New Products Using Ni Alloys

1. INTRODUCTION

Furukawa Techno Materials Co., Ltd. was established in 1958 under its former name, Furukawa Special Metal Industries Co., Ltd. Since that time, based on an integrated manufacturing system for nickel-based special alloys from melting to finished products, we have continued with the development and marketing of products using these alloys. In 1992, with the transfer from Furukawa Electric of its disaster prevention operation, we assumed our present name of Furukawa Techno Materials. The Special Metals Division manufactures Ni-based alloys. By means of our high-accuracy melting and casting technology and control of production processes up to wire drawing, we are manufacturing and marketing the application products described below.

From among our products using Ni alloys, we would like to focus here on two products that are used in the electronics field.

2. PRODUCTS USING Ni-Ti SHAPE-MEMORY ALLOYS

2.1 Ni-Ti Alloys

Ni-Ti alloys are known for their properties of shape-memory and super-elasticity, and many products have been developed using them. By varying the Ni-Ti component ratio slightly from 50:50, it is possible to change the transformation temperature as desired, from 0°C up to about 100°C.

Taking advantage of this temperature characteristic, these alloys can be used in a variety of products, including wire frames for brassieres, mobile phone antennas, eyeglass frames and, more recently, medical devices. Here we will describe an Ni-Ti alloy spring as an example using the property of shape memory in industry.

2.2 Ni-Ti Alloy Spring

Almost all the products that make use of the shape-memory effect are in the form of a coil spring. Springs made of Ni-Ti alloy are used as a combined temperature sensor and actuator. That is to say we utilize the fact that the sensor function operates above the transformation temperature, at the same time producing force to drive the actuator. Since the sensor and actuator are combined, there is no need for such elements as a sequencer, wiring, motor, thermocouples and the like, power supply, etc., thereby effecting savings of space, weight and cost.

Ni-Ti alloy springs, like the general run of coil springs, use a coil molding machine to produce the desired shape. Because of the shape-memory effect, however, spring-back is greater than with ordinary metals, so that it must be deformed to be larger than actual size. Also it is necessary to use a die such that, after molding, shape memory and temperature characteristics are regulated by heat treatment, and shape is also retained during heating. Depending on the product, grinding both ends of the spring, laser marking, hook forming, etc. may be used.

The shape-memory effect is a characteristic whereby deformation imparted in the martensitic phase will return by heating to the original shape in the high-temperature austenitic base material.

2.2.1 Automatic oil volume adjusting unit for Shinkansen driving gear

As operating speeds for Shinkansen trains are increased, there has been a change to aluminum casting to form the gear box for the gear device. In such a case the differing coefficients of thermal expansion for aluminum and steel have an impact on bearing windage, creating the need to suppress temperature rise as much as possible. For this reason an automatic oil volume adjusting unit using Ni-Ti alloy (Figure 1) was developed. With this gear device, rotation of the pinion gear causes a large volume of lubricating oil to be splashed up, providing an adequate supply of oil to the bearings and thereby assuring lubrication at lower temperatures when there is a greater possibility of seizure.

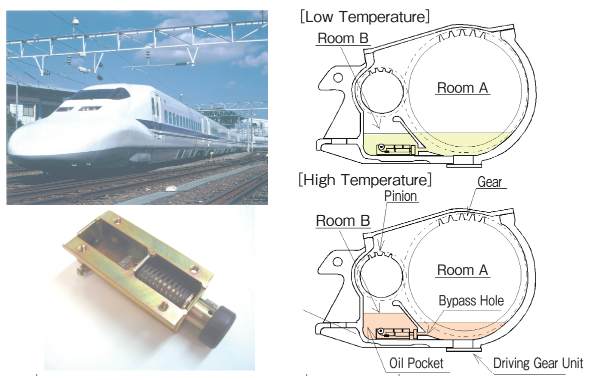

Figure 1 Automatic oil volume adjusting unit for Shinkansen driving gear. (courtesy of Toyo Denki Seizo)

2.2.2 Water mixing valve

A thermostat water mixing valve senses water temperature and automatically controls the temperature of outflow water. The biggest problem with the wax-type water mixing valve was its slow response speed. As for its wax element, paraffin-type wax was enclosed in a copper vessel, one end of which was sealed with a rubber diaphragm. Its actuator operated on volumetric expansion of solid-liquid transformation due to temperature change. Since the response speed was slow, the overshoot temperature was approximately 8°C.

Figure 2 shows a water mixing valve that uses an Ni-Ti coil spring. Turning the temperature control knob changes the total length of the Ni-Ti coil spring and the bias spring thereby controlling the temperature of outflow water. By this means overshoot is kept to less than 2°C, which is not clearly perceptible to a person.

3. EMF MATERIALS (THERMOCOUPLE FILAMENTS)

3.1 Thermocouples

The thermocouple (Figure 3) is a device for measuring temperature that takes advantage of the fact that, when two types of conductor are electrically connected at one end and a difference in temperature is applied between the point of connection and the other end, an electromotive force is generated between the two junctions, in what is known as the Seebeck effect. Table 1 shows some types of thermocouple together with their respective char-

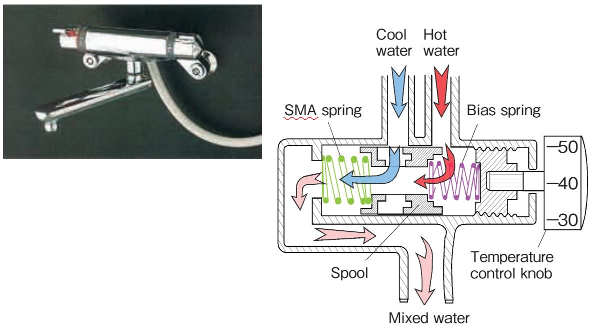

Figure 2 Water mixing valve. (courtesy of TOTO Ltd.)

