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(54) STEEL FOR HOT STAMP DIE, HOT STAMP DIE AND MANUFACTURING METHOD THEREOF

(57) A die steel which enables manufacturing a hot stamp die that has both high hardness and high thermal conductivity, a hot stamp die, and a manufacturing method thereof are provided. This steel for a hot stamp die has a component composition, in mass% of 0.45-0.65% C, 0.1-0.6% Si, 0.1-0.3% Mn, 2.5-6.0% Cr, 1.2-2.6% Mo, and 0.4-0.8% V, the remainder being Fe and unavoidable impurities. Further, this hot stamp die has the aforementioned component composition, and the manufacturing method is for manufacturing said hot stamp die.

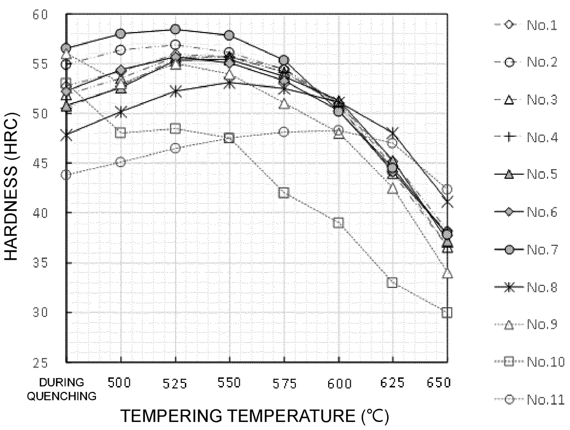

FIG. 1

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Description

[Technical Field]

[0001] The present invention relates to a steel for a hot stamp die, a hot stamp die and a manufacturing method thereof.

[Background Art]

[0002] In recent years, there has been an increasing need for ultra-high tension steel sheets having a tensile strength of more than 1 GPa in order to reduce the weight of automobiles and improve collision safety. However, when a steel sheet having a tensile strength of 1.2 GPa or more is molded by cold pressing, problems such as an increase in molding load and spring back and problems with moldability occur. Therefore, in recent years, a hot stamp (also called hot press or hot stamping) method has been focused on. In the hot stamp method, the steel sheet is heated to an austenite temperature or higher, and then pressed and molded, the die is held at the bottom dead point, and the steel sheet is rapidly cooled and quenched.

[0003] An advantage of the hot stamp method is that, for example, by quenching according to die quenching, which is rapid cooling in a die, a molded article of an ultra-high tension steel sheet having a tensile strength of about 1.5 GPa is obtained. In addition, another advantage is that it has excellent moldability and spring back hardly occurs.

[0004] However, the hot stamp method has a problem such as low productivity. That is, the productivity is lowered because it takes time to hold the bottom dead point for die quenching. As a countermeasure therefore, a die with high thermal conductivity is required. This is because, in die quenching, heat of the steel sheet is absorbed by the die, but the time for holding the bottom dead point becomes shorter as the thermal conductivity of the die increases, and the productivity improves.

[0005] In addition, hot stamp dies are required to have high hardness in order to improve the wear resistance.

[0006] Therefore, a steel for a hot stamp die is required to have both high hardness and high thermal conductivity when made into a die. Generally, in order to obtain a die having high hardness, it is necessary to increase a content of alloying elements of a die steel, but there is a problem that thermal conductivity of the die decreases as the content of alloying elements increases, and there is a trade-off relationship between the hardness and the thermal conductivity. Therefore, an optimal component composition obtained by controlling the content of alloying elements is being investigated. For example, Patent Literature 1 to 3 propose a component composition of a die steel having both hardness and thermal conductivity. In addition, Patent Literature 4 also discloses hot work tool steel having excellent thermal conductivity and excellent wear resistance, which is useful as a material for a die used in hot pressing, die-casting, warm and hot forging, or the like.

[Citation List]

[Patent Literature]

[0007]

[Patent Literature 1]
Japanese Patent Laid-Open No. 2017-43814
[Patent Literature 2]
Japanese Patent Laid-Open No. 2017-53023
[Patent Literature 3]
Japanese Patent Laid-Open No. 2018-24931
[Patent Literature 4]
Japanese Patent No. 5744300

[Summary of Invention]

[Technical Problem]

[0008] The die steels of Patent Literature 1 to 3 and the hot work tool steel of Patent Literature 4 are useful for hot stamping. However, in consideration of quenching and tempering characteristics of the die steel and the hot work tool steel, and the fact that a working surface of the hot stamp die is used after being subjected to a nitriding treatment, the hardness may be insufficient in the case of a conventional die steel and hot work tool steel. Specifically, in recent years, there has been a demand for a steel for hot stamping having a high hardness of 52 HRC or more, but a high hardness of 52 HRC or more is not stably obtained in Patent Literature 1 to 4.

[0009] An objective of the present invention is to provide a die steel, a hot stamp die and a manufacturing method thereof through which it is possible to manufacture a die having both high hardness and high thermal conductivity suitable for a hot stamp method.

[Solution to Problem]

[0010] In view of such circumstances, the inventors conducted extensive studies, and as a result, found an optimal die steel for hot stamping by controlling a content of alloying elements. Also, they found a hot stamp die that can achieve both high hardness and high thermal conductivity using the die steel and a manufacturing method thereof.

