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(54) **SOFTENING RESISTANT COPPER ALLOY, PREPARATION METHOD, AND APPLICATION THEREOF**

ERWEICHUNGSBESTÄNDIGE KUPFERLEGIERUNG, HERSTELLUNGSVERFAHREN UND ANWENDUNG DAVON

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Description**Field of the Invention**

5 **[0001]** The present invention relates to the field of copper alloy manufacturing, and in particular to a softening-resistant copper alloy, a preparation method thereof and applications thereof, belonging to the technical field of novel alloy materials.

Description of the Prior Art

10 **[0002]** Welding is a manufacturing technology that joins metals or other materials by heating, at high-temperature or under high-pressure.

[0003] At present, there are mainly three methods for joining materials: fusion welding, pressure welding and braze welding. During the welding process, a workpiece and the solder are molten to form a molten area, and the molten pool is cooled and solidified to form a connection between the materials. During this process, it is usually necessary to apply a pressure. There are a variety of sources of energy for welding, including gas flame, electric arc, laser, electron beams, friction, ultrasonic waves and the like. Before the end of the 19th century, the only welding process was metal forging already used by the blacksmith for hundreds of years. The earliest modern welding techniques appeared at the end of the 19th century, first arc welding and oxygen-fuel welding and then resistance welding. In the early 20th century, as the first and second world wars happened, the demand for cheap and reliable connection methods for military materials was extremely high, so that the development of the welding techniques was also facilitated. With the extensive use of welding robots in industrial applications, researchers are still studying the nature of welding and continuing to develop new welding methods to further improve the welding quality.

[0004] Throughout the development of modern welding techniques and equipment, the automation of welding equipment and the improvement of production efficiency are major driving forces for the development of welding techniques. Since copper alloys are good in strength and electrical performance, many consumables in the welding equipment use copper and its alloys, for example, electrode caps in resistance welding, conductive nozzles in braze welding and the like. With the use of modern automatic equipment, particularly welding robots, the requirements on copper alloys used for conductive nozzles, electrode caps and the like, particularly their ability to resist against high-temperature softening, are increasing. During the welding process, due to the need for heating, high temperature or high pressure, the actual copper alloy consumables are often used at a very high temperature, so the requirements on the copper alloys are also increasing. In other fields, there are also examples of using materials in a high-temperature environment. For example, electrified railway contact lines are also to be used for a long period of time at a relatively high temperature. Therefore, it is urgent to develop a copper alloy with better high-temperature softening resistance.

[0005] At present, the actually popularized products, such as conductive nozzles for welding equipment, electrode caps and electrified railway contact lines, mostly use conventional copper chromium zirconium alloy (e.g., American Standard C18150) which has been widely applied in the above fields due to its excellent strength and electrical conductivity. However, with the gradual increase of the level of mechanical automation, a strategy of replacing manpower with machines basically comes into use in welding and other industries, in order to improve the production efficiency. This change will present new requirements on the raw material performances of parts, among which high-temperature softening resistance comes first. This is because the wear of the parts will be less if the high-temperature softening resistance is better. Accordingly, the service life of the parts is prolonged and the precision during the welding process is also improved. At present, the conventional copper chromium zirconium alloy (e.g., American Standard C18150) has a high-temperature softening resistance that a hardness loss value is above 15% below 580°C. This already cannot meet the development requirements of the related industries. Therefore, improving the high-temperature softening resistance of materials becomes an urgent need at present. The Chinese patent application CN102534291 A discloses a Cu alloy containing Cr and Zr that offers improved strength and electrical conductivity and is intended for use in applications such as resistance sleeves for welding electrodes, overhead poweline wires and electrical contact materials.

Summary of the Invention

[0006] An objective of the present invention is to provide a copper alloy with better high-temperature softening resistance, in order to solve the problem that the high-temperature softening resistance of the existing copper chromium zirconium alloy is to be improved.