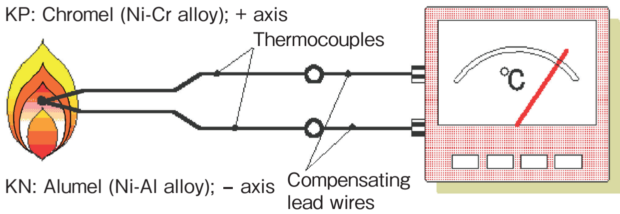

Figure 3 Schematic of thermocouple.

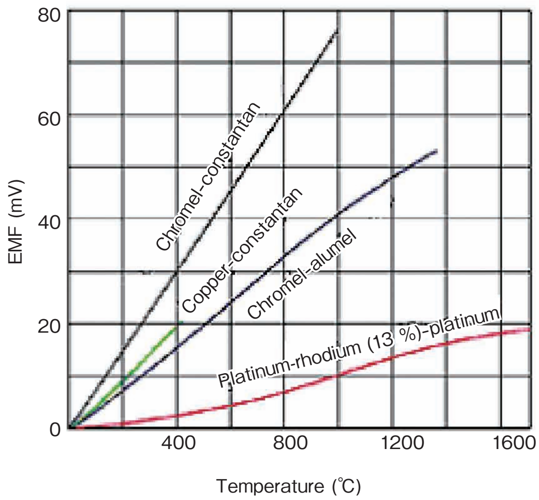

Figure 4 Effect of temperature on EMF.

Table 1 Selected thermocouples and their characteristics.

Code	Component materials		Measuring range	Note
	+Axis	-Axis		
B	Pt-30%Rh	Pt-6%Rh	0°C ~ 1500°C	JIS-designated thermocouple with the highest working temperature
R	Pt-13%Rh	Pt	0°C ~ 1400°C	Used as a standard thermocouple, suitable for measuring high temperatures. EMF is small, so not suitable for measurement at low temperature.
S	Pt-10%Rh	Pt	0°C ~ 1400°C	Suitable for measuring high temperatures. EMF is small, so not suitable for measurement at low temperature.
K	Chromel (Ni-Cr)	Alumel (Ni-Al)	-200°C ~ 1000°C	Linear relationship of temperature vs. thermal EMF. Most widely used in industrial applications.
E	Chromel (Ni-Cr)	Constantan (Cu-Ni)	-200°C ~ 700°C	JIS-designated thermocouple with the highest thermal EMF characteristic. Excellent resistance to oxidation, but not suitable for use in reducing atmospheres.
J	Iron wire (Fe)	Constantan (Cu-Ni)	0°C ~ 600°C	Highest thermal EMF characteristic after Type E, used industrially at mid-range temperatures. Since iron is used it is not suitable for use in oxidizing atmospheres.
T	Copper wire (Cu)	Constantan (Cu-Ni)	-200°C ~ 300°C	Widely used for accurate measurement at low temperatures. Since copper is used it is not suitable for use in oxidizing atmospheres at high temperatures.
N	Nickel-chrome-silicon alloy (Ni-Cr-Si)	Nickel-silicon alloy (Ni-Si)	-200°C ~ 1200°C	Improved version of Type K, excellent for use at high temperatures. (not available from Furukawa)

acteristics. Figure 4 shows the effect of temperature on EMF. Type K is the most widely used thermocouple, and since both terminals are made of nickel-rich alloys, they form one of our main product lines and we have made successive improvements.

The factors with particular influence on the characteristics of thermocouple filaments are variations in the components of the alloys, and control of oxygen and other impurities. Alloy components not only influences the initial characteristics of the thermocouple, but thermal EMF values change over time due to oxidation at high temperatures and concentration of alloy components. This causes service life to be reduced and reliability to be lost.

3.2 Compensating lead wires

The compensating lead wires used to connect the thermocouple and the meter are also of the greatest importance to the reliability of measurement accuracy. Compensating lead wires are made of alloys having substantially the same EMF characteristics as the thermocouple. For this reason the lead wire used must be specifically matched to the type of thermocouple. Note that when we say "having substantially the same EMF as the thermocouple", this applies solely to the range of temperatures at which the compensating lead wire is used (lead wire junction temperature).

4. CONCLUSION

Examples of applications of Ni-Ti alloys as combined temperature sensors/actuators, although widely seen in wet environments, remain relatively little known in general. One factor mitigating against their more general use is that even though the transformation temperature limit is high, it is in the neighborhood of 100°C. In the future we intend to publicize the characteristics and applications of these alloys, and to extend their use in automotive and similar applications. With respect to thermocouple materials, there is an increasing need for higher temperatures and more accurate temperature control with respect to fuel cells and other industrial equipment. Thus thermocouples, which play a crucial role in these temperature control mechanisms are similarly subject to requirements of higher accuracy, higher reliability and longer life.

For many years we have had an integrated production capability, ranging from the casting of various thermocouples and the drawing of filaments right through to manufacturing finished products such as thermocouples with protective tubes, sheathed and PVC coated thermocouples. In recent years we have developed the Type K thermocouples described above, which offer outstanding high-temperature characteristics and high durability, and have been highly evaluated worldwide. We intend to continue our efforts at sales promotion.

For more information, please contact:
Special Metals Sales Dept., Metals Co., Furukawa Electric
TEL: +81-463-21-7316 FAX: +81-463-21-7385