[0011] That is, an aspect of the present invention is a steel for a hot stamp die having a component composition including, in mass%, C: 0.45 to 0.65%, Si: 0.1 to 0.6%, Mn: 0.1 to 0.3%, Cr: 2.5 to 6.0%, Mo: 1.2 to 2.6%, V: 0.4 to 0.8%, the remainder being Fe and unavoidable impurities.

[0012] Another aspect of the present invention is a hot stamp die having a component composition including, in mass%, C: 0.45 to 0.65%, Si: 0.1 to 0.6%, Mn: 0.1 to 0.3%, Cr: 2.5 to 6.0%, Mo: 1.2 to 2.6%, V: 0.4 to 0.8%, the remainder being Fe and unavoidable impurities.

[0013] Preferably, in the hot stamp die according to claim 2, the hardness is 45 HRC or more, and the thermal conductivity λ (W/(m·K)) satisfies the following Formula (1):

$$\lambda \geq -0.5H+53 \quad \ldots \text{Formula (1)}$$

H: Rockwell hardness (HRC) of die

[0014] More preferably, the hardness is 52 HRC or more. Here, in this case, more preferably, the thermal conductivity λ is 25 W/(m·K) or more.

[0015] In addition, preferably, a working surface has a nitrided layer.

[0016] Still another aspect of the present invention is a method of manufacturing a hot stamp die including quenching and tempering the steel for a hot stamp die at a quenching temperature of 1,020 to 1,080°C and a tempering temperature of 500 to 625°C.

[0017] Preferably, the tempering temperature is 540 to 600°C.

[0018] Preferably, after the quenching and tempering are performed, a working surface is additionally subjected to a nitriding treatment.

[Advantageous Effects of Invention]

[0019] According to the present invention, an optimal die steel for hot stamping is obtained. In addition, it is possible to provide a hot stamp die having both high hardness and high thermal conductivity using this die steel, and a manufacturing method thereof.

[Brief Description of Drawings]

[0020]

Fig. 1 is a graph figure showing the hardness of examples of dies manufactured by quenching die steels of examples of the present invention and comparative examples at 1,030°C and then tempering them at 500 to 650°C for each tempering temperature.

Fig. 2 is a graph figure showing the thermal conductivity of examples of dies manufactured by quenching die steels of examples of the present invention and comparative examples at 1,030°C and then tempering them at a hardness of 45 HRC, 50 HRC, and 55 HRC.

Fig. 3 is a graph figure showing the softening resistance of examples of dies manufactured by quenching die steels of examples of the present invention and comparative examples at 1,030°C and then tempering them at a hardness of 55 HRC when they were kept at 600°C.

[Description of Embodiments]

[0021] A feature of the present invention is that, when considering manufacturing a hot stamp die by quenching and tempering a die steel and by performing a nitriding treatment on its working surface, it is found that there is an optimal component composition of a die steel for achieving both high hardness and high thermal conductivity of a hot stamp die.

In particular, it has been found that there is an optimal component composition of a die steel to achieve both a high hardness of 52 HRC or more and a high thermal conductivity of 25 W/(m·K) or more. In addition, optimal quenching and tempering conditions for achieving both high hardness and high thermal conductivity have been found. Hereinafter, constituent elements of the present invention will be described.

[0022] A steel for a hot stamp die of the present invention has a component composition including, in mass% (hereinafter simply referred to as "%"), C: 0.45 to 0.65%, Si: 0.1 to 0.6%, Mn: 0.1 to 0.3%, Cr: 2.5 to 6.0%, Mo: 1.2 to 2.6%, V: 0.4 to 0.8%, the remainder being Fe and unavoidable impurities.

•C: 0.45 to 0.65%

[0023] C is an element that is solid-solutionized in a base (matrix) by quenching and improves the hardness of the die. In addition, it is an element that forms a carbide with a carbide forming element such as Cr, Mo, and V to be described below and improves the hardness of the die. However, when the content of C is too large, the toughness of the die decreases due to coarsening of the primary carbide or the like. Therefore, the content of C is, 0.45 to 0.65%, preferably 0.47% or more, and more preferably 0.49% or more. In addition, the content of C is preferably 0.63% or less, more preferably 0.60% or less, and still more preferably 0.58% or less.

•Si: 0.1 to 0.6%

[0024] Si is used as a deoxidizing agent in the melting process. In addition, it is an element that is solid-solutionized in a base and improves the hardness of the die. However, when the content of Si is too large, the segregation tendency becomes stronger in the steel after melting, and the solidified structure becomes coarse, which leads to a decrease in the toughness of the die. In addition, it is an element that significantly lowers the thermal conductivity of the die after quenching and tempering. Therefore, the content of Si is 0.1 to 0.6%, preferably 0.14% or more, and more preferably 0.17% or more. In addition, the content of Si is preferably 0.45% or less, more preferably 0.4% or less, still more preferably 0.35% or less, and yet more preferably 0.3% or less.

