2009-2010

HITACHI TECHNOLOGY

Materials, Components & Others

Commencement of Trials of Gas Turbine Blades Made of Nickel-based Single-crystal Alloy to Improve Thermal Efficiency of Mid-range Gas Turbines

Hitachi, Ltd. has developed a nickel-based single-crystal alloy for use in gas turbine blades that provides better resistance to oxidation and heat at lower cost than previous materials. Rotor blades made of this alloy can contribute to reducing CO_2 emissions because they can significantly improve the thermal efficiency of mid-range gas turbines. It is also anticipated that the longer life of the rotor blades will provide further benefits such as lower maintenance costs. Working jointly with the New Energy and Industrial Technology Development Organization (NEDO), Hitachi commenced trials of gas turbine blades made of the new alloy in June 2008 with the aim of commercializing the product.

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Techniques for Improving Efficiency in Gas Turbines

As global warming becomes more severe, measures for reducing the CO_2 emissions that are part of the cause are picking up pace. In Japan, power generation makes up one third of total domestic CO_2 emissions, of which the majority is produced by thermal power stations. As a result, measures taken in the thermal power generation industry are particularly significant for reducing CO_2 emissions.

One effective measure is to apply technology for further improving the thermal efficiency of gas turbine generation plant, even though gas turbines are already very efficient by the standards of power generation. Increasing gas turbine efficiency requires the use of rotor blades made of material that can withstand higher temperatures, is stronger, and is less prone to oxidation so that the combustion temperature can be increased. We undertook the development of this nickel-based single-crystal alloy to produce a rotor blade material able to satisfy these requirements.

Rotor Blade Achieves Excellent High-temperature Strength, Long Life, and High Reliability

Although nickel-based single-crystal alloy is widely used in applications such as jet engine rotor blades, its use of rare metals makes it an expensive material. Further, when used in gas turbine blades, because their structure is more complex than jet engine blades, manufacturing is more difficult and the cost of production higher. Despite this, we have been able to reduce the material cost to about one third its previous level by optimizing the alloy composition including reducing the use of rare metals. We also adopted unique technology for the casting process which dramatically improves ease-of-manufacture by ensuring that the strength is not compromised even in the presence of polycrystalline regions, which form with high probability when producing single-crystal blades.

We also developed a highly durable porous ceramic with low thermal conductivity which we used as a coating for the surface of the rotor blades produced using this new nickel-based single-crystal alloy. This was done to improve reliability because better insulation of the rotor blades prevents their temperature from rising, thereby extending the life of the blades even under very high temperature conditions. This in turn makes possible lower plant maintenance costs.

Gas turbine blade made of nickel-based single-crystal alloy

Reducing Burden on Environment through Thermal Efficiency Improvement and Material Recycling

The newly developed rotor blades were installed in an H-25 gas turbine at the Goi Power Station of Goi Coast Energy, Ltd. in June 2008 and since then trials have been conducted. This involves reducing the cooling flow to approximately 70% of its standard level to recreate an environment equivalent to that when a higher combustion temperature is used so that performance factors such as long-term reliability can be confirmed over several years and the increased thermal efficiency verified. An improvement in thermal efficiency of 0.5% is anticipated. Compared to a standard H-25 gas turbine, this is equivalent to a reduction in CO_2 emissions of about 700 t/year for each turbine in continuous operation.

The new rotor blades are intended for use in mid-range gas turbines in the several tens of megawatts class, and it is anticipated that further improvements in thermal efficiency of several percent will be possible in the future. In addition to CO_2 reductions, we also considered the issue of resource conservation and put in place technology for recycling used rotor blades.

Our aim for the future is to commercialize this technology as soon as possible and get it into wide use while also continuing to work on developing new technologies that will lighten the burden placed on the global environment.

