained through sinter hardening which is a process of rapidly cooling the sintered member **1** at the cooling step in the sintering process. Since the sintered member **1** has been subjected to sinter hardening, it need not be subjected to quenching and tempering after sintering. The variation width of the Vickers hardness of a sintered member **1** which has not been subjected to sinter hardening but has been subjected to quenching and tempering after sintering, exceeds 100 HV, for example.
(116) The Vickers hardness of the sintered member **1** is more preferably not lower than 620 HV, and particularly preferably not lower than 625 HV. The variation width of the Vickers hardness is more preferably not larger than 75 HV, and particularly preferably not larger than 50 HV. The Vickers hardness of the sintered member **1** is an average of Vickers hardness values measured at a plurality of points in the range from the surface of the sintered member **1** to the predetermined depth at the cross section of the sintered member **1**, as described later in detail. The variation width of the Vickers hardness of the sintered member **1** is a difference between the maximum value and the minimum value of the Vickers hardness values measured in the range from the surface to the predetermined depth at the cross section of the sintered member **1**.
(117) (Toughness)
(118) The sintered member **1** preferably has high toughness. Specifically, the sintered member **1** preferably has a large stress amplitude that bears 10.sup.7 times of bending repeated in an Ono-type rotating bending fatigue test described later in detail, and preferably has excellent bending fatigue strength. The stress amplitude that bears 10.sup.7 times of bending is preferably not smaller than 420 MPa. The stress amplitude that bears 10.sup.7 times of bending is more preferably not smaller than 423 MPa, and particularly preferably not smaller than 425 MPa.
(119) [Sintered Member Manufacturing Method]
(120) The sintered member **1** of the present embodiment can be manufactured by a sintered member manufacturing method including a process of preparing a powder compacted body and a process of sintering the powder compacted body, similar to the aforementioned sintered member manufacturing method. This preparation process is identical to the aforementioned preparation process in that a powder compacted body including a plurality of tooth groups, a plurality of tooth-missing parts, and a plurality of ball grooves is prepared. This preparation process is different from the aforementioned preparation process in that the powder compacted body includes, as material powders, iron-based alloy powder, Ni powder, and C powder. In the sintering process, rapid cooling is performed at the cooling step.
(121) [Preparation Process]
(122) (Iron-Based Alloy Powder)
(123) The iron-based alloy powder has a composition containing Cr, Mo, and the balance of Fe and inevitable impurities. The contents of Cr and Mo in the iron-based alloy are maintained even after the sintering process described later. That is, the contents of Cr and Mo in the iron-based alloy are maintained in the aforementioned sintered member **1**. The content of Cr in the iron-based alloy is, for example, preferably not less than 2 mass % and not larger than 4 mass %, more preferably not less than 2.2 mass % and not larger than 3.8 mass %, and particularly preferably not less than 2.5 mass % and not larger than 3.5 mass %, as described above. The content of Mo in the iron-based alloy is, for example, preferably not less than 0.2 mass % and not larger than 0.9 mass %, more preferably not less than 0.3 mass % and not larger than 0.8 mass %, and particularly preferably not less than 0.4 mass % and not larger than 0.7 mass %, as described above. The reasons for the above ranges of the contents of Cr and Mo are as described above. The content of Cr (Mo) is the amount

of Cr (Mo) contained in the iron-based alloy when the total amount of the elements contained in the iron-based alloy is 100 mass %.

(124) The average particle diameter of the iron-based alloy powder is, for example, not smaller than 50 μm and not larger than 150 μm. The iron-based alloy powder whose average particle diameter is within the above range is easy to be handled and easy to be pressure-molded. The iron-based alloy powder whose average particle diameter is not smaller than 50 μm is easy to ensure fluidity. The iron-based alloy powder whose average particle diameter is not larger than 150 μm is easy to provide a sintered member **1** of a dense structure. Furthermore, the average particle diameter of the iron-based alloy powder may be not smaller than 55 μm and not larger than 100 μm. The "average particle diameter" is a particle diameter (D50) of particles the cumulative volume of which is 50% in a volume particle size distribution measured by a laser diffraction particle size distribution measurement device. This also applies to the average particle diameters of Ni powder and C powder described later.