•Mn: 0.1 to 0.3%

[0025] Mn is used as a deoxidizing agent or a desulfurizing agent in the melting process. In addition, it is an element that contributes to strengthening the base and improving quenching properties, and toughness after quenching and tempering. However, when the content of Mn is too large, the thermal conductivity of the die significantly decreases. Therefore, the content of Mn is 0.1 to 0.3%. The lower limit of Mn is preferably 0.15% or more. In addition, the upper limit of Mn is preferably 0.28% or less. The upper limit of Mn is more preferably 0.26% or less.

•Cr: 2.5 to 6.0%

[0026] Cr is an element that is solid-solutionized in a base and increases the hardness. In addition, it is an element that increases the hardness by forming a carbide, and is an element that contributes to secondary hardening during tempering like Mo and V to be described below. In particular, Cr is an element that can increase the tempering softening resistance (even if the tempering temperature is raised, the rate of decrease in hardness obtained by secondary hardening can be reduced) as compared with Mo and V. Generally, the die is adjusted to have a working hardness by quenching and tempering the die steel, and thus it is effective to increase the tempering temperature in order to improve the thermal conductivity of the hot stamp die. Here, in the present invention, when the content of Cr is 2.5% or more, even if the tempering temperature is raised (for example, even if it exceeds 600°C), since a sufficient hardness such as 45 HRC or more can be maintained, the thermal conductivity can be increased at the same time. Here, even if the tempering temperature is, for example, 540°C or higher, it is possible to achieve a hardness of 52 HRC or more and a hot stamp die having a thermal conductivity of 25 W/(m·K) or more can be obtained. Thus, it is possible to obtain a hot stamp die in which the thermal conductivity is further improved to 28 W/(m·K) or more or 30 W/(m·K) or more while maintaining the above hardness. Here, the hardness and the thermal conductivity are values measured at room temperature (normal temperature).

[0027] In addition, since nitriding characteristics of the die steel can be improved by increasing the content of Cr, for example, the working surface of the die after quenching and tempering is additionally subjected to a nitriding treatment, and thus it is possible to improve the wear resistance of the die (the hardness of the working surface).

[0028] However, when the content of Cr is too large, a larger content of alloying elements of the die steel itself makes it difficult to increase the thermal conductivity of the die. Therefore, the content of Cr is 2.5 to 6.0%, and preferably 2.8% or more, and more preferably 3.0% or more. In addition, the content of Cr is preferably 5.5% or less, more preferably 4.8% or less, and still more preferably less than 4.5%. Here, when it is particularly important to improve the thermal conductivity, the content of Cr can be 4.0% or less, or 3.5 or less.

•Mo: 1.2 to 2.6%

[0029] Mo is an element that is solid-solutionized in a base and increases the hardness, is an element that increases the hardness by forming a carbide, and is an element that contributes to secondary hardening during tempering like Cr. In addition, it is an element that improves quenching properties. However, when the content of Mo is too large, a larger content of alloying elements of the die steel itself lowers the thermal conductivity of the die. Therefore, the content of Mo is 1.2 to 2.6%, preferably 1.5% or more, more preferably 1.7% or more, and still more preferably 1.9% or more. In addition, the content of Mo is preferably 2.5% or less, more preferably 2.3% or less, and still more preferably 2.1% or less.

•V: 0.4 to 0.8%

[0030] V is an element that increases the hardness by forming a carbide, and is an element that contributes to secondary hardening during tempering like Cr. However, when the content of V is too large, a larger content of alloying elements of the die steel itself lowers the thermal conductivity of the die. Therefore, the content of V is 0.4 to 0.8% and preferably 0.5% or more. In addition, the content of V is preferably 0.75% or less, more preferably 0.65% or less, and still more preferably 0.6% or less.

• The remainder being Fe and unavoidable impurities

[0031] In consideration of the fact that the thermal conductivity of the die decreases when the content of alloying elements of the die steel is large, it is preferable that the remainder other than the above elemental species be substantially Fe. However, elemental species not specified here (for example, elemental species such as P, S, Cu, Al, Ca, Mg, O (oxygen), and N (nitrogen)) are elements that may unavoidably remain in steel, and it is allowable to include these elements as impurities. In this case, when the content of P is too large, it segregates at the former austenite grain boundary during a heat treatment such as tempering, and the toughness of the die deteriorates. Therefore, the content of P is preferably restricted to 0.05% or less, more preferably restricted to 0.03% or less. Here, when the content of S is too large, hot processability deteriorates when a steel ingot is divided. Therefore, the content of S is preferably restricted to 0.01% or less, and more preferably restricted to 0.008% or less.

[0032] In addition, Ni is useful as an elemental species that contributes to improving the toughness of the die, but its content is also preferably kept low in order to minimize a decrease in thermal conductivity of the die due to the increase of the content of alloying elements of the die steel. Therefore, 0.25% is preferably allowed as the upper limit restriction of the content of Ni.

[0033] When a die steel having the component composition is quenched and tempered, it is possible to obtain a hot stamp die of the present invention having excellent hardness and thermal conductivity. The hardness of the hot stamp die of the present invention is a value measured at room temperature (normal temperature), and it is easy to achieve a sufficient hardness, for example, 45 HRC or more. Thus, when the tempering temperature is adjusted, the hardness of the die can be preferably 52 HRC or more, and excellent wear resistance can be imparted to the die during use. The hardness of the die is more preferably 53 HRC or more, and still more preferably 55 HRC or more.