55 **[0007]** To solve the technical problem, the softening-resistant copper alloy, comprises: 0.1%-1.0 wt% Cr, 0.01% -0.2 wt% Zr, 0.01%-0.10 wt% Si, and ≤0.10 wt% Fe, 0.0001-0.10 wt.% Mg, 0.01-2.5 wt.% of at least one of Co, Zn, Mn, Sn and Nb, with their total amount not exceeding 3.5 wt.% and with the remaining of copper and inevitable impurities, characterized in that, the microstructure of the copper alloy comprises: an elemental Cr phase, a Cu₅Zr phase, and a

Cr₃Si phase and wherein the elemental Cr phase and the Cr₃Si phase satisfy the following relationship; if the weight of the elemental Cr phase is X and the weight of the Cr₃Si phase is Y, then the ratio X/Y is greater than zero and smaller than twenty ($0 < X/Y < 20$). In the copper alloy of the present invention, the high-temperature softening resistance effect of the material is improved by adding a proper amount of Si to form a compound Cr₃Si, and the strength and the high-temperature softening resistance of the material are further improved by strengthening the copper alloy matrix by the elemental Cr phase and the Cu₅Zr phase, using the synergistic effect of the Cr₃Si phase and the elemental Cr phase and by controlling the content of the impurity Fe.

[0008] The effects of the alloy elements and the related precipitated phases in the copper will be described below.

[0009] The solid solubility of chromium in copper at the normal temperature is very small (less than 0.5%), but the solid solubility of chromium in copper at a high temperature is relatively high (up to 0.65%). Therefore, chromium is able to realize precipitation strengthening and used as a main strengthening element in the copper alloy of the present invention. In the copper alloy, dispersion strengthening phase particles of the elemental Cr can be obtained by heat treatment, so the copper matrix is strengthened. While strengthening the copper matrix, Cr will also form a compound Cr₃Si with Si solid-dissolved in the copper matrix. Researches have indicated that the compound Cr₃Si is a compound phase that is stable at a high temperature and will not be dissolved even at a high temperature of 800 °C, so that the high-temperature softening resistance is very high. The content of chromium in the copper alloy of the present invention is 0.1% to 1.0%. If the content of chromium is less than this range, Cr and Si are difficult to form Cr₃Si or can form a small amount of Cr₃Si so that the desired effect cannot be achieved; however, if the content of chromium is greater than this range, chromium will be largely precipitated to form a strengthening phase, so that the chromium will be largely accumulated at the crystal boundary and the plasticity of the material is damaged.

[0010] Zirconium has a certain solubility in the copper alloy. By adding zirconium, the recrystallization temperature of the copper matrix can be increased and the high-temperature softening resistance of the copper alloy can be thus improved. Moreover, zirconium and copper will form an intermediate compound Cu₅Zr, strengthening the copper matrix and also improving the electrical performance of the copper alloy. The content of zirconium in the copper alloy of the present invention is 0.01% to 0.2%. If the content of zirconium is less than this range, the desired effect cannot be achieved; however, if the content of zirconium is greater than this range, although the alloy can be strengthened, the electrical conductivity of the alloy will be greatly reduced and the overall performance of the alloy will be influenced.

[0011] Silicon has a certain solid solubility in copper. Silicon can strengthen the copper alloy matrix, but will greatly influence the electrical conductivity of copper and will greatly reduce the electrical conductivity of the copper alloy. However, when there is a proper amount of chromium in the copper alloy, silicon and chromium can form a Cr₃Si phase compound. Since Cr₃Si is a precipitated phase, the electrical conductivity of the material can be greatly improved after Cr₃Si is precipitated, so that the overall performance of the copper alloy is positively influenced. The content of silicon in the copper alloy of the present invention is 0.01% to 0.1%. If the content of silicon is less than this range, the Cr₃Si phase formed in the copper alloy is not enough to achieve the desired effect; however, if the content of silicon is greater than this range, although sufficient Cr₃Si phase can be formed, the precipitation of Cr will be greatly reduced and the overall performance of the alloy will thus be influenced.

[0012] In the present invention, Fe is controlled as an impurity element. A small amount of Fe facilitates the improvement of strength, but a too high content of Fe will affect the electrical conductivity. Therefore, in the present invention, the content of Fe is controlled below 0.1 wt. %.

[0013] The elemental Cr phase, the Cu₅Zr phase and the Cr₃Si phase in the microstructure of the copper alloy of the present invention have the following effects.