(125) (Ni Powder)

(126) The Ni powder may be pure Ni powder. The content of the Ni powder is maintained even after the sintering process described later. That is, the content of the Ni powder is maintained in the aforementioned sintered member **1**. As described above, the content of the Ni powder is preferably larger than 2 mass % and not larger than 6 mass %, more preferably not less than 2.5 mass % and not larger than 5.5 mass %, and particularly preferably not less than 3 mass % and not larger than 5 mass %. When the content of the Ni powder is large, a part of Ni is alloyed with Fe during the sintering process while the remaining Ni is not alloyed but is present as pure Ni. Moreover, a multiphase structure including a martensitic phase and a retained austenite phase is formed. Therefore, the sintered member **1** having excellent toughness is easily manufactured. Moreover, since the content of the Ni powder is not excessively large, reduction in hardness is easily inhibited. Therefore, when the content of the Ni powder satisfies the above range, the sintered member **1** having both high strength and high toughness can be manufactured. The content of the Ni powder is the amount of the Ni powder contained in the material powder when the entirety of the material powder is 100 mass %.

(127) The average particle diameter of the Ni powder has an influence on the distribution state of the retained austenite phase. The average particle diameter of the Ni powder is not smaller than 1 μm and not larger than 40 μm, for example. The Ni powder whose average particle diameter is not larger than 40 μm easily causes the retained austenite phase to be uniformly distributed. The Ni powder whose average particle diameter is not smaller than 1 μm is easy to be handled, whereby workability in manufacturing can be improved. The average particle diameter of the Ni powder is, furthermore, not smaller than 1 μm and not larger than 30 μm, and, particularly, not smaller than 1 μm and not larger than 20 μm.

(128) (C Powder)

(129) The C powder becomes an Fe—C liquid phase during a healing step in the sintering process, and rounds off edges of voids in the sintered member **1**, thereby increasing hardness of the sintered member **1**. The content of the C powder, similar to the Ni powder and the like, is maintained even after the sintering process described later. That is, the content of the C powder in the material powder is maintained in the aforementioned sintered member **1**. As described above, the content of the C powder is, for example, preferably not less than 0.2 mass % and not larger than 1.0 mass %, more preferably not less than 0.3 mass % and not larger than 0.95 mass %, and particularly preferably not less than 0.4 mass % and not larger than 0.9 mass %.

(130) The average particle diameter of the C powder is preferably smaller than the average particle diameter of the iron-based alloy powder. The C powder smaller than the iron-based alloy powder is easy to be uniformly distributed in the iron-based alloy powder, which allows alloying to be easily advanced. The average particle diameter of the C powder is, for example, not smaller than 1 μm and not larger than 30 μm, and, furthermore, not smaller than 10 μm and not larger than 25 μm.

From the viewpoint of generating an Fe—C liquid phase, the average particle diameter of the C powder is preferred to be larger. However, if the average particle diameter of the C powder is excessively large, the time during which the liquid phase appears is increased, which may cause the voids to be excessively increased in size and become defects.

(131) (Others)

(132) The material powder may contain a lubricant. The lubricant increases lubricity of the material powder during molding, and improves moldability. Examples of the lubricant include higher fatty acid, metallic soap, fatty acid amide, higher fatty acid amide, and the like. As these lubricants, known lubricants can be used. The lubricant may exist in any form such as solid, powder, and liquid. Any of the above lubricants may be used alone or at least two of them may be used in combination. When the material powder is 100 mass %, the content of the lubricant in the material powder is, for example, not less than 0.1 mass % and not larger than 2.0 mass %, furthermore, not less than 0.3 mass % and not larger than 1.5 mass %, and, particularly, not less than 0.5 mass % and not larger than 1.0 mass %.

(133) The material powder may contain an organic binder. Any of known organic binders can be used. When the material powder is 100 mass %, the content of the organic binder is not larger than 0.1 mass %. The content of the organic binder being not larger than 0.1 mass % allows the ratio of the metal powder contained in the powder compacted body to be increased, whereby dense powder compacted body is easily obtained. When the material powder contains no organic binder, the powder compacted body need not be degreased in a subsequent process.