[0034] Here, in the present invention, it is not necessary to define the upper limit of the hardness of the die. However, in the case of a die steel having the above component composition, about 60 HRC from the peak hardness (a tempering temperature range of about 500 to 600°C) of the secondary hardening is realistic. Therefore, the upper limit of the hardness is preferably 58 HRC or less because it exceeds the peak hardness and the tempering temperature can be raised (that is, the thermal conductivity can be increased).

[0035] Therefore, when a die steel having the above component composition is quenched and tempered, the hardness of the die is adjusted to 45 HRC or more, and also a thermal conductivity λ (W/(m·K)) that satisfies the following Formula (1) is provided.

$$\lambda \geq -0.5H+53 \quad \ldots \text{Formula (1)}$$

[0036] Here, H in Formula (1) is a Rockwell hardness (HRC) of the die. For example, when the hardness of the die of the present embodiment is 45 HRC, the thermal conductivity is 30.5 W/(m·K) or more. In addition, when the hardness of the die is 52 HRC, the thermal conductivity is 27 W/(m·K) or more. Here, "$\lambda \geq -0.5H+54$" is preferable. Here, the thermal conductivity is a value measured at room temperature (normal temperature).

[0037] Since the die steel of the present invention satisfies the relationship of Formula (1) according to quenching and tempering, it is possible to maintain a thermal conductivity of 25 W/(m·K) or more even when the tempering hardness is in a high hardness range (for example, 52 HRC or more) in which a decrease in thermal conductivity has been a problem. When the hardness of the die is 52 HRC or more, a preferable thermal conductivity is 28 W/(m·K) or more. A more preferable thermal conductivity is 30 W/(m·K) or more. Therefore, if the tempering hardness is in a low hardness range (for example, less than 52 HRC), it is possible to achieve a thermal conductivity of 30 W/(m·K) or more, and if the tempering hardness is near 45 HRC, it is possible to achieve a thermal conductivity of 32 W/(m·K) or more. Accordingly, it is possible to maintain high thermal conductivity in the die used in the hot stamp method (for example, 100 to 400°C).

[0038] Such thermal conductivity can be easily achieved by increasing the tempering temperature in addition to the component composition of the die steel. For example, it is possible to adjust the thermal conductivity to 30 W/(m·K) or more by raising the tempering temperature to a temperature at which the peak hardness is obtained or higher.

[0039] In the case of the present invention, it is not necessary to specify the upper limit of the thermal conductivity of the die. However, in consideration of the fact that the hardness of the die decreases when the tempering temperature is raised (for example, adjusted to a temperature exceeding 600°C), since the thermal conductivity when the hardness of the die is less than 45 HRC exceeds 50 W/(m·K), about 50 W/(m·K) when the hardness is maintained at 45 HRC or more is realistic. The thermal conductivity is preferably 47 W/(m·K) or less, and more preferably 45 W/(m·K) or less. Therefore, when the die maintains a hardness of 52 HRC or more, an upper limit of the thermal conductivity of about 40 W/(m·K), preferably 38 W/(m·K) or less, and more preferably 35 W/(m·K) or less is realistic. Therefore, regarding the upper limit of the thermal conductivity, a relationship between the thermal conductivity λ (W/(m·K)) and the Rockwell hardness H (HRC) as shown in Formula (2) of about "$\lambda \leq -0.5H+70$" is realistic. "$\lambda \leq -0.5H+66$" is preferable, and "$\lambda \leq -0.5H+61$" is more preferable.

[0040] The hot stamp die of the present invention preferably has a nitrided layer on the working surface.

[0041] As described above, the hot stamp die of the present invention has both high hardness and high thermal conductivity. Therefore, when the working surface of the die further has a nitrided layer, the wear resistance (the hardness of the working surface) of the die can be further improved. Here, the working surface is a surface of the die in contact with the steel sheet in the hot stamp.

[0042] In the method of manufacturing a hot stamp die of the present invention, the die steel is quenched and tempered.

[0043] When the die steel having the above component composition is quenched and tempered, the quenching temperature varies depending on the target hardness and the like, but can be, for example, about 1,020 to 1,080°C, and is preferably 1,050°C or lower.

[0044] Therefore, when the die steel quenched at the quenching temperature is tempered, for example, at a tempering temperature of 500 to 625°C, it is possible to maintain a sufficient hardness such as 45 HRC or more. The quenching temperature and the tempering temperature in this case can be selected so that the hardness and the thermal conductivity of the die after quenching and tempering satisfy the above relationship of Formula (1).

[0045] Therefore, tempering at a high temperature is effective in maintaining sufficient hardness of the die and increasing the thermal conductivity of the die, and a hardness of 52 HRC or more can be achieved, for example, at a tempering temperature of 540°C or higher, and thus a die having a thermal conductivity of 25 W/(m·K) or more can be obtained. In this case, in order to maintain a hardness of 52 HRC or more, the upper limit of the tempering temperature is preferably about 600°C, more preferably 595°C or lower, and still more preferably 590°C or lower.