[0014] As a primary phase of alloy, the Cr₃Si phase is generated during the liquid state and crystallization process of the alloy, is stable in both structure and performance at a high temperature, and will not be dissolved at 800 °C while still maintaining its original structure. Accordingly, the high-temperature softening resistance of the alloy can be greatly improved. As one of main precipitation strengthening phases in the copper alloy of the present invention, the Cu₅Zr phase is completely dissolved in the copper matrix to form a supersaturated solid solution after solid solution treatment on the alloy, then precipitated out of the copper matrix during the subsequent aging process and dispersedly distributed in the alloy. After the Cu₅Zr phase is precipitated, a pinning effect on the dislocation is achieved, so that the strength and hardness of the copper matrix are improved. Meanwhile, due to the precipitation of the Cu₅Zr phase, the copper matrix becomes pure, the inhibition of electrons is reduced, the electrical resistivity is reduced, and the electrical conductivity is thus greatly improved. Another strengthening phase in the copper alloy of the present invention is the elemental Cr phase. Similarly to the generation principle of the Cu₅Zr phase, the elemental Cr phase is also generated during the heat treatment of the alloy. The elemental Cr phase is completely dissolved in the copper matrix to form a supersaturated solid solution after the solid solution treatment, then precipitated out of the copper matrix during the subsequent aging process and dispersedly distributed in the alloy. As the most important strengthening phase in the alloy of the present invention, the elemental Cr phase plays a crucial role in the improvement of the strength of the alloy.

[0015] The three main strengthening phases in the alloy of the present invention exist independently and have a certain dependence. The addition of a suitable proportion of alloy elements to form a rational proportion of phases is very

important for the performance of the alloy. The elemental Cr phase, as the main strengthening phase in the alloy, plays a leading role in the strengthening of the alloy; the Cr_3Si phase, as a high-temperature phase, plays a leading role in the high-temperature softening resistance of the alloy; and, the Cu_5Zr phase, as another moderate strengthening phase, can strengthen the alloy and can also increase nucleating particles, refine the elemental Cr phase and the Cr_3Si phase and allow the elemental Cr phase and the Cr_3Si phase to be dispersedly distributed, so that both the strength and the high-temperature softening resistance are further improved.

[0016] The elemental Cr phase and the Cr_3Si phase satisfy the following relationship:

if the weight of the elemental Cr phase is X and the weight of the Cr_3Si phase is Y, then $0 < X/Y < 20$.

[0017] When the strengthening phases satisfy this ratio, both the high-temperature softening resistance and the strength of the copper alloy will be greatly improved. When the ratio of the strengthening phases is greater than 20, the amount of the Cr_3Si phase in the alloy is very small. As a result, the high-temperature softening resistance of the alloy cannot satisfy the requirements.

[0018] The copper alloy further comprises: 0.0001 % - 0.10 wt% Mg. By providing magnesium in this proportion, magnesium can be dissolved in the copper matrix to strengthen the copper alloy, with little influence on the electrical conductivity of the copper alloy; and meanwhile, oxygen in the copper alloy can be effectively eliminated, so that the content of oxygen in the copper alloy is reduced and the quality of the material is improved.

[0019] The copper alloy further comprises: 0.01% to 2.5 wt% of any one or more of Co, Zn, Mn, Sn and Nb, and their total amount does not exceed 3.5 wt% of the copper alloy. By adding the above alloy elements in the copper alloy, solid solution strengthening can be realized, the recrystallization temperature of the material is increased, and the softening temperature of the material is further increased. However, the amount of addition of the above alloy elements should not be too large, otherwise the electrical conductivity of the material will be greatly reduced.

[0020] Preferably, the softening temperature of the copper alloy is greater than or equal to 580°C . When the softening temperature of the copper alloy is greater than or equal to 580°C , the demands for various welding processes by the material can be greatly increased, and the service life of the welding material is prolonged.

