Development and Application of High Silicon Stainless Steel

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The new material with high strength, high hardness, and high corrosion resistance was developed by combining Ni, Cr, and Mo, the main components of stainless steel, with high silicon and low carbon components. High hardness was obtained by solution annealing followed by age hardening heat treatment instead of quenching. Silicon-adding alloys was named "Silicolloy" by the late Professor Emeritus Keiichi Ohta of Kansai University. The history of research on silicon addition to steel is long, starting with Professor Emeritus Ota's efforts to make steel tougher. It was known at that time that increasing the silicon content made the steel brittle, but by lowering the carbon content to less than 0.02% and increasing the silicon content to as high as 4.0%. He succeeded in making an excellent stainless steel Silicolloy A2 steel, a precipitation hardening system, has high strength, high hardness, and corrosion resistance, and has been applied as a new material for environmental use. Design of large bridges for the Japan Highway Public Corporation began in the 1970s. We participated in open experiments in the research and development of materials with high strength, high hardness, and high corrosion resistance. We developed high-silicon, low-carbon stainless steel among various standards as a new material, and completed the development with Silicolloy A2 steel. Certified as C-13B 2

Keywords: *high silicon stainless steel, silicolloy A2 steel, D-13B2 bearings, roller bearings, 3D metal printer*

1. Development of "hard and corrosion-resistant roller bearings"

Silicolloy A2 steel began development of bearings for larger roads and bridges in Japan, a maritime country, certifying by the Japan Road Association as a high hardness roller bearing "C-13B2". Features as Bearing are as follows:

(1) Material: 6% Ni, 12% Cr, 3.5% Si, 0.02% C, and balance Fe. Microstructure is 3 phase stainless steel.

(2) Design load: High bearing strength. Allowable bearing strength, σ_{Pa} is 1860MPa which is 3.2 times higher than that of SS400.

(3) Mechanical properties: Toughness and toughness are high. Tensile strength is 1500 MPa over and surface hardness is 475 HB over, showing high strength with toughness.

(4) Special heat treatment: surface hardness is 475 HB or higher with 20% elongation at internal hardness of 300 HB.

(5) Heat treatment including both solution heat treatment and precipitation hardening heat treatment ensures internal toughness. (Fig. 1) (Hardness and hardening depth are depending on intermetallic compounds.)

(6) Based on the results of rigorous testing of corrosion resistance and durability, Silicolloy rollers and support plates "C-13B2" are capable of performing as a bearing that requires high load capacity and high corrosion resistance. This alloy is currently installed on 800 bridges including the Osaka Bay Hanshin Expressway, Setonaikai Bridge, and Osaka Airport Monorail. Silicolloy bearing (C-13B2) was intact at the time of the Great Hanshin-Awaji Earthquake.

(7) Heat treatment is an important standard (roller hardening depth of 0.035 position from roller radius is 475 HB or more). (Fig. 2) The microstructure is not a quenched martensitic structure, but a three-phase (martensite, austenite, and ferrite) microstructure due to both solution heat treatment and age hardening treatment.

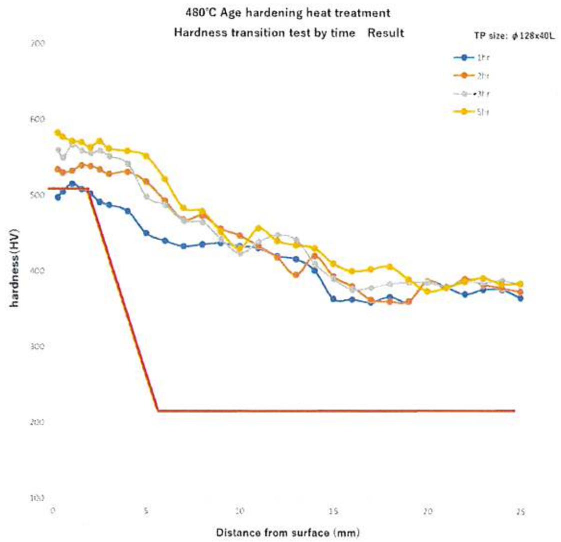

Fig. 1 Hardness distribution after age heat treatment at 480 °C.