(134) [Sintering Process]

(135) The sintering conditions are as described above. The cooling rate at the cooling step in the sintering process may be not lower than 1° C./sec, as described above. The cooling rate being not lower than 1° C./sec allows the sintered member **1** to be rapidly cooled. Therefore, a multiphase structure including a martensitic phase and a retained austenite phase is easily formed. Thus, the sintered member **1** excellent in hardness and toughness is manufactured. In particular, when the content of C is larger, the martensitic phase is more easily formed, which allows the sintered member **1** having higher hardness to be manufactured. When the content of the Ni powder is larger, the retained austenite phase is more easily formed, which allows the sintered member **1** having higher toughness to be easily manufactured. Moreover, rapid cooling of the sintered member **1** allows the sintered member **1** having a small variation width of Vickers hardness from the surface to the predetermined depth to be easily manufactured. Specifically, the sintered member **1** whose variation width of Vickers hardness is not larger than 50 HV is manufactured. The preferable cooling rate is as described above.

Advantageous Effects

(136) The sintered member **1** of the present embodiment can have both high hardness and high toughness, in addition to the effects of Embodiment 1. The reasons are as follows. That is, the sintered member **1** is excellent in toughness because the content of Ni is large, and can inhibit reduction in hardness because the content of Ni is not excessively large. Furthermore, the sintered member **1** has the multiphase structure including the martensitic phase having high hardness and the retained austenite phase having high toughness. Moreover, the sintered member **1** has uniform hardness from the surface to the predetermined depth. The sintered member **1** has the small variation width of the Vickers hardness. Consequently, the sintered member **1** of the present embodiment can be suitably used as the first cam **110** (FIG. **6**) included in the electromagnetic coupling **10**.

Example of Analysis

(137) In an example of analysis, how the magnitude of maximum stress acting on spline teeth varies depending on presence/absence of a tooth-missing part, was checked through FEM (Finite Element Method) analysis.

(138) [Analysis Model No. 1]

(139) A first member of Analysis Model No. 1 was composed of the sintered member **1** having been described with reference to FIG. **1** through FIG. **5**. That is, the first member of this model includes: a plurality of tooth groups and a plurality of tooth-missing parts formed at an inner peripheral face connected to a first face; and a plurality of ball grooves formed at a second face. As for the plurality of tooth groups, the plurality of tooth-missing parts, and the plurality of ball grooves of the first member, the plurality of tooth groups **16**, the plurality of tooth-missing parts **17**, and the plurality of ball grooves **12***a* shown in FIG. **1** through FIG. **5** may be referred to as appropriate. The number of the tooth groups was 3, and the number of spline teeth in each tooth group was 8. The number of the tooth-missing parts was 3 which was the same as the number of the tooth groups. In each tooth-missing part, the number of missing spline teeth was 2. The number of the ball grooves was 3.

(140) [Analysis Model No. 101]

(141) A first member of Analysis Model No. 101 was identical to the first member of Analysis Model No. 1 except that it does not include tooth-missing parts at the inner peripheral face connected to the first face but includes a plurality of spline teeth disposed in parallel in the circumferential direction of the peripheral face. The number of the spline teeth was 30. The number of the ball grooves was 3.

(142) [Stress Analysis]

(143) The maximum stress acting on the spline teeth in each of the first members of the respective analysis models was checked as follows. A second member **220**, a ball **230**, a first jig **310**, and a second jig **320** shown in FIG. **10** were prepared. FIG. **10** is a cross-sectional view showing the respective components being cut at the same position as in the cross-sectional view shown in FIG. **5**. The second member **220** was composed of the second cam **120** described with reference to FIG. **6**. That is, the second member **220** had a ball groove **121** in which a ball **230** is disposed. As shown in FIG. **10**, the ball **230** was interposed between the ball groove **12***a* of the first member **210** and the ball groove **121** of the second member **220** in each analysis model. The ball **230** was placed in the ball groove **12***a* of the first member **210** at a position slightly shifted from the deepest part of the ball groove **12***a*, and was fixed to the part. The first jig **310** was disposed on the outer peripheral edge side of the first face **11** of the first member **210**. The second jig **320** was disposed on the outer peripheral edge side, opposing the ball **230**, of the surface on the side opposite to the ball groove **121** of the second member **220**. The first member **210** and the second member **220** were pressed in the axial direction of the first member **210** by the first jig **310** and the second jig **320**. At this time, the maximum stress acting on the spline teeth of the first member **210** was checked through FEM analysis. For the FEM analysis, Workbench Mechanical (manufactured by ANSYS, Inc) was used as software.