[0021] The softening temperature of the copper alloy is determined by tests. Generally, when the material is kept at a certain temperature for 2 hours and then cooled in water, the hardness of the treated material is tested. If the hardness loss of the treated material is within 15%, it is considered that the material is not softened at this temperature; or otherwise, it is considered that the material is softened. The softening temperature of the conventional copper chromium zirconium alloy is about 550°C . If the conventional copper chromium zirconium alloy is kept at 550°C for 2 hours and then cooled in water, the hardness loss of the treated material is about 13% to 15%; and, if the conventional copper chromium zirconium alloy is kept at 580°C , the hardness loss is far greater than 15%. Therefore, the softening temperature of the conventional copper chromium zirconium alloy is 550°C . However, for the copper alloy of the present invention, under the above experimental conditions, the hardness loss of the material at 550°C is 4% to 8%, and the hardness loss of the material at 550°C does not exceed 10%. Therefore, the softening temperature of the copper alloy of the present invention is greater than or equal to 580°C .

[0022] The present invention further discloses a method for preparing copper alloy, the method comprising: alloying and refining-casting into an ingot-ingot sawing, heating and extruding-solid solution heat treatment-stretching and drawing-aging heat treatment-straightening and finalizing;

[0023] characterized in that, the casting temperature for the alloying treatment and the covered refining is 1150°C to 1350°C ; the temperature for the hot extrusion is 850°C to 950°C ; the temperature for the solid solution treatment is 850°C to 1000°C ; the cooling medium is water, and the cooling rate is $10^\circ\text{C}/\text{min}$ to $150^\circ\text{C}/\text{s}$; the machining rate of the cold stretching and drawing is 20% to 60%; the temperature for the aging heat treatment is 420°C to 520°C ; and the copper alloy is insulated for 2h to 4h. In the material produced by this production process, the elemental Cr phase, the Cu_5Zr phase and the Cr_3Si phase are rational in size and more dispersive in distribution, so that various performances of the copper alloy of the present invention are improved.

[0024] The present invention discloses a method of using the copper alloy, the method comprising using the softening-resistant copper alloy in contact lines and welding materials..

[0025] Compared with the prior art, the present invention has the following advantages:

[0026] 1. In the copper alloy of the present invention, the high-temperature softening resistance effect of the material is improved by adding a proper amount of Si to form a compound Cr_3Si , and the strength and the high-temperature softening resistance of the material are further improved by strengthening the copper alloy matrix by the elemental Cr phase and the Cu_5Zr phase, using the synergistic effect of the Cr_3Si phase and the elemental Cr phase and by controlling the content of the impurity Fe.

[0027] 2. Since the softening temperature of the copper alloy of the present invention is greater than or equal to 580°C , the requirements on various performances of the copper alloy in the fields of welding and contact lines are better satisfied.

Detailed Description of the Preferred Embodiment

[0028] To enable a further understanding of the present invention content of the invention herein, refer to the detailed description of the invention and the accompanying drawings below:

[0029] To avoid repetition, the technical parameters involved in the specific implementations will be uniformly described below, and will not be repeated in embodiments.

[0030] wt%: weight percentage.

[0031] %IACS: used for representing the electrical conductivity of a metal or alloy (reference to the standard annealed pure copper). The electrical conductivity of the standard annealed pure copper is generally defined as 100%IACS, i.e., $5.80 \times 10^8 \text{ S/m}$ or $58 \text{ (m/}\Omega \cdot \text{mm}^2)$. The value is the ratio of the resistivity (in volume or mass) specified by the International Annealed Copper Standard to the resistivity of the sample in the same unit multiplied by 100.

[0032] HR: Rockwell hardness.

[0033] Rem.: remaining amount.

[0034] Embodiments 1-20 (embodiments 1-17 and all further embodiments produced using these compositions are not part of the invention)

Table 1: Composition instances of components of the softening-resistant copper alloy of embodiments 18-20 of the present invention (wt%):

