INSG Insight

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Some Innovative Uses of Nickel

Introduction

This report, the tenth in the series of INSG Insight briefing reports, provides members with information on innovative use of nickel. As part of the April 2010 Joint Seminar of the three Study Groups, the secretariat delivered a presentation on New and Innovative Uses of Nickel. Several members requested additional information on this topic. This report expands on the presentation and provides contact information for several organizations involved in innovative uses of nickel.

This Insight report looks at innovative projects which use nickel and new and innovative products using nickel. Some of the innovative projects use substantial amounts of nickel. The new products mentioned may not use large quantities of nickel but represent new uses which expand on the traditional uses of nickel and may offer new markets in the future.

Innovative Projects using Nickel

Transportation of liquefied natural gas LNG

Long distance transportation of liquefied natural gas (LNG) by oceangoing ships has increased in volume in recent years. Major gas fields are located in the Persian Gulf, but large consumers are in Europe, the Far East and North America. The long distance transportation required offers technical challenges. Specially designed ships known as Q-Max carriers are used for the transport of LNG. (The term Q-Max is derived from the maximum size of ship able to dock at the LNG terminals in Qatar.) Nickel-containing alloys, in the form of membranes fashioned into massive containers, are utilized for storage of the LNG during the voyage. The first Q-Max vessels entered service in December 2008. These innovative ships carry up to 80 percent more cargo, yet require approximately 40 percent less energy per unit of cargo, than conventional LNG carriers due to economies of scale and efficiency of the engines.

Membranes for the onboard tanks are made from one of two nickel-containing alloys, depending on the shipyard building the vessel. One is 304L stainless which is 1.2 millimetres thick with a corrugated surface that allows for contraction on contact with the LNG. The other is a double membrane of 0.7-mm thick nickel-iron Invar® alloy. With

36% nickel and 64% iron, it has an extremely low thermal expansion and contraction rate. In both cases, the insulated tanks will have the same effect as a gigantic thermos bottle, keeping the contents cold during the voyage. Each on board tank is 48 metres wide, 28 metres high and 58 metres long and lined with the thin metal membrane of nickel-containing alloy.

About 700 tonnes of of the nickel-containing metal are needed for the tanks of a single Q-Max carrier.

Further details can be found in the June 2009 edition of nickel magazine
http://www.nickelinstitute.org/index.cfm/ci_id/19076.htm
and at http://gcaptain.com/maritime/blog/q-max-lng-tankers/

Concentrating Solar Power

A second group of major projects which demands nickel use is that of concentrating solar power (CSP). These plants generate electricity from solar energy by focusing a large area of sunlight onto a small area. The concentrated light is then used as heat or as a heat source for a conventional power plant. A wide range of concentrating technologies exist, each capable of producing high temperatures and correspondingly high thermodynamic efficiencies. In some types of these systems the heat is stored and moved by molten nitrate salt because of its superior heat-transfer and energy-storage capabilities. The energy-storage capability, or thermal storage, allows the system to continue to dispatch electricity during cloudy weather or at night. Nickel-containing stainless steels find applications in these projects. With new innovations in the technology, concentrating solar thermal is becoming increasingly cost-effective.

A study done by Greenpeace International, the European Solar Thermal Electricity Association, and the International Energy Agency's SolarPACES group investigated the potential and future of concentrated solar power. The study suggested that concentrated solar power could account for up to 25% of the world's energy needs by 2050. Estimates are that annual worldwide investment in CSP could grow to as much as 92.5 billion euros by 2050. A copy of the study may be found at http://www.estelasolar.eu/fileadmin/ESTELAdocs/documents/Greenpeace_Concentrating_Solar_Power_2009.pdf

In contrast to photovoltaic systems, CSP plants respond more slowly to changing weather and, especially when combined with thermal energy storage, output from CSP plants is easier to forecast and integrate into the electric grid.

The International Energy Agency has established an international cooperative organization known as Solarpaces to encourage technological development of solar energy. The U.S. Department of Energy also promotes research in solar technology at its National Renewable Energy Laboratory (NREL). More information is available at:
NREL website http://www.nrel.gov/learning/re_csp.html
Solarpaces website http://www.solarpaces.org/CSP_Technology/csp_technology.htm

Offshore Platforms

Nickel-copper alloys find applications in offshore oil and gas platforms because of their excellent resistance to seawater corrosion and resistance to biofouling. While nickel-copper alloys have been used for some time in offshore oil and gas platforms, the projected growth of offshore wind projects offers a substantial new use for these alloys.