Environmentally Friendly Lead-free Vanadium-based Low-melting-point Glass

Lead-free vanadium-based low-melting-point glass

Lead, a toxic substance, and bismuth, a scarce resource produced as a by-product of lead production, are both important raw materials in the low-melting-point glasses used for low-temperature glass sealing and coating at 500℃ or less. To reduce the burden on the environment and ensure reliability of supply, Hitachi has developed a new vanadium-based low-melting-point glass that does not use lead or bismuth.

The newly developed glass has superior reliability in terms of parameters such as air tightness and moisture resistance when used as a sealant, coating, or similar. This is achieved by controlling the valence of the vanadium so as to transform the material from a layered structure that absorbs water molecules into a dense three-dimensional structure. Also, control of the glass structure can make the glass conductive to electrons which makes it suitable for use as an anti-static coating. Hitachi Powdered Metals Co., Ltd. has commenced sales and sample shipments of the newly developed glass in granulated and paste form.

Electromagnetic Wave Absorption Composites

Hitachi has developed new composite grains that can be used as filler in the next generation of semiconductors. In addition to adding an electromagnetic wave absorption property, the material has similar insulation performance and Young's modulus to conventional silica filler kneading resin but approximately three times the heat conductivity.

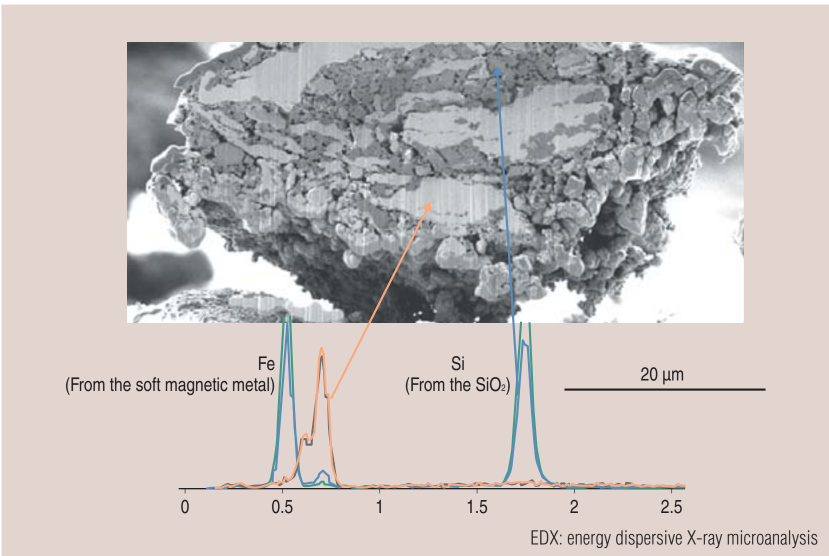
[Key features]

(1) High filling rate

(2) When used with a soft magnetic metal, the filler combines superior electromagnetic wave absorption characteristics with high heat conductivity.

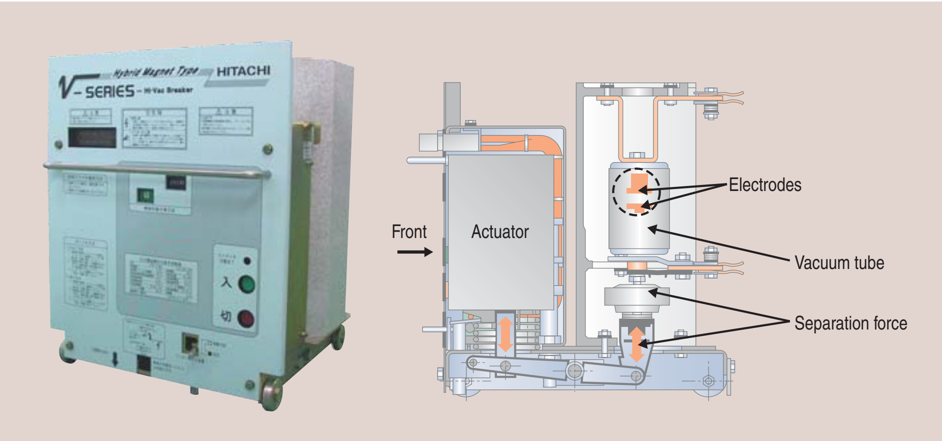
(3) The insulating properties of the grains are achieved by coating the surface of the metal grains with SiO_2 (silicon dioxide) to prevent them from coming into contact with each other.