Component Embodiment	Chemical component (wt%)						
	Cr	Zr	Si	Mg	Fe	Other elements	Cu
Embodiment 1	0.10	0.010	0.015	—	—	—	Rem.
Embodiment 2	0.187	0.016	0.010	0.018	0.027	—	Rem.
Embodiment 3	0.192	0.189	0.027	0.014	0.017	—	Rem.
Embodiment 4	0.24	0.027	0.022	0.035	0.009	—	Rem.
Embodiment 5	0.297	0.029	0.026	0.043	0.028	—	Rem.
Embodiment 6	0.367	0.046	0.026	0.016	0.009	—	Rem.
Embodiment 7	0.43	0.048	0.035	0.006	0.042	—	Rem.
Embodiment 8	0.46	0.059	0.038	0.068	0.021	—	Rem.
Embodiment 9	0.51	0.06	0.065	0.072	0.057	—	Rem.
Embodiment 10	0.59	0.072	0.046	0.088	0.068	—	Rem.
Embodiment 11	0.64	0.079	0.028	0.096	0.079	—	Rem.
Embodiment 12	0.68	0.085	0.067	0.005	0.100	—	Rem.
Embodiment 13	0.75	0.091	0.096	0.052	0.062	—	Rem.
Embodiment 14	0.81	0.115	0.062	0.002	0.004	—	Rem.
Embodiment 15	0.84	0.127	0.042	0.017	0.037	—	Rem.
Embodiment 16	0.89	0.149	0.019	0.002	0.023	—	Rem.
Embodiment 17	0.89	0.147	0.031		0.021	Nb:0.03 1	Rem.
Embodiment 18	0.95	0.176	0.079	0.021	0.023	Nb:0.09 7	Rem.
Embodiment 19	0.87	0.177	0.082	0.031	0.014	Co:0.12	Rem.
Embodiment 20	1.00	0.200	0.100	0.012	0.067	Zn:0.13	Rem.

Comparison embodiment	0.92	0.051	0.0021	0.013	0.032	—	Rem.
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[0035] The finished softening-resistant copper alloy products in Embodiments 21-40 of the present invention were obtained by preparing materials according to the components and their mass percentages of the softening-resistant copper alloy in Embodiments 1-20 in Table 1, then smelting, casting into an ingot, processing and molding, heating to 450°C to 520°C at an average heating rate of 1 °C/min to 30°C/min and holding this temperature for 2h to 4h (Embodiments 21-40 where the finished products were obtained, corresponding to the components and their mass percentages of the softening-resistant copper alloy in Embodiments 1-20, respectively).

[0036] The microstructures of the finished softening-resistant copper alloy products in Embodiments 21-40 were analyzed. The results of analysis are shown in Table 2.

[0037] In the softening-resistant copper alloys in Embodiments 21-40 of the present invention, microscopic intermediate phases and elementary substances with different properties are formed by various added alloy elements and a particular aging process, and the microscopic phases are dispersedly distributed in the copper matrix, so that various performances of the copper alloys are effectively improved. The related phases and their contents in the softening-resistant copper alloys in Embodiments 21-40 of the present invention are shown in Table 2. The embodiments 21-37 fall outside the scope of the present invention.

[0038]

Table 2: Intermediate phases and their contents in the softening-resistant copper alloys in Embodiments 38-40 of the present invention

Embodiment	Second phase	Cr(wt%)	Cr ₃ Si (wt%)	Cu ₅ Zr (wt%)
Embodiment 21		0.0525	0.0975	0.0495
Embodiment 22		0.1045	0.0975	0.072
Embodiment 23		0.0435	0.1755	0.8505
Embodiment 24		0.119	0.143	0.1215
Embodiment 25		0.154	0.169	0.1305
Embodiment 26		0.224	0.169	0.207
Embodiment 27		0.2375	0.2275	0.216
Embodiment 28		0.251	0.247	0.2655
Embodiment 29		0.1525	0.4225	0.27
Embodiment 30		0.337	0.299	0.324
Embodiment 31		0.486	0.182	0.3555
Embodiment 32		0.3115	0.4355	0.3825
Embodiment 33		0.0312	0.624	0.4095
Embodiment 34		0.469	0.403	0.5175
Embodiment 35		0.609	0.273	0.5715
Embodiment 36		0.7855	0.1235	0.6705
Embodiment 37		0.7195	0.2015	0.6615
Embodiment 38		0.5155	0.5135	0.792
Embodiment 39		0.419	0.533	0.7965
Embodiment 40		0.4365	0.6305	0.873
Comparison embodiment		0.92	-	0.2295