[0046] The die steel of the present invention is quenched and tempered to prepare a hot stamp die having a predetermined hardness. Therefore, during this period, the die steel is subjected to various types of machining such as cutting and drilling, and adjusted to the shape of the hot stamp die. The timing of this machining can be performed when the hardness before quenching and tempering is low (that is, an annealed state). Then, in this case, finishing may be performed after quenching and tempering. In addition, in some cases, in combination with the above finishing, the above machining may be performed in a pre-hardened state after quenching and tempering are performed.

[0047] In the method of manufacturing a hot stamp die of the present invention, preferably, the working surface of the die after the quenching and tempering are performed is additionally subjected to a nitriding treatment.

[0048] As described above, when the die steel having the above component composition is quenched and tempered, for example, it is possible to obtain a die having a hardness of 45 HRC or more and a thermal conductivity that satisfies Formula (1). Therefore, since the die steel having the above component composition has excellent nitriding characteristics, the working surface of the die after quenching and tempering are performed is additionally subjected to a nitriding treatment, and thus the wear resistance of the die (the hardness of the working surface) can be improved. In this case, for nitriding treatment conditions, various known nitriding treatments, for example, a gas nitriding treatment and a salt bath nitriding treatment, can be applied.

Example 1

[0049] A 10 kg steel ingot having the component composition shown in Table 1 was melted. Then, the steel ingot was heated at 1,160°C and extended-forged with a hammer, and then cooled, and the cooled steel material was annealed at 870°C, and thereby steels of examples Nos. 1 to 8 of the present invention and steels of comparative examples Nos.

9 to 11 were manufactured.

[Table 1]

(mass%)											
Die steel	C	Si	Mn	P	S	Cr	Mo	V	Ni*	Fe	Note
No. 1	0.52	0.20	0.30	0.005	0.001	4.36	2.38	0.57	-	Bal.	Example of the present invention
No. 2	0.57	0.20	0.30	0.005	0.001	4.44	2.37	0.56	-	Bal.	
No. 3	0.56	0.20	0.30	0.005	0.001	4.34	2.37	0.73	-	Bal.	
No. 4	0.54	0.20	0.30	0.005	0.001	4.37	2.37	0.73	-	Bal.	
No. 5	0.53	0.21	0.28	0.005	0.001	4.22	2.35	0.71	-	Bal.	
No. 6	0.53	0.20	0.25	0.005	0.001	4.47	1.97	0.57	-	Bal.	
No. 7	0.53	0.60	0.25	0.005	0.001	4.47	1.97	0.57	-	Bal.	
No. 8	0.53	0.20	0.25	0.005	0.001	3.20	1.97	0.57	-	Bal.	
No. 9	0.40	1.00	0.40	0.005	0.001	5.20	1.30	0.90	-	Bal.	Comparative example
No. 10	0.50	0.30	0.90	0.005	0.001	1.30	0.40	0.20	1.8	Bal.	
No. 11	0.53	0.20	0.25	0.005	0.001	2.00	1.97	0.57	-	Bal.	
*[-]: 0.25% or less											

<Evaluation of tempering hardness>

[0050] The die steels Nos. 1 to 11 were quenched at a quenching temperature of 1,030°C. In this case, for cooling conditions, assuming the cooling rate when the die steels of the steels of the present invention and comparative steels had a size of an actual hot stamp die, the half-cooling time was set to 40 minutes (half-cooling time is a time required for cooling from the quenching temperature to a temperature of (quenching temperature+room temperature)/2). Then, the quenched die steels were tempered at a tempering temperature of 500 to 650°C. Tempering was performed twice and each temperature was maintained for 2 hours. The tempering temperature was set to a total of 7 conditions in increments of 25°C. Then, for Nos. 1 to 11, at each tempering temperature, the Rockwell hardness (C scale) at room temperature in the center thereof was measured. The results are shown in Fig. 1.

[0051] The examples Nos. 1 to 8 of the present invention maintained a tempering hardness of 45 HRC or more over the entire tempering temperature range of 500 to 625°C. Here, in particular, all examples had about 52 HRC or more in the tempering temperature range of 540 to 600°C. In addition, even if the tempering temperature was raised to be higher than 600°C, which is said to be effective in improving the thermal conductivity of the die, a tempering hardness of about 45 HRC or more was achieved.

[0052] On the other hand, the comparative example No. 9 also maintained a tempering hardness of 45 HRC or more in a tempering temperature range of 500 to 600°C, but No. 10 already had a tempering hardness of less than 45 HRC when the tempering temperature was 575°C. No. 11 had a tempering hardness of 45 HRC or more in a tempering temperature range of 500 to 625°C, but a hardness of 50 HRC or more was not obtained.