Whereas it is the permeability of the magnetic material that gives electromagnetic absorption materials their ability to absorb electromagnetic waves, the newly developed composite has a grain structure in which a soft magnetic metal with a high level of magnetic saturation is formed into geometrically flat shapes and then coated with SiO_2 to give it its insulating properties. This achieves high permeability across a wide frequency range. The material can also be matched to a resin by changing the compounding ratio of SiO_2 in the composite grain to adjust the bulk density.



Cross section of soft magnetic metal and silica lamination structure taken using a scanning electron microscope (upper) and EDX result (lower)

New Electrode Material for Reducing the Size of Environmentally Friendly Power Distribution Equipment



Appearance (left) and construction (right) of vacuum circuit breaker

Although vacuum circuit beakers do not require insulators and are environmentally friendly, one of the issues faced in meeting the demands to reduce the size of these components has been the problem of how to miniaturize the actuator mechanism used to separate the electrodes which become welded together by the heat generated by the contact resistance when power is flowing through the circuit.

Hitachi has developed a chromium and copper based electrode material that allows the force used to separate welded contacts to be reduced by 30% (compared to Hitachi's existing electrode material). The weld strength in the new material has been reduced by the addition of a third element which has the effect of reducing the grain boundary strength for the grains that make up the electrode. The electrodes are produced using a high-temperature reduction sintering method which achieves high density at low cost. This has halved the volume of the actuator and ensured the energy-efficient operation of the vacuum circuit breaker while maintaining both the circuit breaking and current flow performance at the same level as the previous electrode material.

Hitachi intends to expand the range of different equipment in which the electrode material can be used by control of its microstructure and composition, and to help encourage the widespread adoption of environmentally friendly power distribution equipment.

Advanced Plastic Mold Steel for General Applications

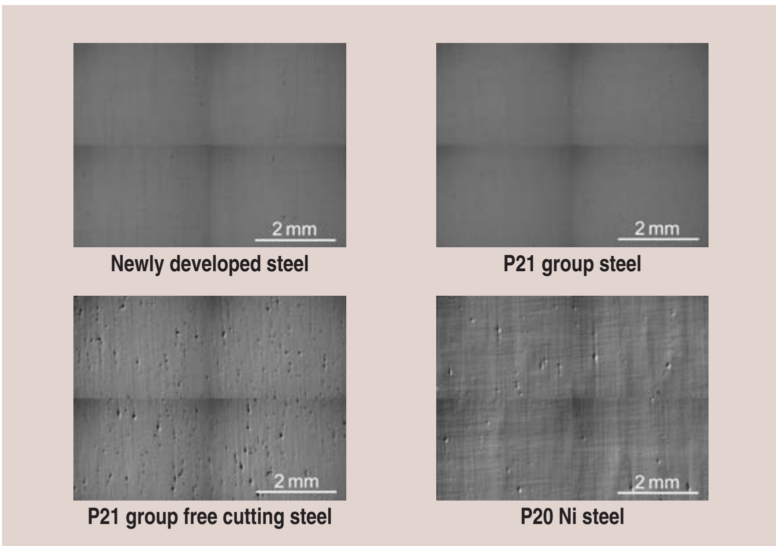
This newly developed prehardened tool steel has a hardness between 37 to 41 HRC (Rockwell hardness C-scale) and is used for high precision plastic molds for household appliance components, office equipment, automobiles, and other products. The main material used for plastic molds in Europe and America is P20Ni steel (AISI P20 steel with 1% nickel). In Japan, the improved P21 grade (low carbon steel hardened by NiAl (aluminum) precipitation) is mainly used. Unfortunately, these steels are subject to a number of problems. The high carbon content of P20Ni reduces its machinability and weldability, whereas the improved P21 grade has low durability due to its low toughness and also requires a remelting process for Al addition which makes it expensive. The newly developed steel resolves these problems by control of the microstructure and nonmetallic inclusion composition.