[0039] The materials were prepared according to the components and their mass percentages of the softening-resistant copper alloy in Embodiments 1-20 in Table 1, and then treated under the following conditions: the casting temperature for the alloying treatment and the covered refining was 1150°C to 1350°C, the temperature for hot extrusion was 850°C to 950°C, the temperature for solid solution treatment was 850°C to 1000°C, the cooling medium was water, the cooling rate was 10°C/min to 150°C/s, the machining rate of cold drawing was 20% to 60%, the temperature for aging heat treatment was 420°C to 520°C, and the temperature holding time was 2 h to 4 h. Finally, the finished softening-resistant copper alloy bar products in $\Phi 8$ in Embodiments 41-60, corresponding to the components and their mass percentages of the softening-resistant copper alloy in Embodiments 1-20, were obtained by finishing.

[0040] The tensile strength, hardness, electrical conductivity and softening temperature of the softening-resistant copper alloy bars in Embodiments 58-60 of the present invention were tested by methods specified by the related national and industrial Embodiments 41-57 fall outside the scope of the invention. The test results are shown in Table 3. The room-temperature tensile tests were carried out by an electronic universal mechanical property testing machine according to GB/T228.1-2010 Metal Material Tensile Test Section 1: Test at Room Temperature. The samples were circular cross-section proportional samples having a proportional coefficient of 5.65. The electrical conductivity tests were carried out according to GB/T228.1-2010 Test Methods for Electrical Performance of Electric Wires and Cables Section 2: Metal Material Resistivity Test. As the test instrument, a ZFD microcomputer bridge DC resistance tester was used, and the samples were 1000 mm in length. The electrical conductivity was represented by %IACS. The hardness tests were carried out by a hardness tester according to GB/T 230.1-2009 Metal Material: Rockwell Hardness Test.

[0041] Table 3: Test results of performances of the softening-resistant copper alloy bars in Embodiments 58-60 of the present invention

Performance Embodiment	Tensile strength (MPa)	Hardness (HR)	Electrical conductivity (%IACS)
Embodiment 41	472	75	90.1
Embodiment 42	491	77	88.6
Embodiment 43	482	75	91.1
Embodiment 44	487	78	86
Embodiment 45	496	78	85.7
Embodiment 46	499	80	86
Embodiment 47	489	81	84.2
Embodiment 48	492	80	85.1
Embodiment 49	498	82	83.8
Embodiment 50	506	81	84.1
Embodiment 51	517	84	81.2
Embodiment 52	528	86	79.1
Embodiment 53	509	82	76.4
Embodiment 54	558	87	75.2
Embodiment 55	537	85	76.3
Embodiment 56	568	85	77.7
Embodiment 57	566	87	77.5
Embodiment 58	571	86	76.8
Embodiment 59	573	86	75.7
Embodiment 60	578	88	75.2

Comparison embodiment	495	85	83.1
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[0042] In the present invention, the tensile strength is higher than or equal to 470MPa, the Rockwell hardness is above 75, and the electrical conductivity is above 75%IACS.

[0043] Embodiments 61-80 The components and their mass percentages of the softening-resistant copper alloys in Embodiments 61-80 are the same as those in Embodiments 41-60. That is, the materials were prepared according to the components and their mass percentages of the softening-resistant copper alloy in Embodiments 1-20 in Table 1,

and then treated under the following conditions: the casting temperature for the alloying treatment and the covered refining was 1150°C to 1350°C, the temperature for hot extrusion was 850°C to 950°C, the temperature for solid solution treatment was 850°C to 1000°C, the cooling medium was water, the cooling rate was 10°C/min to 150°C/s, the machining rate of cold drawing was 20% to 60%, the temperature for aging heat treatment was 420 °C to 520 °C, and the temperature holding time was 2h to 4h. Finally, the finished softening-resistant copper alloy bar products in $\Phi 8$ were obtained by finishing.

[0044] The softening temperature tests were carried out by methods specified by HB5420-89 Copper and Copper Alloys for Resistance Welding Electrodes and Auxiliary Devices. The test temperature was 580°C. The test results are shown in Table 4. Embodiments 61-77 fall outside of the scope of the invention.

