

High Performance Parts Using by Hot Isostatic Pressing Process

1. Introduction

Since the hot isostatic press (HIP) was invented by Battelle Institute, USA, in 1955¹⁾, HIP has been used in diverse fields - to eliminate defects in castings for aircraft, make more dense ceramics, diffusion-bonding of different metals and sinter powders. In Japan, HIP units became more popular in the latter half of the 1980s. Today, they have become the primary process for manufacturing certain industrial products. In 1987, Nippon Steel Corporation built a large-scale HIP unit capable of applying high temperatures and high pressures on the basis of the technology the company introduced from the former National Forge Inc. This HIP unit has been used mainly to commercialize various types of new materials and parts which apply diffusion bonding and powder sintering technologies. The HIP unit is also employed in the commissioned processing business that consists mainly of improving the functions of ceramics. The company is steadily expanding this business, for example by introducing a second HIP unit in 2001.

2. Characteristics

2.1 Characteristics of Nippon Steel's HIP Equipment (hardware)

Photo 1 shows Nippon Steel's HIP equipment, and **Table 1** shows its principal specifications. The main characteristics of the HIP equipment are as follows.

The HIP equipment is among the largest manufacturing facilities of its kind in Japan. It is capable of applying temperatures of up to 1,950 °C and pressures up to 196 MPa.



Photo 1 HIP unit in Tobata HIP Works

Table 1 Facilities in Tobata HIP Works

Maximum weight of work load (ton)		2.5							
Process cycles		Several type of hot isostatic pressing cycle can be used							
Thermocouple type		W-Re5/26							
Temperature distribution		± 10							
Maximum pressure (MPa)		196							
Pressure medium		Ar	Ar, N ₂						
Furnace elements		Mo	Graphite-1		Graphite-2		Graphite-3		
Maximum Temperature (°C)		1250	1300	1500	1850	1850	1950	1700	1950
Work zone (mm)	Diameter	500	440	440	440	350	400	550	400
	Length	1500	1300	1200	700	1000	500	700	500
No. 1 HIP unit									
No. 2 HIP unit		—							

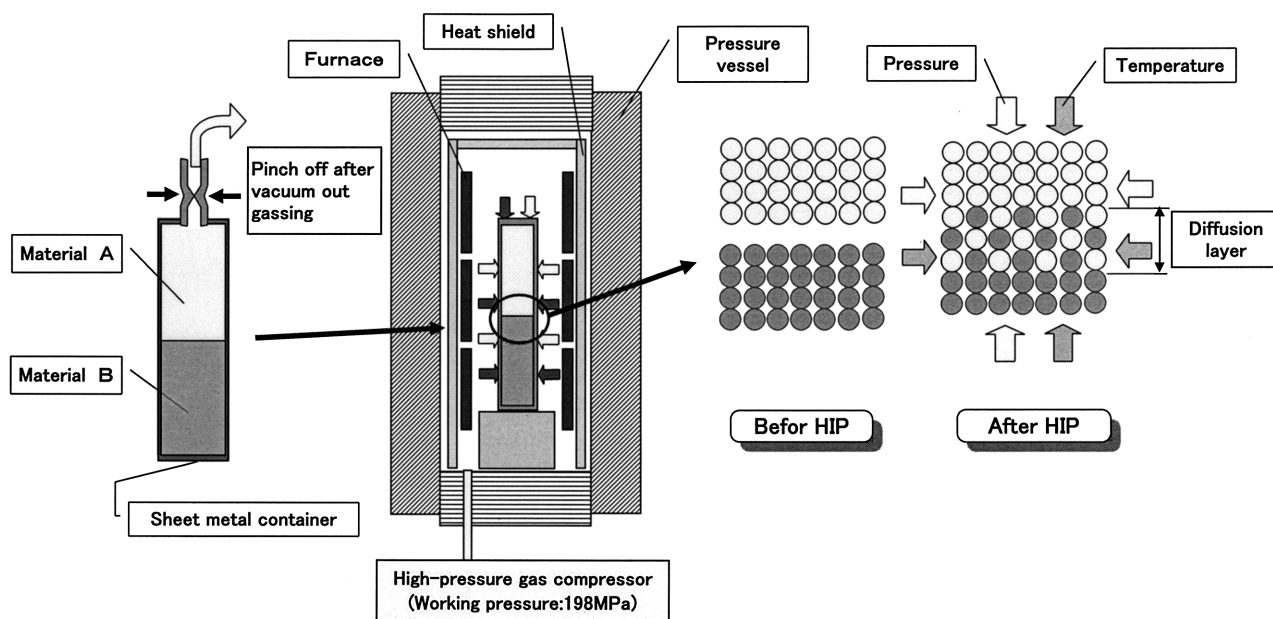


Fig. 1 Diffusion bonding model using by HIP process

So far, the HIP equipment (2 units) has processed 5,000 charges.

2.2 Characteristics of Nippon Steel's HIP Equipment (software)

Fig. 1 shows a model of diffusion bonding for different metals using the HIP process. The metals to be bonded together - metal A and metal B - are previously inserted into a metallic container under a vacuum. In the HIP furnace, a high temperature and inert gas under high pressure are applied to the metallic container. As the applied temperature and pressure are isostatically transferred to metal A and metal B with the metallic container as the medium, the interface between the two metals is metallurgically unified by creep deformation and diffusion. The same principle applies to the diffusion bonding of different types of powders. A dense sinter can be obtained by this process. Since the alloy (sinter) obtained by this HIP process allows for speedy diffusion bonding and densification at a low temperature, the following advantages can be secured.