The two main alloys finding applications offshore are 90/10 and 70/30. The 70/30 is stronger and has greater resistance to sea water flow; but the 90/10 will provide good service for most applications and being less expensive tends to be more widely used. The two alloys are often used in sheathing of legs and risers on offshore platforms and in boat hulls*. For further information on nickel-copper alloys in offshore platforms see: http://www.copper.org/Applications/cuni/txt_cuni.html*

The construction of offshore wind energy projects appears set to expand rapidly in the next few years. Major projects are planned in Europe and in North America. Europe currently has over 1,500 MW of installed offshore wind turbine capacity and a target to expand this to 40,000 MW by 2020.

The UK Government announced in early 2010 its intention to build the largest offshore wind energy development project in Europe. The plan would see turbines mounted in deeper waters further from the shore than previously attempted. More details are available at:
http://www.euractiv.com/en/energy/uk-plans-unprecedented-offshore-wind-expansion/article-188742

There are several large offshore wind projects proposed in the U.S., including projects in the Northeast and in the Great Lakes. In late 2009 the U.S. government moved forward with legislation to promote innovative offshore wind technologies, including integrated systems, components, structures, materials and infrastructure. It is proposed to spend $50 million annually from FY 2011 through FY 2021 for a cumulative investment of $500 million. More information on this U.S. legislation can be found at:
http://www.congressional.energy.gov/documents/12-8-09_Final_Testimony_(Johnson).pdf

In April 2010 the U.S. Government approved the Cape Wind renewable energy project on federal submerged lands in Nantucket Sound, off the coast of Massachusetts. If it proceeds on schedule, this will be the first U.S. offshore wind project to be built. The project involves the construction of 130 wind turbines to produce up to 420 megawatts of electricity. Construction is anticipated to take about two years.

New Products

Several new and innovative products which contain nickel were mentioned in the Joint Seminar presentation. Two of the products described here are related to energy storage, reflecting the global interest in batteries in hybrid vehicles and in applicances.

Nickel-zinc batteries

Nickel-zinc batteries have been described as "the first new rechargeable battery technology in more than 20 years" by Popular Science magazine. Introduced to the market about a year ago, nickel zinc batteries claim several advantages in comparison to conventional batteries including relatively high energy density, 25 % higher voltage, safety and rapid recharge.

The new batteries are initially targeted toward the digital camera market but are also recommended for use in GPS units, MP3 players and handheld game controlers. The manufacturer, Powergenix, is headquartered in the U.S. but the batteries are manufactured in China. In early 2010, the company announced it is working on a nickel- zinc battery to replace lead-acid batteries in military vehicles. The company also is seeking to develop larger format NiZn batteries for use in hybrid electric vehicles as an alternative to nickel-metal hydride and lithium-ion technologies.
The website of the company is http://www.powergenix.com/

Electrodes of lithium-ion batteries

Lithium-ion batteries are widely used in consumer electronics such as laptop computers and mobile phones because of their energy-to-weight ratio. These batteries are also finding increasing applications in hybrid and electric vehicles where they are often seen as the battery technology likely to become dominant. Different alloys can be used in the electrodes of lithium-ion batteries. While combinations of manganese, cobalt and iron can be used, adding nickel has been shown to improve performance.

Researchers at MIT developed lithium nickel manganese oxide electrodes for a new type of battery that performs better than lithium cobalt oxide (LiCoO2), the current battery electrode material of choice. The ability of lithium nickel manganese oxide to store a lot of energy had been recognized previously, but problems of slow recharging had limited its commercial use. The MIT researchers modified the material's structure to make it capable of charging and discharging more quickly. Using a computer model, they showed that the new material has a very ordered crystalline structure, allowing lithium ions to flow freely between the metal layers of nickel and manganese. The new material could replace the batteries used in hybrid cars today, and could advance plug-in hybrids that run from electricity stored from an overnight charge.

The lithium nickel manganese oxide batteries are potentially less expensive and more stable than lithium cobalt oxide cells. But before the material can be used commercially, the manufacturing process needs to be made less expensive.
Source: MIT Spectrum spring 2008 http://spectrum.mit.edu/issue/2008-spring/battery-technology/

Another alloy that may find an application in lithium-ion battery cathodes is a combination of nickel, cobalt and manganese. Nissan Motor Co. is working on development of a lithium-ion battery using a lithium nickel manganese cobalt oxide cathode (NMC). The new system, which will reportedly offer almost double the capacity of Nissan/AESC's current manganese cell, is slated for deployment in electric vehicles in 2015. Nissan is raising capacity by improving the positive electrode, specifically, using nickel and cobalt, in addition to manganese. The new battery can store about twice as much electricity as batteries with positive electrodes made only from manganese. Nissan estimates that the battery will cost about the same as conventional lithium ion ones to produce.
Source: http://www.greencarcongress.com/2009/Oct. 2009

Lithium-Nickel batteries

Beyond using nickel in lithium-ion batteries, there is the potential to make nickel-lithium batteries. This is a new technology, different from lithium-ion technology.