Table 4: Test results of the softening temperature of the softening-resistant copper alloy bars in Embodiments 78-80 of the present invention

Embodiment	Original hardness (HRB)	580°C	
		Hardness after softening (HRB)	Softening rate (%)
Embodiment 61	75	70	6.67
Embodiment 62	77	71	7.79
Embodiment 63	75	69	8
Embodiment 64	78	73	6.41
Embodiment 65	78	72	7.69
Embodiment 66	80	75	6.25
Embodiment 67	81	77	4.94
Embodiment 68	80	76	5
Embodiment 69	82	76	7.32
Embodiment 70	81	75	7.41
Embodiment 71	84	79	5.95
Embodiment 72	86	80	6.98
Embodiment 73	82	78	4.88
Embodiment 74	87	81.5	6.32
Embodiment 75	85	80	5.88
Embodiment 76	85	81	4.71
Embodiment 77	87	81	6.90
Embodiment 78	86	80	6.98
Embodiment 79	86	81	5.81
Embodiment 80	88	82	6.82
Comparison embodiment	85	69	18.8

[0045] It can be known from the above embodiments that, in accordance with the standard test methods, the hardness loss of the copper alloy of the present invention at 580°C is below 8%, while the hardness loss of the conventional copper chromium zirconium alloy in the comparison embodiment is greater than 18%. It is indicated that the high-temperature softening resistance of the copper alloy of the present invention is greatly improved.

Application embodiment

[0046] The softening-resistant copper alloy bars in any one of Embodiments 41-60 are machined into appliances for welding.

[0047] The softening-resistant copper alloy bars in any one of Embodiments 41-60 are machined into contact lines for

electrified railways.

[0048] In conclusion, the softening-resistant copper alloy of the present invention has high strength, good electrical performance and excellent high-temperature softening resistance, and is particularly applied in industrial fields such as welding appliances and contact lines for electrified railways.

Claims

1. A softening-resistant copper alloy, comprising:

0.1 - 1.0 wt.% Cr,
0.01 - 0.2 wt.% Zr,
0.01 - 0.10 wt.% Si,
 ≤ 0.10 wt.% Fe,
0.0001 - 0.10 wt.% Mg, and
0.01 - 2.5 wt.% of at least one of Co, Zn, Mn, Sn and Nb, with their total amount not exceeding 3.5 wt.% of the copper alloy,

with the balance being copper and inevitable impurities,
wherein the microstructure of the copper alloy comprises:

an elemental Cr phase,
a Cu_5Zr phase, and
a Cr_3Si phase, and
wherein the elemental Cr phase and the Cr_3Si phase satisfy the following relationship:
if the weight of the elemental Cr phase is X and the weight of the Cr_3Si phase is Y, then the ratio X/Y is greater than zero and smaller than twenty ($0 < X/Y < 20$).

2. A method for preparing the copper alloy according to claim 1, the method comprising steps of: alloying and refining-casting into an ingot-ingot sawing, heating and extruding-solid solution heat treatment-stretching and drawing-aging heat treatment-straightening and finalizing;
characterized in that, the casting temperature for the alloying treatment and the covered refining is 1150 °C to 1350 °C; the temperature for the hot extrusion is 850 °C to 950 °C; the temperature for the solid solution treatment is 850 °C to 1000 °C; the cooling medium is water, and the cooling rate is 10 °C/min to 150 °C/s; the machining rate of the cold stretching and drawing is 20% to 60%; the temperature for the aging heat treatment is 420 °C to 520 °C; and, the copper alloy is insulated for 2h to 4h.