It is possible to control not only the direct solid-state bonding of different metals but also the formation of an interfacial brittle layer and residual stress by applying a suitable insert. Therefore, high bond strength can be secured.

By applying the HIP powder sintering technology, it is possible to manufacture a dense, homogeneous material even from hard-to-melt metals having a high melting point or high alloys susceptible to segregation.

Since the HIP process is unaffected by the material shape, it is possible to secure uniform product quality even if the product is of a complicated shape.

3. Examples of Products

3.1 Parts for Steelmaking Equipment

Nippon Steel utilizes the above advantages of the HIP process to design various alloys, develop various materials and manufacture steelmaking equipment parts which are used under extreme condi-

tions. Here, as a representative example, a conductor roll (see Photo 2) as used in an electrolytic galvanizing line is discussed.

The conductor roll conducts a pulsed current to a steel sheet which is continuously passed through a very acidic solution of about pH1. Its barrel material is required to have exceptional resistance to corrosion, wear and roughening of the skin. In order to meet all those requirements, the company developed a corrosion- and wear-resistant Ni-Mo-Cr alloy in which a fine, hard intermetallic compound is precipitated by the powder HIP process. So far, the company has manufactured more than 120 conductor rolls of the Ni-Mo-Cr alloy.

3.2 Electronic Parts

(1) Parts made by solid-phase diffusion bonding process

Generally speaking, when it comes to bonding different metals together, it is very important not only to secure sufficient bond strength but also to control the residual stress in the neighborhood of the interface that is caused by the difference in thermal expansion coefficients. By fusing various basic techniques (elasticity-plasticity analysis, interfacial analysis, etc.) and HIP technology, Nippon Steel has developed an original technology for bonding different metals that permits obtaining a solid interface and controlling the residual stress.



Photo 2 EGL conductor roll produced by HIP

Photo 3 shows a cross section of a precision part made of a special copper alloy and carbon steel which were diffusion-bonded. In this example, the bond strength was increased to that of the special copper alloy and the residual stress in the interface was reduced significantly. As a result, perfect cohesion along the entire interface and a fine machining accuracy of 3 μ m or less could be secured.

(2) Sputtering targets

With the rapid progress of digitalization, the demand for sputtering targets is ever expanding and at the same time, the need for larger sputtering targets is increasing. Capitalizing on its HIP sintering technology that has continually been refined to develop better steelmaking parts, Nippon Steel manufactures various types of HIP-sintered targets using pure metals, multi-element composite materials and alloy powders as raw materials.

The main features of the manufacturing process are as follows.

By subjecting a hard-to-sinter material (e.g., metal with a high melting point) to sintering for densification at a relatively low temperature, it is possible to manufacture a fine-grained material with good splash resistance.

The process permits manufacturing multi-element composite materials of uniform dispersion type using the company's original powder mixing technology.

By predicting and controlling the material shrinkage during HIP sintering through use of the company's original profile control technology, it is possible to improve the yield of expensive raw materials.

The process permits HIP sintering of even large materials exceeding 2,000 mm in length.

As an example, a chromium alloy sputtering target manufactured by Nippon Steel is shown in **Photo 4**. The company also manufactures many other types of sputtering targets.

Reference

- 1) Price, E.P. et al.: Metals Handbook. Vol.7, 9th ed., American Society for metals, p.419

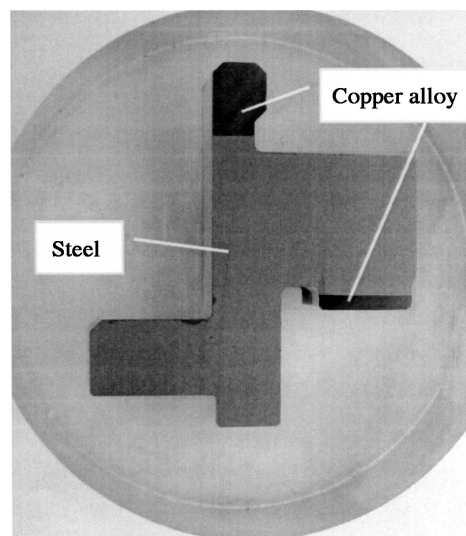


Photo 3 Cross section of diffusion bonding parts with copper alloy and steel

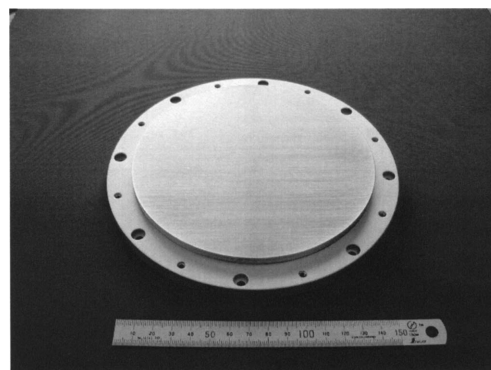


Photo 4 Chromium alloy sputtering target

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