# Improvement of Copper Stave Technology for Extending Service Life of Blast Furnace

## 1. Introduction

In consideration of the vast capital investment required for blast furnace relining, great efforts have been made to extend the campaign life of blast furnaces. The copper stave technology is one of the products of such efforts. A stave is a cooling device having one or more internal water channel, and is installed in numbers on the inner surface of a blast furnace to protect its steel shell and maintain the inner profile. The staves were made conventionally of cast iron, but the viability of manufacturing them of copper, which is excellent in heat conductivity, was confirmed in Germany in the mid-1990s, and thus copper staves have come to be used for many blast furnaces ever since.

The water channel of a copper stave was formed mostly by drilling a hole into a rolled copper plate and welding water pipes at the ends of the hole, and it was formed sometimes by casting using a disposable sand core, however, copper welding work was indispensable in either of the cases. While conventional copper staves proved excellent in the cooling capacity, their manufacture required many work steps, and therefore, they were expensive. For this reason, an economical manufacturing method of copper staves was looked for.

In view of the above, Nippon Steel Corporation has developed and commercialized an economical new type of copper stave having substantially the same cooling capacity as that of conventional ones.

## 2. Characteristics

High reliability and low manufacturing costs are realized by a casting technology to embed a steel pipe in a copper casting applied to the production of the new-type copper stave. This casting technology was developed based on the manufacturing of cast-iron staves, which the company had manufactured for about 40 years.

The new-type copper stave having the embedded steel pipe has the following advantages:

A. High cooling capacity
The casting of high-purity copper ensures a cooling capacity as high as that of a conventional copper stave.

B. High reliability
Embedding a steel pipe in a copper casting eliminates welding of copper in the formation of a water channel and the possibility of water leakage.

C. Wide flexibility in design
The manufacture by casting and embedding a steel pipe allows a far greater flexibility in the stave design than that of conventional copper staves in terms of the stave shape and the arrangement of the water channel.

D. Low costs
The simple manufacturing process realizes lower production costs.

### 2.1 Comparison of cooling capacity with conventional copper staves

**Table 1** shows the temperature analysis results of the new-type and conventional rolled copper staves by three-dimensional FEM.

The analysis assumed a thermal condition severer than that under the maximum instantaneous heat load of a blast furnace. The surface temperature of the new-type cast copper stave under the analysis condition was higher than that of a conventional rolled copper stave by only 70℃; this evidences the high cooling capacity of the new-type copper stave comparable to that of conventional copper staves.

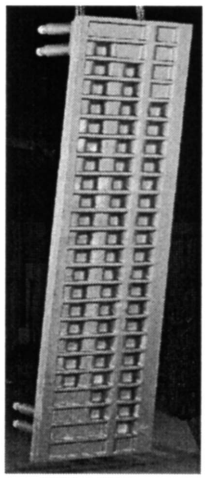

**Fig. 1 New type cast copper stave**

**Table 1 Simulation conditions and results**

| Copper material | New type cast copper | Rolled copper |
|---|---|---|
| Gas temperature of furnace inside (℃) | 1200 (stable condition) | |
| Heat transfer coefficient of furnace inside (kcal/m²h℃) | 300 (constant) | |
| Thermal conductivity of copper body (kcal/mh℃) | 260 | 315 |
| Cast-in pipe material | Carbon steel | None |
| Thermal conductivity of pipe (kcal/mh℃) | 40 | (315) |
| Maximum temperature of surface (℃) | 448 | 378 |
| Heat flux (kW/m²) | 548 | 592 |

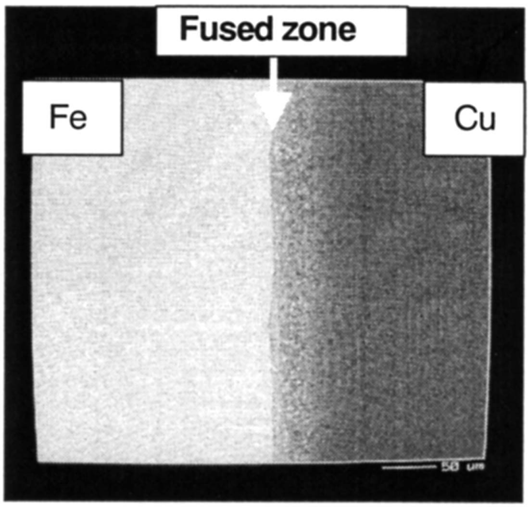


Fig. 2 Analysis of Fe content

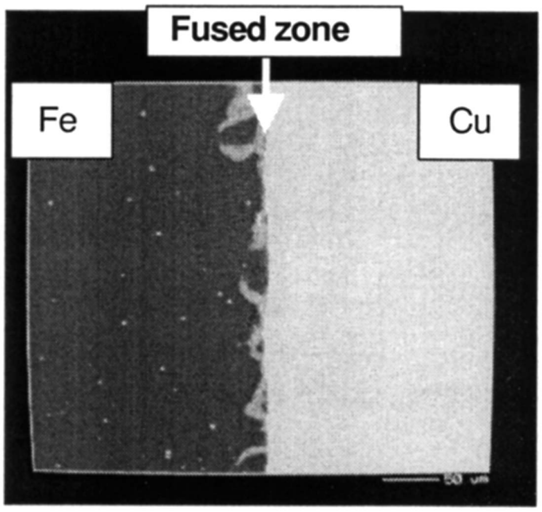


Fig. 3 Analysis of Cu content

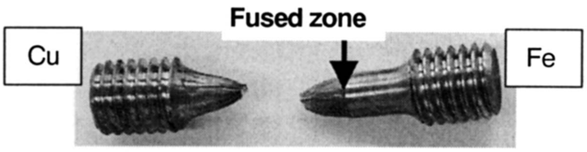


Fig. 4 Tensile test result

**2.2 Technology to embed steel pipe in copper casting (fusion of copper and steel)**

In order for the new-type staves to maintain a high cooling capacity for a long period, it is necessary for the fused joint between the copper body and the embedded steel pipe not to part during blast-furnace operation. Nippon Steel confirmed the metallographic structure of the joint using an electron probe micro analyzer (EPMA); **Figs. 2** and **3** show the results. Fig. 2 shows the distribution of Fe, and Fig. 3 that of Cu. The photomicrographs clearly show how Fe and Cu fuse together through mutual diffusion at the joint.

**Fig. 4** shows a test piece of tensile tests carried out to confirm the strength of the fused joints. The fact that the failure occurred in the copper portion demonstrates that the strength of the fused joint was higher than that of the copper body, and thus we confirmed that the joint would not part during the operation of a blast furnace.

## 3. Applications

Nippon Steel has established the technology to embed a steel pipe in a copper casting, and commercialized a highly reliable and economical new-type cast copper stave. The new-type staves were applied to a Japanese blast furnace for test purposes in April 2002, and thereafter, they were commercially applied to two overseas blast furnaces in August 2004. The cast copper staves have been used successfully and stably for five blast furnaces in the world.

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