(144) In the first member of Analysis Model No. 1, the maximum stress acted on the roots of the spline teeth. The maximum stress value was 281 MPa. Meanwhile, in the first member of Analysis Model No. 101, as in Analysis Model No. 1, the maximum stress acted on the roots of the spline teeth at the parts in the circumferential direction which overlapped the ranges in which the ball grooves were formed. The maximum stress value was 366 MPa. Thus, in the first member of Analysis Model No. 1, the maximum stress value acting on the roots of the spline teeth was about 16% reduced as compared to the first member of Analysis Model No. 101. Thus, it is found that the tooth-missing parts being disposed at the parts in the circumferential direction which overlapped the ranges in which the ball grooves were formed, can reduce stress concentration on the roots of the spline teeth.

Example of Test

(145) In an example of test, sintered members were subjected to evaluation for hardness and toughness.

(146) [Sample No. 1, Sample No. 2]

(147) Sintered members of Sample No. 1 and Sample No. 2 were manufactured through a process

of preparing a material powder, a process of manufacturing a powder compacted body, and a process of sintering the powder compacted body.

(148) [Preparation Process]

(149) Mixed powder containing iron-based alloy powder, Ni powder, and C powder was prepared as material powder.

(150) The iron-based alloy powder contains a plurality of iron alloy particles composed of Cr and Mo, and the balance of Fe and inevitable impurities. The content of Cr and the content of Mo in the iron-based alloy are shown in Table 1. That is, the content of Cr in the iron-based alloy is 3.0 mass %, and the content of Mo in the iron-based alloy is 0.5 mass %. Table 1, "-" indicates that the iron-based alloy does not contain the corresponding element.

(151) The content of the Ni powder and the content of the C powder in the material powder are shown in Table 1. In Sample No. 1, the content of the Ni powder is 3 mass %, the content of the C powder is 0.65 mass %, and the content of Fe powder is the balance. In Sample No. 2, the content of the Ni powder is 4 mass %, the content of the C powder is 0.75 mass %, and the content of Fe powder is the balance.

(152) [Powder Compacted Body Manufacturing Process]

(153) Powder compacted bodies were manufactured through pressure molding of the material powder. The molding pressure was 700 MPa.

(154) [Sintering Process]

(155) The powder compacted bodies were sintered to manufacture sintered members. For sintering of the powder compacted bodies, a continuous sintering furnace having a sintering furnace and a rapid cooling chamber connected downstream of the sintering furnace, was used. As for the sintering conditions, the sintering temperature was 1300° C., and the sintering time was 15 minutes.

(156) (Cooling Step)

(157) At a cooling step in the sintering process, sinter hardening was performed to rapidly cool the sintered members. Specifically, the cooling rate was 3° C./sec until the atmospheric temperature reached 300° C. from the start of cooling. This cooling was performed by spraying nitrogen gas as cooling gas to the sintered members.

(158) [Sample No. 101, Sample No. 102]

(159) Sintered members of Sample No. 101 and Sample No. 102 were manufactured in the same manner as that for the sintered member of Sample No. 1 except that the content of the Ni powder and the content of the C powder in the prepared material powder were different from those of Sample No. 1. Specifically, in Sample No. 101, the content of the Ni powder in the material powder was 1 mass %, and the content of the C powder in the material powder was 0.7 mass %. In Sample No. 102, the content of the Ni powder in the material powder was 2 mass %, and the content of the C powder in the material powder was 0.7 mass %.

(160) [Sample No. 110]

(161) A sintered member of Sample No. 110 was manufactured in the same manner as that for Sample No. 2 except for the following points (a) to (e). (a) The composition of the prepared iron-based alloy powder did not contain Cr but contained Ni and Cu. (b) The material powder did not contain Ni powder. (c) The content of the C powder in the material powder was different from that of Sample No. 2. (d) Not rapid cooling but slow cooling was performed in the cooling step in the sintering process. (e) After the sintering process, quenching and tempering were performed.

(162) The iron-based alloy powder contains a plurality of iron alloy particles composed of Cu, Mo, and Ni, and the balance of Fe and inevitable impurities. The content of Cu in the iron-based alloy is 1.5 mass %, and the content of Mo in the iron-based alloy is 0.5 mass %. The content of Ni in the iron-based alloy is 4 mass %. In Sample No. 110, the content of the C powder in the material powder is 0.5 mass %, and the content of Fe powder is the balance.