[Customer advantages]

(1) Better machinability and mirror polishability improve work efficiency by reducing process lead times for mold manufacturing.

(2) The excellent durability and weldability of the new steel minimizes problems such as mold cracking during the development of new products.

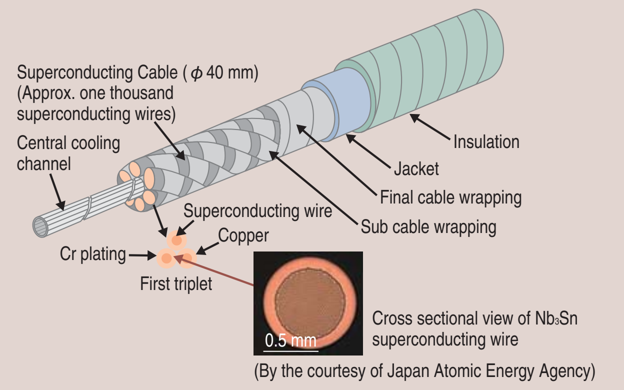
(Hitachi Metals, Ltd.)



Images of specimens after #5000 mirror polishing taken using a differential interference microscope

High-performance Nb_3Sn Superconducting Wire for ITER

Technology for practical fusion energy is being developed with the aim of providing a next-generation energy source that does not emit CO_2. The purpose of the ITER (international thermonuclear experimental reactor) is to demonstrate the scientific and technical feasibility of fusion power. The partners in the project are Japan, EU, USA, South Korea, China, and India. The Japan Atomic Energy Agency commenced procurement in Japan in October 2007. ITER is a magnetic confinement fusion reactor that works by confining plasma at very high temperatures, sometimes in excess of one hundred million degrees Celsius, using a strong magnetic field. The superconducting coil is used to generate this strong magnetic field over a long time period.
Hitachi Cable, Ltd. is involved in the manufacture of the superconducting wires and stranded cables for the TF (toroidal field) coils at ITER. The Nb_3Sn superconducting wire has a diameter of 0.8 mm and can carry a current of 190 A or more at 12 T and 4.2 °K (-268.95℃). The tin content in bronze is 15.5% which is almost equal to the solubility limit of tin in copper. Tantalum is also added in the niobium filaments. Use of these materials improves the critical current characteristics at high field strength. The Nb_3Sn wires are fabricated uniformly along their full length and the cable used in the TF coil contains about a thousand of these superconducting wires. The resulting superconducting cable can carry a current of 68 kA in a magnetic field of 12 T. Making fusion energy a reality will fulfill the dream of providing an energy source for the future.
(Hitachi Cable, Ltd.)



Structure of ITER TF conductor

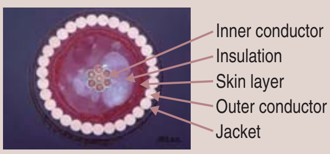
46AWG Micro-miniature Multi-coaxial Cable with High Impedance for Ultrasound Medical Equipment

Item		Unit	Specified value	
Number of cores		–	200	300
Inner conductor	AWG size	–	46	
	Material	–	Silver plated copper alloy	
	Stranding	Strands/mm	7/0.016	
	Diameter	mm	0.048	
Insulation	Material	–	Cellular PFA	
	Thickness	mm	0.05	
Skin layer	Material	–	Polyester tape	
	Thickness	mm	0.01	
Outer conductor	Material	–	Silver plated copper alloy	
	Thickness	mm	0.02	
Jacket	Material	–	Polyester tape	
	Diameter	mm	0.245	
Assembly diameter		mm	4.3	5.3
Braid shield	Material	–	Tinned, spiral wrapped tinsel copper	
	Thickness	mm	0.17	
Sheath	Material	–	PVC	
	Thickness	mm	0.75	
	Diameter	mm	6.3	7.3