<Evaluation of thermal conductivity>

[0053] Based on the results of the above <Evaluation of tempering hardness>, for Nos. 1 to 6, and 9, the thermal conductivities when the tempering hardness was 45 HRC, 50 HRC, and 55 HRC were measured. In the measurement procedure, first, a die was processed into a disc-shaped test piece with a diameter of 10 mm×a thickness of 2 mm, and the thermal diffusivity and specific heat of this test piece were measured by a laser flash method. Then, using the measured thermal diffusivity and specific heat values, the thermal conductivity at room temperature was calculated by the following Formula (3). The results are shown in Fig. 2.

$$\text{thermal conductivity } \lambda\ (\mathrm{W/(m\cdot K)}) = \rho\cdot\alpha\cdot C_p \quad \ldots\text{Formula (3)}$$

(ρ: room temperature density, α: thermal diffusivity, C_p: specific heat)

[0054] Based on the results of Fig. 2, it was found that, in the example Nos. 1 to 6 of the present invention, at all hardnesses of 45 HRC, 50 HRC, and 55 HRC, the thermal conductivity satisfied the formula $\lambda \geq -0.5H+53$, and even if the hardness was increased to 52 HRC, a high thermal conductivity such as 30 W/(m·K) or more was maintained. In addition, at a high hardness such as a hardness of 55 HRC, a high thermal conductivity of 25 W/(m·K) or more was obtained.

[0055] On the other hand, in the comparative example No. 9, the thermal conductivity was small (not satisfying the formula $\lambda \geq -0.5H+53$) when the hardness was adjusted to a low hardness of 45 HRC and 50 HRC, and even if the hardness was increased to 52 HRC, it was found that $\lambda \geq -0.5H+53$ was not satisfied.

[0056] For the samples Nos. 7 and 8, the thermal conductivity when the tempering hardness was 52 HRC was measured. The measurement procedure was the same as in the case of the above Nos. 1 to 6, and 9. As a result, it was confirmed that the thermal conductivity of No. 7 was 31 W/(m·K), the thermal conductivity of No. 8 was 37 W/(m·K), and a high thermal conductivity of 30 W/(m·K) or more was obtained at a hardness of 52 HRC.

<Evaluation of softening resistance>

[0057] Since the die in the hot stamp method was used at a high temperature, the softening resistance of the die steel was important. Therefore, the examples Nos. 1 to 6 of the present invention and the comparative example No. 9 that were tempered at 55 HRC were kept at 600°C, and the change in the hardness was measured. The results are shown in Fig. 3. In the examples Nos. 1 to 6 of the present invention, since the tempering temperature could be raised, the hardness of 50 HRC or more was maintained even after being kept for 4 hours. On the other hand, in the comparative example No. 9, since the tempering temperature was low, the hardness after being kept for 4 hours was less than 50 HRC. After that, when the keeping time was longer, the difference in the hardness between the steels of the present invention and the comparative steels was larger. The steels of the present invention had a large softening resistance and was effective in the hot stamp method.

Claims

1. A steel for a hot stamp die having a component composition including, in mass%, C: 0.45 to 0.65%, Si: 0.1 to 0.6%, Mn: 0.1 to 0.3%, Cr: 2.5 to 6.0%, Mo: 1.2 to 2.6%, V: 0.4 to 0.8%, the remainder being Fe and unavoidable impurities.

2. A hot stamp die having a component composition including, in mass%, C: 0.45 to 0.65%, Si: 0.1 to 0.6%, Mn: 0.1 to 0.3%, Cr: 2.5 to 6.0%, Mo: 1.2 to 2.6%, V: 0.4 to 0.8%, the remainder being Fe and unavoidable impurities.

3. The hot stamp die according to claim 2,
wherein the hardness is 45 HRC or more, and the thermal conductivity λ (W/(m·K)) satisfies the following Formula (1):

$$\lambda \geq -0.5H+53 \quad \ldots \text{Formula (1)}$$

H: Rockwell hardness (HRC) of die

4. The hot stamp die according to claim 3,
wherein the hardness is 52 HRC or more.

5. The hot stamp die according to claim 4,
wherein the thermal conductivity λ is 25 W/(m·K) or more.

6. The hot stamp die according to any one of claims 2 to 5,
wherein a working surface has a nitrided layer.

7. A method of manufacturing a hot stamp die, comprising
quenching and tempering the steel for a hot stamp die according to claim 1 at a quenching temperature of 1,020 to 1,080°C and a tempering temperature of 500 to 625°C.

8. The method of manufacturing a hot stamp die according to claim 7,
wherein the tempering temperature is 540 to 600°C.

9. The method of manufacturing a hot stamp die according to claim 7 or 8,
wherein, after the quenching and tempering are performed, a working surface is additionally subjected to a nitriding treatment.