(163) At the cooling step in the sintering process, the sintered member was cooled not rapidly but

slowly. The cooling rate was about 0.5° C./sec.
(164) [Measurement of Apparent Density]
(165) An apparent density (g/cm.sup.3) of the sintered member of each sample was measured by the Archimedes method. The apparent density was obtained by "(dry weight of sintered member)/{(dry weight of sintered member)—(underwater weight of oil-immersed sintered member)}×density of water". The underwater weight of the oil-immersed sintered member is the weight of the sintered member that has been immersed and impregnated in oil and then immersed in water. N (number of samples) was 3. An average of measurement results of three sintered members (samples) was obtained as the apparent density of the sintered member corresponding to each Sample No. The results are shown in Table 1.
(166) [Evaluation of Hardness]
(167) The hardness of each sintered member was evaluated by obtaining Vickers hardness of the sintered member, and the variation width of the Vickers hardness from the surface of the sintered member to the predetermined depth.
(168) The Vickers hardness was measured on the basis of JIS Z 2244 (2009). A test piece was cut out from each sintered member. The shape of the test piece was rectangle. The size of the test piece was 55 mm×10 mmx 10 mm (thickness). The test piece was cut out such that one face in the thickness direction of the test piece was the surface of the sintered member.
(169) Vickers hardness was measured at 11 points in a range from the surface of the test piece to the predetermined depth at the cross section of the test piece. The surface of the test piece was the aforementioned one face in the thickness direction of the test piece. The predetermined depth was 5.0 mm along a direction orthogonal to the surface of the test piece. The measurement points were: a point 0.1 mm apart from the surface; and ten points spaced apart from each other at a pitch of 0.5 mm from the surface. N (number of samples) was 3.
(170) An average of the Vickers hardnesses measured at all the measurement points in three test pieces was obtained as the Vickers hardness of the corresponding sintered member. A difference between the maximum value and the minimum value of the averages of the Vickers hardnesses at the respective measurement points of the three test pieces was obtained as the variation width of the Vickers hardness of the corresponding sintered member. The results are shown in Table 1.
(171) Regarding the sintered members of Sample No. 2, Sample No. 101, and Sample No. 110 as representatives, the averages of the Vickers hardnesses at the respective measurement points in the three test pieces are shown by circles, crosses, and black rhombuses in FIG. **7**. In the graph shown in FIG. **7**, the horizontal axis indicates depth (mm) from the surface, and the vertical axis indicates Vickers hardness (HV).
(172) [Evaluation of Toughness]
(173) The toughness of each sintered member was evaluated by measuring the stress amplitude through an Ono-type rotating bending fatigue test.
(174) The Ono-type rotating bending fatigue test was performed on the basis of JIS Z 2274 (1978) by using FTO-100 manufactured by TOKYO KOKI TESTING MACHINE CO. LTD., as a testing machine. A test piece was cut out from each sintered member. The test piece conforms to No. 1 test piece specified in JIS Z 2274 (1978). Specifically, the test piece has a dumbbell-like shape. This test piece has a pair of large-diameter parts and a small-diameter part. The large-diameter parts are disposed at opposed ends in the axial direction of the test piece. Each large-diameter part has a cylindrical shape. The diameter of each large-diameter part is uniform in the axial direction of the large-diameter part. The small-diameter part is disposed between the opposed large-diameter parts. The large-diameter parts and the small-diameter part are continuous with each other. The small-diameter part has a cylindrical shape. The small-diameter part has a parallel part and a pair of curved parts. The parallel part is a uniform-diameter part disposed at the center in the axial direction of the small-diameter part, along the axial direction. Each curved part connects the parallel part with each large-diameter part, and has a diameter gradually increasing from the