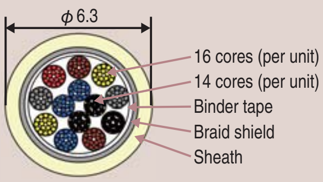
(a)

Item		Unit	Specified value
Inner conductor resistance (20℃)		Ω/km	Max. 15,500
Insulation resistance (20℃)		MΩ-km	Min. 1,000
Dielectric strength	Inner to outer conductor	–	Can withstand AC 500 V for 1 min.
	Shield–ground earth	–	Can withstand AC 4,000 V for 1 min.
Capacitance (1 kHz)		pF/m	Nom. 60
Characteristic impedance (10 MHz)		Ω	Nom. 75
Attenuation (10 MHz)		dB/m	Nom. 0.85

(b)



(c)



(d)

PVC: polyvinyl chloride

Construction and materials (a), electrical properties (b), cross-section of coaxial cable (c), and cross-section of 200-core cable (d)

Obtaining high quality image transmission in ultrasound medical equipment requires probe cables with high impedance, light weight, and more cores.
Hitachi has successfully developed a high-impedance 46AWG (American wire gauge) probe cable with very-small-diameter copper alloy conductors that uses ultra-thin cellular PFA (perfluoroalkoxy) technology.
[Key features]
(1) Enhancements to the cable design have improved bending resistance and increased conductivity.
Use of a copper-alloy conductor allows the same resistance to be achieved with a narrower cable diameter.
(2) Ultra-thin cellular PFA extrusion technology is used to reduce cable diameter and increase impedance.
(3) Improved weight, bending resistance, and flexibility characteristics
[Applications]
Probe cable for ultrasound equipment
(Hitachi Cable Fine-Tech, Ltd.)

New Recycling Technology Using Supercritical Fluid to Produce Thermoplastic Polyethylene from Cross-linked Polyethylene

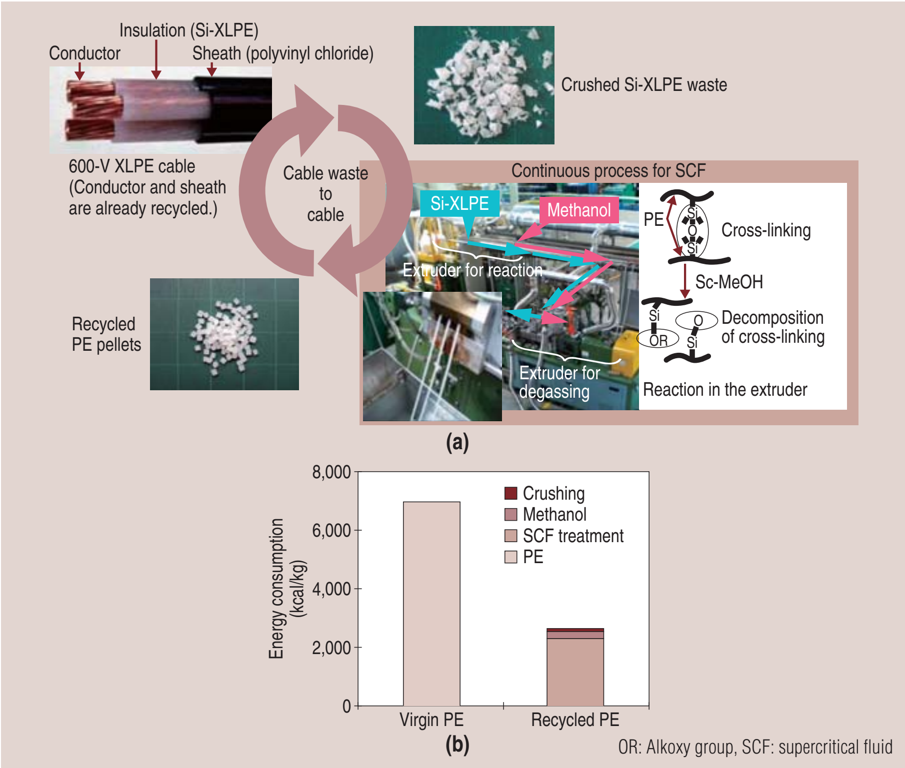
Finding a better scheme for recycling cable insulation is an important issue for the cable industry. Hitachi has developed a new recycling technology that makes cable-to-cable recycling (use of waste cable materials in the production of new cables) possible. The technology can transform Si-XLPE (silane cross-linked polyethylene) into thermoplastic PE (polyethylene) which can be recycled as insulation in new cable. This technology uses Sc-MeOH (supercritical methanol) at a temperature of 330℃ and pressure of 10 MPa.