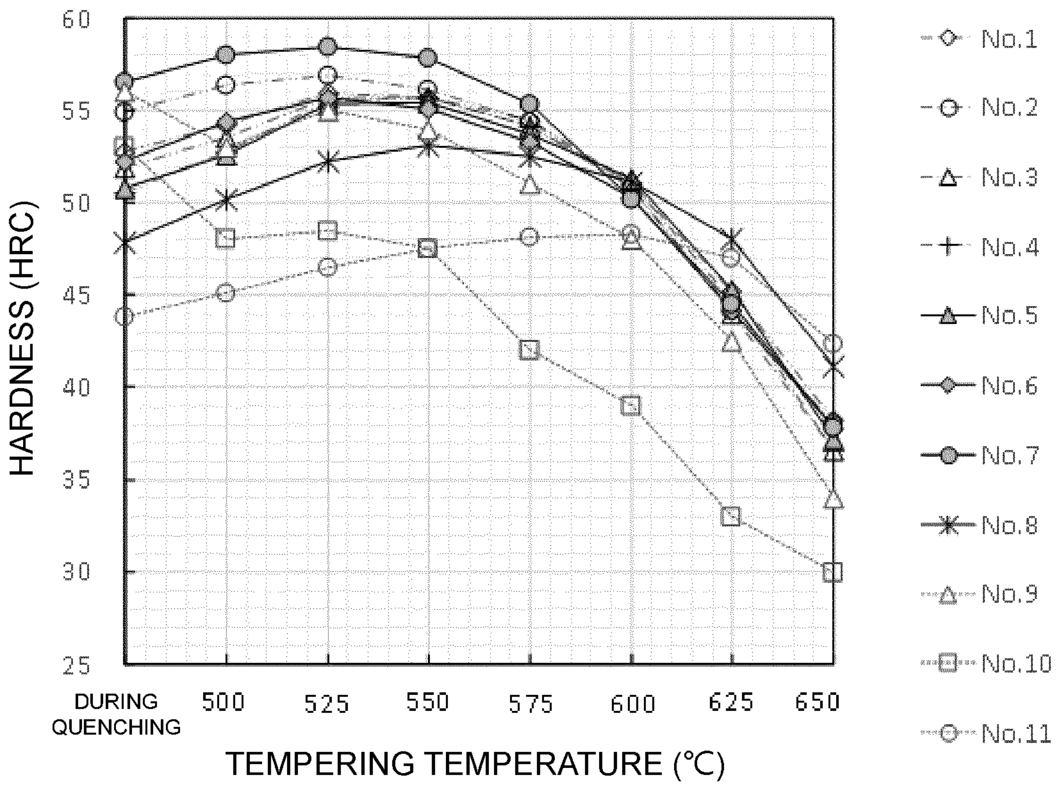
60
55
50
45
40
35
30
25
HARDNESS (HRC)
DURING QUENCHING
500
525
550
575
600
625
650
TEMPERING TEMPERATURE (℃)
No.1
No.2
No.3
No.4
No.5
No.6
No.7
No.8
No.9
No.10
No.11

FIG. 1

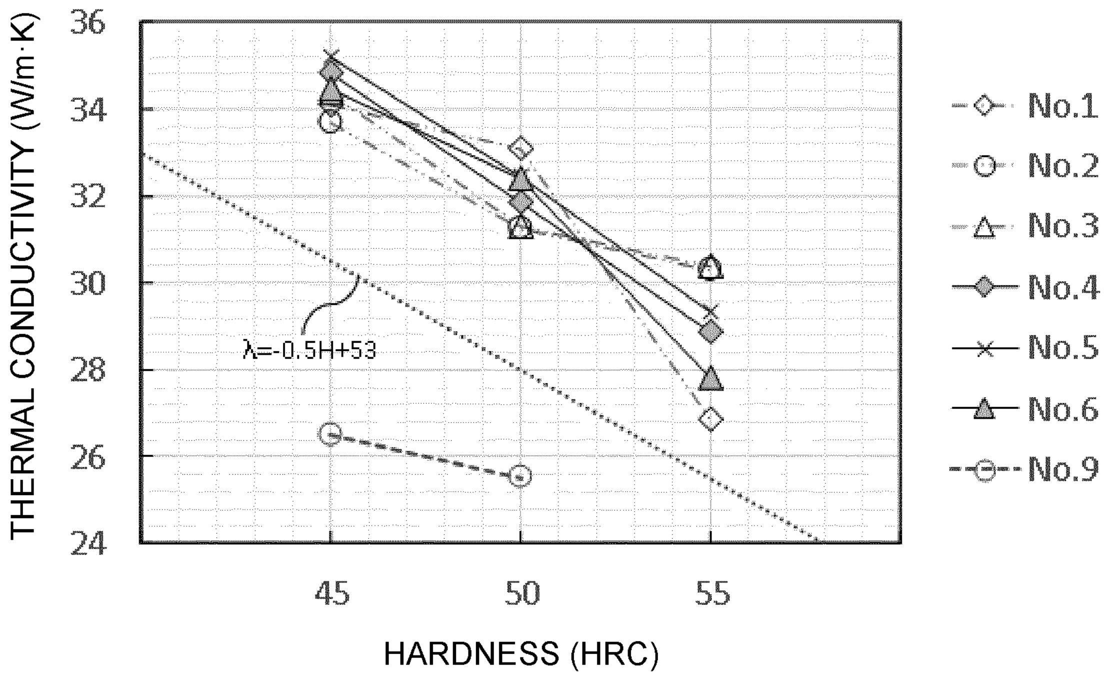
36
34
32
30
28
26
24
THERMAL CONDUCTIVITY (W/m·K)
λ=-0.5H+53
45
50
55
HARDNESS (HRC)
No.1
No.2
No.3
No.4
No.5
No.6
No.9