3. Use of the softening-resistant copper alloy according to claim 1 in contact lines and welding materials.

Patentansprüche

1. Eine erweichungsbeständige Kupferlegierung, umfassend:

0,1 - 1,0 Gew.-% Cr,
0,01 - 0,2 Gew.-% Zr,
0,01 - 0,10 Gew.-% Si,
 $\leq 0,10$ Gew.-% Fe,
0,0001 - 0,10 Gew.-% Mg, und
0,01 - 2,5 Gew.-% mindestens eines der folgenden Elemente Co, Zn, Mn, Sn und Nb, wobei deren Gesamtmenge 3,5 Gew.-% der Kupferlegierung nicht übersteigt,

wobei der Rest aus Kupfer und unvermeidlichen Verunreinigungen besteht,
wobei das Mikrogefüge der Kupferlegierung umfasst:

eine elementare Cr-Phase,
eine Cu_5Zr -Phase, und
eine Cr_3Si -Phase, und

wobei die elementare Cr-Phase und die Cr_3Si -Phase die folgende Beziehung erfüllen:

wenn das Gewicht der elementaren Cr-Phase X und das Gewicht der Cr_3Si -Phase Y ist, dann ist das Verhältnis X/Y größer als null und kleiner als zwanzig ($0 < X/Y < 20$).

2. Verfahren zur Herstellung der Kupferlegierung nach Anspruch 1, wobei das Verfahren die folgenden Schritte umfasst: Legieren und Raffinieren -- Gießen zu einem Barren -- Sägen des Barrens, Erhitzen und Strangpressen -- Wärmebehandlung in fester Lösung - Strecken und Ziehen -- Wärmebehandlung durch Alterung -- Richten und Endbearbeitung;

dadurch gekennzeichnet, dass die Gießtemperatur für die Legierungsbehandlung und das verdeckte Raffinieren 1150 °C bis 1350 °C beträgt; die Temperatur für das Warmstrangpressen 850 °C bis 950 °C beträgt; die Temperatur für die Wärmebehandlung in fester Lösung 850 °C bis 1000 °C beträgt; das Kühlmedium Wasser ist und die Kühlrate 10 °C/min bis 150 °C/s beträgt; die Dehnungsrate bei Kaltstrecken und Ziehen 20 % bis 60 % beträgt; die Temperatur bei der Alterungswärmebehandlung 420 °C bis 520 °C beträgt; und die Kupferlegierung für 2 h bis 4 h isoliert wird.

3. Verwendung der erweichungsbeständigen Kupferlegierung nach Anspruch 1 in Oberleitungen und Schweißmaterialien.

Revendications

1. Alliage de cuivre résistant au ramollissement, comprenant :

0,1 - 1,0 % en poids de Cr,

0,01 - 0,2 % en poids de Zr,

0,01 - 0,10 % en poids de Si,

$\leq 0,10$ % en poids de Fe,

0,0001 - 0,10 % en poids de Mg, et

0,01 - 2,5 % en poids d'au moins un élément parmi Co, Zn, Mn, Sn et Nb, leur quantité totale ne dépassant pas

3,5 % en poids de l'alliage de cuivre,

le reste étant du cuivre et des impuretés inévitables,
dans lequel la microstructure de l'alliage de cuivre comprend :

une phase de Cr élémentaire,

une phase Cu_5Zr , et

une phase Cr_3Si , et

dans laquelle la phase de Cr élémentaire et la phase de Cr_3Si satisfont à la relation suivante :

si le poids de la phase Cr élémentaire est X et le poids de la phase Cr_3Si est Y, alors le rapport X/Y est supérieur à zéro et inférieur à vingt ($0 < X/Y < 20$).

2. Procédé de préparation de l'alliage de cuivre selon la revendication 1, le procédé comprenant les étapes de : alliage et affinage-coulée en un lingot-sciage, chauffage et extrusion du lingot-traitement thermique en solution solide-étirage et tréfilage-traitement thermique de vieillissement-redressement et finalisation ;

caractérisé en ce que, la température de coulée pour le traitement d'alliage et l'affinage couvert est de 1150 °C à 1350 °C ; la température pour l'extrusion à chaud est de 850 °C à 950 °C ; la température pour le traitement en solution solide est de 850 °C à 1000 °C ; le milieu de refroidissement est l'eau, et la vitesse de refroidissement est de 10 °C/min à 150 °C/s ; le taux d'usinage de l'étirage à froid et du tréfilage est de 20% à 60% ; la température pour le traitement thermique de vieillissement est de 420 °C à 520 °C ; et, l'alliage de cuivre est isolé pendant 2h à 4h.

3. Utilisation de l'alliage de cuivre résistant au ramollissement selon la revendication 1 dans les lignes de contact et les matériaux de soudage.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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