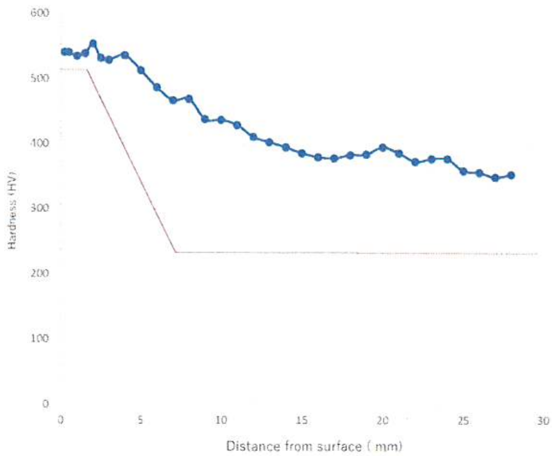

Fig. 2 Roller hardness distribution.

This high Si stainless steel (Silicolloy A2 steel) is used in Japan for bearing rollers and support plates for highway long-life component, including rollers and bearings for continuous casting in steel mills, screws as environmental materials, impellers in desulfurization equipment, and ball valves in dedicated seawater radioactivity tanks.

In recent years, we have been focusing on the development of high-strength powders for 3D metal printers through joint research with industry, government, and academia. Its strength of 1800 MPa is comparable to that of maraging steel, and there are high expectations for this new material, for which a powder patent has been obtained in Germany.

The important heat treatment (patented) of large rollers and the hardness, hardening depth, and even higher strength of the material were confirmed for the new standards and specifications of the Japan Road Association and certified as C-13B2. The material was certified as C-13B2.

We report on the development and application status of Silicolloy steels. Silicolloy steel has been developed as an effective material for high strength, high hardness, high corrosion resistance, seizure and rodent resistance, heat resistance, ultra-low temperature environmental materials, large castings, and ultra-thin-walled castings. Here, we will report on the superiority of the material as an ultra-thin-walled casting, metal powder for 3D printers, and as an environmental material for ultra-low temperatures, along with the results of Charpy tests and a poster.

2. Thin-wall complex high-strength casting is possible (environmental materials)

(1) screws, (2) manifolds, (3)screws and agitators for desulfurization equipment, (4) waste plastic oil reduction furnace body, (5) carbonization furnace centrifugal casting furnace body, and (6)golf head, etc. Large castings, precision castings, high-strength castings (A2), parts in seawater (B2), heat resistance (D). Ultra-low temperature (-253°C, casting valves for liquid hydrogen, etc.). Silicolloy D4 is patented. High strength: 1100 N/mm^2 for A2 castings.

3. Metallic fine powder: 30μm~105μm [German Patent]

Metallic fine powder is produced from silicolloy steel material. High strength and hardness powder is obtained. This powder is applied for metal 3D printer and metal injection molding (MIM), having high strength as high as 1800 N/mm^2 for metal 3D printers, equivalent to maraging steel. Its hardness is increased by age-hardening heat treatment. This powder is also possible for space and submarine applications. Silicolloy steel materials A2, B2, D, and D4 are available for various purposes.

4. New materials for ultra-low temperature (liquid hydrogen) Forging materials + Casting materials [Patented in Japan, Patent pending in Germany and the U.S.]

Charpy impact test results show 290J/mm^2 for forging materials (world standard 27 J/mm^2) and 60~105 J/mm^2 for casting materials. In the hydrogen society, SUS316L stainless steel is the mainstream material for ultra-low temperature applications. Silicolloy D and D4 have excellent Charpy impact values at -253°C, and we are exploring casting tests. We are looking forward to using Silicolloy D and D4 as new materials for casting valves and other applications in the future.

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