A new extrusion process was developed to improve the energy efficiency of the supercritical fluid technology. Ordinarily, a liquid pump is used to pressurize the mixture of Si-XLPE and methanol, but this requires that the Si-XLPE be crushed into small particles and dispersed into a volume of methanol 10 times that of the Si-XLPE. This process is very energy-intensive.

In contrast, pressurization of Si-XLPE is much easier in the new process which involves injecting Sc-MeOH into the Si-XLPE. As a result, the volume of methanol required by the process is only 10% of the Si-XLPE volume. Fig. (b) shows the results of an evaluation of the energy consumption for recycled PE which found that recycling of Si-XLPE requires less energy than virgin PE.

These results indicate that the technology can reduce the energy consumption required for the production of polyethylene and in the overall cable production process.

(Hitachi Cable, Ltd.)



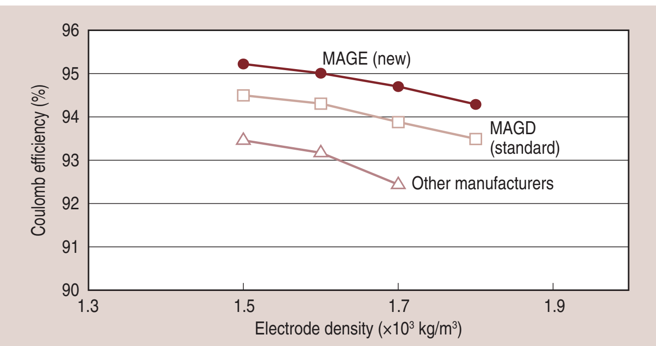
Recycling of silane-XLPE using supercritical methanol (a) and evaluation of energy consumption (b)

Graphite Anode Material for High-energy Lithium Ion Batteries

It is 18 years since lithium-ion batteries first entered commercial use. During this time, the energy density of the batteries has increased by approximately 10% every year and part of this increase has been due to the improved performance of the carbon anode material. Hitachi Chemical Co., Ltd. commercialized a high-performance artificial anode material called MAGD which has a unique particle shape and crystal structure, and which was adopted by several battery makers. However, further improvement was required to meet the demand from mobile devices for higher energy density. One method that was tried was to increase the electrode density of the anode but this tended to decrease the general performance of most parts of the anode. Instead, to achieve the desired result, Hitachi developed a graphite anode by optimizing the micro and macro structure of the graphite.

Figure shows the relation between electrode density and the charge/discharge efficiency for the first cycle. In general, the efficiency decreases with greater electrode density. However, the new MAGE anode material maintains a higher efficiency than MAGD over the entire range of densities and this trend is even extended to past 1.7-g/cm^3 range. This means that cells made using MAGE will have a higher capacity. This performance has seen the MAGE material adopted in high-capacity cylindrical cells (18650 type, 2.6 Ah) and Hitachi Chemical Co., Ltd.'s share of the market for anode materials is now over 45%.

(Hitachi Chemical Co., Ltd.)



Relation between electrode density and first charge-discharge efficiency