parallel part side toward the large-diameter part side. The length in the axial direction of the test piece was 90.18 mm. The length in the axial direction of each large-diameter part was 27.5 mm, and the length in the axial direction of the small-diameter part was 35.18 mm. The diameter of each large-diameter part was 12 mm. The diameter of the parallel part was 8 mm. The length of the parallel part was 16 mm.
(175) As for measurement conditions, the number of revolutions was 3400 rpm. The maximum stress amplitude at which the test piece was not broken after 10.sup.7 times of repetition of bending, was measured. N (number of samples) was 3. An average of stress amplitudes measured for three test pieces was obtained as the stress amplitude of the sintered member. The results are shown in Table 1.
(176) [Observation of Cross Section]
(177) The cross sections of the sintered members of Sample No. 1, Sample No. 2, Sample No. 101, and Sample No. 102 were observed.
(178) The cross section of each sintered member was an arbitrary cross section. The cross section was exposed as follows. That is, a test pieces obtained by cutting a part of the sintered member was embedded in an epoxy resin to manufacture a resin molded body. The resin molded body was subjected to polishing. The polishing was performed in two steps. In the first polishing step, the resin of the resin molded body was polished until the cross section of the sintered member was exposed. In the second polishing step, the exposed cross section was polished. Mirror polishing was adopted. That is, the cross section observed was a mirror-polished surface.
(179) An optical microscope (GX51) manufactured by Olympus Corporation was used for observation of the cross section. FIG. **8**A and FIG. **8**B, FIG. **9**A and FIG. **9**B, FIG. **11**, and FIG. **12** show micrographs at the cross sections of the sintered members of Sample No. 1, Sample No. 2, Sample No. 101, and Sample No. 102, respectively. Each of the micrographs shown in FIG. **8**A, FIG. **9**A, FIG. **11**, and FIG. **12** has a size of about 2.82 mm×2.09 mm. Each of the micrographs shown in FIG. **8**B and FIG. **9**B has a size of about 1.38 mm×1.02 mm.
(180) From the micrographs, presence/absence of the retained austenite phase in the four samples was confirmed. In the micrographs, the retained austenite phase is indicated by arrows, for convenience of description. A white part indicated ahead of each arrow is the retained austenite phase. A part surrounding each white part is the martensitic phase. Since no retained austenite phase is seen in FIG. **11**, no arrows are appended.
(181) The area ratio of the retained austenite phase in each of the five samples was obtained. Here, a portable X-ray residual stress measurement device (μ-X360) manufactured by Pulstec Industrial Co., Ltd. was used, and the ratio of the total area of the retained austenite phase to the whole area of a measurement field was obtained. The number of measurement fields was 2. The size of each measurement field was 2 mm in diameter. An average of the ratios of the total areas of the retained austenite phase at the respective measurement fields was obtained as the area ratio of the retained austenite phase. The result is shown in Table 1.
(182) TABLE-US-00001 TABLE 1 Sintered member Material powder Retained Vickers hardness austenite Iron-based alloy powder Ni C Variation Stress phase Sample Cr Cu Mo Ni powder powder Density Average width amplitude Area ratio No. mass % mass % mass % mass % mass % mass % g/cm.sup.3 HV HV Mpa % 1 3.0 — 0.5 — 3 0.65 7.20 643 42 422 21 2 3.0 — 0.5 — 4 0.75 7.23 636 36 428 25 101 3.0 — 0.5 — 1 0.7 7.15 604 63 378 14 102 3.0 — 0.5 — 2 0.7 7.10 650 48 415 16 110 — 1.5 0.5 4 — 0.5 7.21 608 106 398 43
(183) As shown in Table 1, the sintered members of Sample No. 1 and Sample No. 2 are higher in the Vickers hardness, smaller in the variation width of the Vickers hardness, and larger in the stress amplitude than the sintered members of Sample No. 101, Sample No. 102, and Sample No. 110.
(184) As shown in FIG. **8**A, FIG. **8**B, FIG. **9**A, and FIG. **9**B, it was found that the sintered members of Sample No. 1 and Sample No. 2 each had the multiphase structure including the martensitic phase and the retained austenite phase. Meanwhile, as shown in FIG. **11** and FIG. **12**, it

was found that the sintered members of Sample No. 101 and Sample No. 102 each included little or no retained austenite phase, and were substantially composed of the martensitic phase. The area ratios of the retained austenite phase in the sintered members of Sample No. 1 and Sample No. 2 were higher than those in the sintered members of Sample No. 101 and Sample No. 102.
(185) The present disclosure is not limited to these examples, and is defined by the scope of the claims and intended to include meaning equivalent to the scope of the claims and all modifications within the scope.
REFERENCE SIGNS LIST
(186) **1** sintered member **11** first face **12** second face **12***a* ball groove **13** third face **15** peripheral face **16** tooth group **16***a* spline teeth **17** tooth-missing part **19** hole Cp pitch circle Cr root circle Ta tooth thickness Wa width of tooth groove La length of tooth group Lb length of tooth-missing part Lc length of ball groove **10** electromagnetic coupling **110** first cam **120** second cam **121** ball groove **130** ball **210** first member **220** second member **230** ball **310** first jig **320** second jig