Researchers at Japan's National Institute of Advanced Industrial Science and Technology created the first Nickel-Lithium battery. Combining the best properties of NiMH batteries and Lithium-ion batteries these batteries are described as having "Ultrahigh" energy density (more than 3.5 times Li-ion batteries) and no risk of catching fire. Issues to be overcome include slow recharge time and the expense to manufacture.

More information can be found at:http://www.allcarselectric.com/blog/1037692_new-nickel-lithium-battery-has-ultra-high-energy-density

Nickel in Catalysts

In chemical reactions, catalyts promote a reaction. A catalyst is not consumed by the reaction itself. Nickel catalysts find a wide range of applications. Activated nickel catalysts are used in:

- pharmaceuticals
- food industries
- in fine and industrial chemicals

Products that are manufactured using materials produced with nickel catalysts include:

- pharmaceutical active substances
- Sweeteners

- Starting materials for polyurethanes for the building materials and automotive sectors

One area of research where nickel catalysts show promising results is in fuel cells. Polymer electrolyte membrane (PEM) fuel cells generate electricity from hydrogen or hydrocarbons using the chemical energy released during oxidation. While conventional power plants convert the energy tied up in hydrocarbons into thermal energy, then into kinetic energy, and then into electrical energy with loss at every stage, fuel cells achieve the conversion in a single step and with much greater efficiency. The reaction within a fuel cell is promoted by a catalyst. Platinum is often used as a catalyst in PEM fuel cells. However, research at the Colorado School of Mines has tested alloys and found that platinum-nickel and platinum-cobalt both show an improvement over pure platinum by a factor of two.

Research on the use of nickel platinum alloys in PEM fuel cells has been conducted at Colorado School of Mines
http://magazine.mines.edu/2009/Fall_Winter/Features/worth.html

Nickel in Nanotechnology

Materials scientists at the Idaho National Labs run by the U.S. Department of Energy have come up with a plastic with embedded nanoantennas that catch heat energy and transform it into electricity. The material employs nickel-chromium alloy, embossed on a plastic backing. The material is a flexible sheet covered with thousands of microscopically small antennae which are able to convert infrared waves into energy. These tiny antennae pick up infrared waves and convert it into electricity, much as photovoltaic cells convert light into electricity. This material can absorb virtually as much energy on a cloudy day as on a clear day. The process also operates at night because the heat soaked up by the Earth during the day is radiated back up into the atmosphere as infrared radiation at night. The material is inexpensive to produce (much less than existing solar panels) and is reckoned to be 80% efficient compared to a typical 20% efficiency achieved by conventional solar panels. One problem still to be overcome with the process is that the infrared rays create alternating currents in the nanoantennas that oscillate trillions of times per second, requiring a rectifier to convert the alternating current to direct current. Currently available rectifiers can't handle such high frequencies. If these technical hurdles can be overcome, nanoantennas have the potential to be a cheaper, more efficient alternative to solar cells.

Further information is available at:
https://inlportal.inl.gov/portal/server.pt?open=514&objID=1555&mode=2&featurestory=DA_144483

A New Reversible Adhesive Using Nickel

A synthetic, fully reversible, switchable, gecko-inspired adhesive has been developed using nickel. The biomimetic system is composed of flexible nickel paddles coated with aligned vertical polymeric nanorods. When subjected to a magnetic field, adhesion decreases by a factor of 40. The ability of the adhesive to controllably stick and release

from a surface could enable technologies from ubiquitous latching systems to climbing microrobotics.
This biomimetic system provides a mechanism for decreasing adhesion using a magnetic field to actuate nickel cantilevers which are coated with aligned vertical polymeric nanorods. When subjected to a magnetic field, the nickel paddles rotate. This rotation conceals the nanostructures on the paddle surface and therefore greatly reduces the available surface area, leading to an adhesion decreased by a factor of 40. The process is complete reversibility, which allows the switching of adhesion countless times; this is the main advantage of this biomimetic approach. Further improving this system in terms of the absolute adhesion strength will lead to a full range of applications. The work was done at Max Planck Institute for Metals Research (Germany) and University of California at Santa Barbara. Source: MaterialsViews.com
Abstract available at: http://www3.interscience.wiley.com/journal/121398427/abstract

Conclusions

Because of its inherent characteristics, nickel is finding innovative applications in a wide range of new products and new technologies. New and innovative uses for nickel have been developed in Europe, North America and Japan. Many of these applications are linked to the need to improve energy efficiency, reduce emissions of green house gases and promote a more sustainable economy.

Comments or Questions

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