FIG. 2

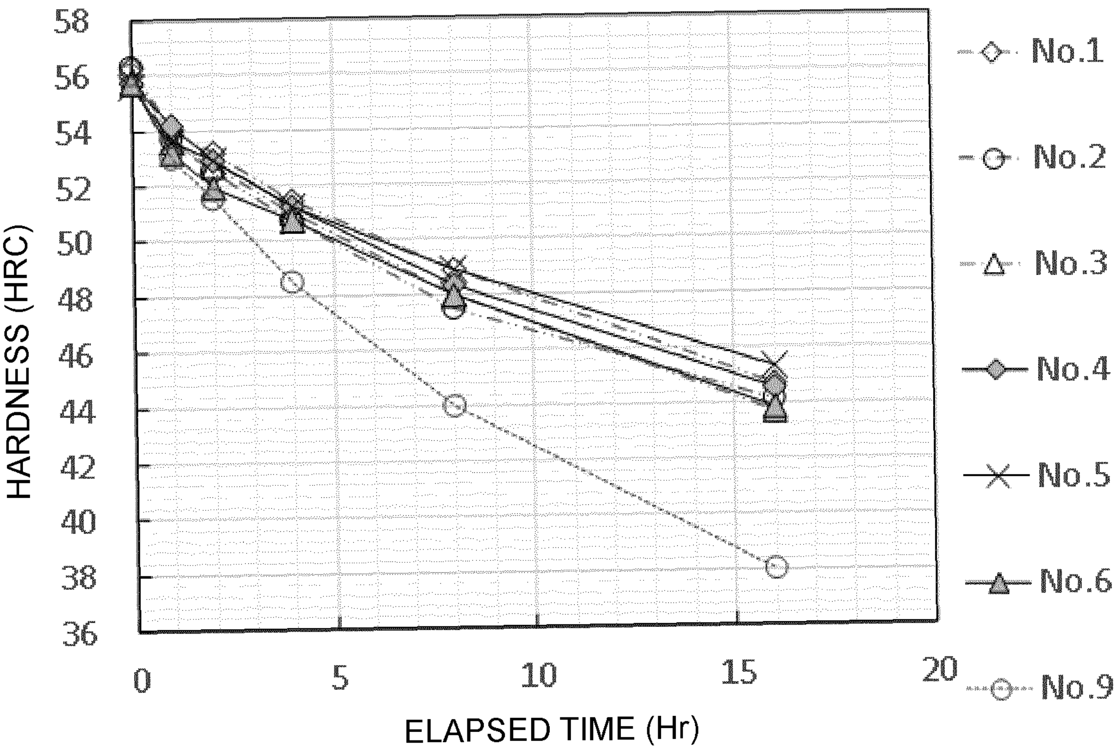
58
56
54
52
50
48
46
44
42
40
38
36
HARDNESS (HRC)
0
5
10
15
20
ELAPSED TIME (Hr)
No.1
No.2
No.3
No.4
No.5
No.6
No.9

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/010562

A. CLASSIFICATION OF SUBJECT MATTER
C21D 6/00(2006.01)i; C21D 9/00(2006.01)i; C22C 38/00(2006.01)i; C22C 38/24(2006.01)i; C21D 1/06(2006.01)i
FI: C22C38/00 301H; C22C38/00 302E; C22C38/24; C21D6/00 L; C21D6/00 101K; C21D1/06 A; C21D9/00 M

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C21D6/00; C21D9/00; C22C38/00-C22C38/60; C21D1/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2019-44254 A (DAIDO STEEL CO., LTD.) 22.03.2019 (2019-03-22) claims, paragraphs [0001]-[0003], [0018]-[0034], tables 1-2	1-5, 7-8 6, 9
Y A	WO 2017/043446 A1 (DAIDO STEEL CO., LTD.) 16.03.2017 (2017-03-16) paragraphs [0001], [0096]	6, 9 1-5, 7-8
A	JP 2015-521235 A (VALLS BESITZ GMBH) 27.07.2015 (2015-07-27) entire text, all drawings	1-9
A	JP 2015-221933 A (DAIDO STEEL CO., LTD.) 10.12.2015 (2015-12-10) entire text, all drawings	1-9
A	JP 6-145884 A (HITACHI METALS, LTD.) 27.05.1994 (1994-05-27) entire text	1-9

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

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 June 2020 (03.06.2020)	16 June 2020 (16.06.2020)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/010562

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 104928586 A (BAOSHAN IRON & STEEL CO., LTD.) 23.09.2015 (2015-09-23) entire text, all drawings	1-9
P, X	JP 2020-26567 A (HITACHI METALS, LTD.) 20.02.2020 (2020-02-20) entire text, all drawings	1-9

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/010562

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2019-44254 A	22 Mar. 2019	(Family: none)	
WO 2017/043446 A1	16 Mar. 2017	US 2018/0229294 A1 paragraphs [0001], [0236] EP 3348660 A1 TW 201718880 A CN 107949651 A KR 10-2018-0034656 A	
JP 2015-521235 A	27 Jul. 2015	US 2015/0118098 A1 entire text, all drawings US 2018/0363110 A1 WO 2013/167580 A1 EP 2662462 A1 EP 2847359 A1 CA 2872748 A1 KR 10-2015-0013256 A	
JP 2015-221933 A	10 Dec. 2015	(Family: none)	
JP 6-145884 A	27 May 1994	(Family: none)	
CN 104928586 A	23 Sep. 2015	(Family: none)	
JP 2020-26567 A	20 Feb. 2020	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

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- JP 2018024931 A **[0007]**
- JP 5744300 B **[0007]**