Claims

1. A sintered member having an annular shape, comprising: a first face facing one side in an axial direction; a second face facing the other side in the axial direction; an inner peripheral face connected to an inner peripheral edge of the first face; and a plurality of tooth groups and a plurality of tooth-missing parts which are alternately disposed along a circumferential direction of the inner peripheral face, wherein the second face includes a plurality of ball grooves arranged in parallel in the circumferential direction, each tooth group includes a plurality of spline teeth that are continuous in the circumferential direction of the peripheral face, the number of the plurality of tooth-missing parts is the same as the number of the plurality of ball grooves, positions in a radial direction in which the plurality of tooth-missing parts are formed are within ranges in the radial direction in which the plurality of ball grooves are formed, and ranges in the circumferential direction in which the plurality of tooth-missing parts are formed overlap ranges in the circumferential direction in which the plurality of ball grooves are formed.
2. The sintered member according to claim 1, wherein a variation width of Vickers hardness up to a depth of 5.0 mm along a direction orthogonal to a surface of the sintered member is not larger than 100 HV.
3. The sintered member according to claim 2, having a composition containing Ni, Cr, Mo, and C, and a balance of Fe and inevitable impurities, wherein under a condition a total content of elements contained in the sintered member is 100 mass %, a content of Ni in the sintered member is larger than 2 mass % and not larger than 6 mass %.
4. The sintered member according to claim 3, wherein a content of Cr is not less than 2 mass % and not larger than 4 mass %, a content of Mo is not less than 0.2 mass % and not larger than 0.9 mass %, and a content of C is not less than 0.2 mass % and not larger than 1.0 mass %.
5. The sintered member according to claim 4, having a multiphase structure including a martensitic phase and a retained austenite phase, wherein an area ratio of the retained austenite phase at an arbitrary cross section of the sintered member is not lower than 5%.
6. The sintered member according to claim 3, having a multiphase structure including a martensitic phase and a retained austenite phase, wherein an area ratio of the retained austenite phase at an arbitrary cross section of the sintered member is not lower than 5%.
7. An electromagnetic coupling comprising: a first cam; a second cam; and a ball interposed between the first cam and the second cam, wherein the first cam being a sintered member having an annular shape, the sintered member including a first face facing one side in an axial direction, a second face facing the other side in the axial direction, an inner peripheral face connected to an inner peripheral edge of the first face, and a plurality of tooth groups and a plurality of tooth-missing parts which are alternately disposed along a circumferential direction of the inner

peripheral face, wherein the second face includes a plurality of ball grooves arranged in parallel in the circumferential direction, each tooth group includes a plurality of spline teeth that are continuous in the circumferential direction of the peripheral face, the number of the plurality of tooth-missing parts is the same as the number of the plurality of ball grooves, positions in a radial direction in which the plurality of tooth-missing parts are formed are within ranges in the radial direction in which the plurality of ball grooves are formed, and ranges in the circumferential direction in which the plurality of tooth-missing parts are formed overlap ranges in the circumferential direction in which the plurality of ball grooves are formed.

8. The electromagnetic coupling according to claim 7, wherein a variation width of Vickers hardness up to a depth of 5.0 mm along a direction orthogonal to a surface of the sintered member is not larger than 100 HV.

9. The electromagnetic coupling according to claim 8, wherein the sintered member has a composition containing Ni, Cr, Mo, and C, and a balance of Fe and inevitable impurities, wherein under a condition a total content of elements contained in the sintered member is 100 mass %, a content of Ni in the sintered member is larger than 2 mass % and not larger than 6 mass %.

10. The electromagnetic coupling according to claim 9, wherein the sintered member has a content of Cr is not less than 2 mass % and not larger than 4 mass %, a content of Mo is not less than 0.2 mass % and not larger than 0.9 mass %, and a content of C is not less than 0.2 mass % and not larger than 1.0 mass %.

11. The electromagnetic coupling according to claim 10, wherein the sintered member has a multiphase structure including a martensitic phase and a retained austenite phase, and an area ratio of the retained austenite phase at an arbitrary cross section of the sintered member is not lower than 5%.

12. The electromagnetic coupling according to claim 9, wherein the sintered member has a multiphase structure including a martensitic phase and a retained austenite phase, and an area ratio of the retained austenite phase at an arbitrary cross section of the sintered member is not lower than 5%.