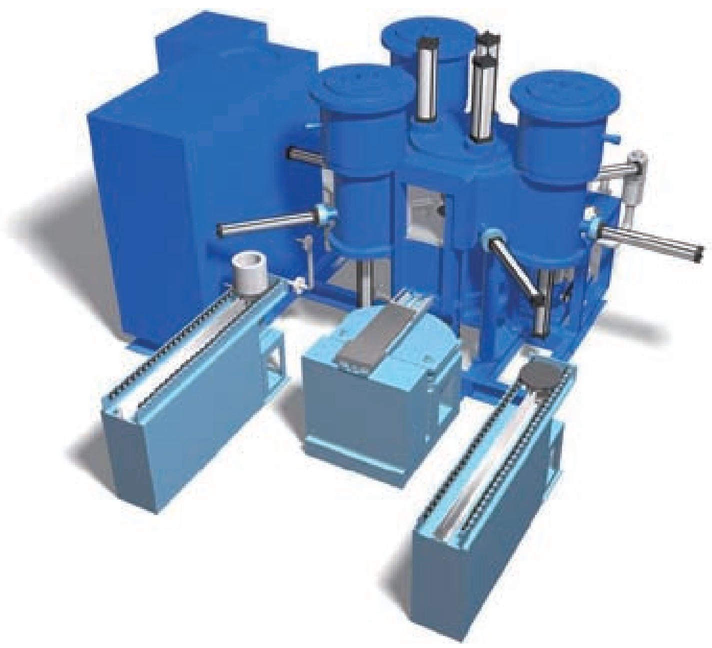
In-Line Heat Treatment!?

Next-generation heat treatment equipment

Conventionally, heat treatment in components manufacturing has been carried out in areas separate from the processing lines. Overturning this common practice, IHI Corporation (IHI) and IHI Machinery and Furnace Co., Ltd. (IMS) have used our unique mist cooling technology to develop in-line heat treatment equipment which can be integrated into processing lines.



In-line heat treatment equipment

Heat treatment processes

There are a wide variety of factories in the industrial world, including those that manufacture food, detergents and other daily necessities as well as those that manufacture chemical products, machine components, automobiles and various other products. Each factory has an industrial engineering flow for each type of product. Flows consist of processes, and among such processes one nearly always finds a process in which heat is applied to products. Such a process is known as a heat treatment process and is very important in industrial engineering. To contribute to society's development through industrial engineering, IHI and IMS have provided and continue to provide numerous heat treatment technologies. This report describes the roles of such technologies in heat treatment processes using the example of a heat treatment process for machine components.

Heat treatment is the process of changing a material's properties through heating and cooling. For metallic components, there are two types of heat treatment : refining and surface modification. Refining is the process of hardening the entire component, removing any distortion that occurred while the material was being processed to be made into a component, and/or homogenizing the composition distribution inside the component to make it less likely to break. Surface modification is the process of modifying the component's surface properties and state to increase the hardness, strength, and/or smoothness of the surface.

The basic steps in heat treatment can be summarized as "heat then cool." Note that what is important in heating is to ensure that the temperature of the entire component — rather than the measured furnace temperature — is close to the desired temperature. Meanwhile, how components are cooled is a very important factor in determining their properties after improvement. Both refining and surface modification often require super-quench (extremely rapid cooling) to harden components.

When components are heated and then cooled, they expand and then contract. In other words, components show some distortion after heat treatment. How to minimize such distortion is the know-how of cooling. Distortion is mainly caused by temperature variations due to differences in the way materials are cooled. When a metal is cooled after reaching a high temperature, it precipitates a hard structure known as martensite. There is a method for bringing an entire workpiece to a uniform temperature just before it is cool enough to form the martensitic structure and then quenching the workpiece. This is the most effective method known for minimizing distortion.

Inside a factory

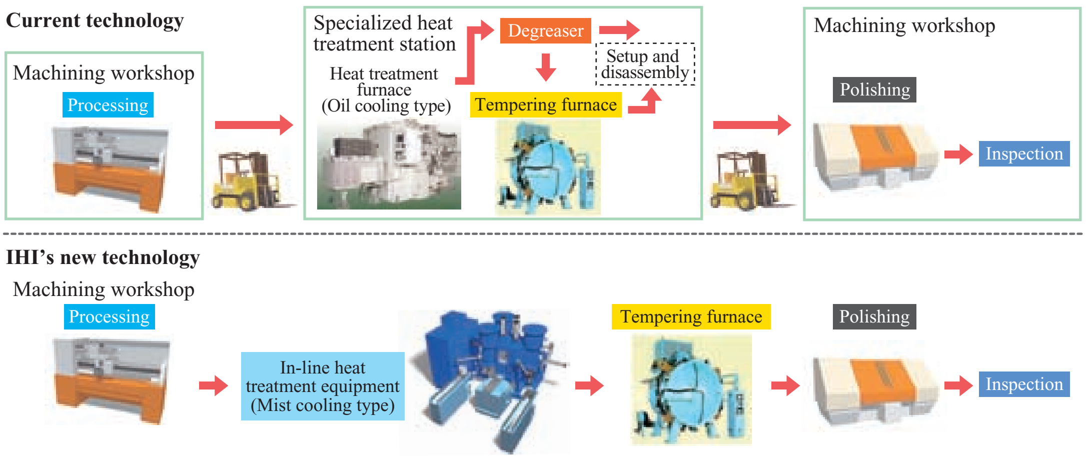
Heat treatment is generally carried out by heating workpieces in a nitrogen atmosphere and then quenching them in oil. Nearly 90% of heat treatment processes use this method, which requires no expensive equipment and provides a very high processing efficiency for mass production. However, there are restrictions regarding where cooling devices can be installed because of a limitation in the Fire Defense Regulation concerning the total amount of oil. For heat-treating in mass production, it is necessary to establish a heat treatment area or station where heat treatment devices can be installed en masse or to outsource the heat treatment process.

However, the rest of the components manufacturing flow is composed of continuous processes, such as cutting, grinding and drilling. Only heat treatment is carried out separately for large quantities of components. In other words, the flow of components is interrupted by the heat treatment process.

Heating and mist cooling

In the mass production era, interruptions to the flow of manufacturing components caused by heat treatment did not result in any problems. The processes before and after heat treatment were carried out in areas separate from the heat treatment area, and the large quantities of components were gathered in the heat treatment area using many lines, where they were then heat-treated collectively before being returned to their respective processes. This method was advantageous in terms of both components flow planning inside the factory and cost. There are demands for integrating heat treatment processes into the processing flow to allow individual products to be processed as well as to facilitate small lot production; however, heretofore there has been no method more cost-effective than heat treatment in a separate area.

Recently, manufacturers have been reviewing the scale of their mass production lines, possibly because of difficulties in maintaining stable production. One automobile manufacturer is considering reducing its basic production lines from a capacity of 100 000 cars to 1/10 of that



Comparison of heat treatment processes

number. There are demands for unorthodox heat treatment processes that can treat individual products as well as small lot products at low cost.

The new concept proposed by IHI

To integrate the heat treatment process into the processing flow, the heat treatment time per product and the total system cost must be reduced more than the conventional type. To this end, IHI has used our unique mist cooling technology to develop in-line heat treatment equipment to realize such an objective.

• Super-quench and cooling speed control with the mist cooling method

The conventional cooling methods for heat treatment equipment are oil and gas cooling implemented using inert gas. Oil cooling provides high cooling performance and can be used for many types of steels. However, it is difficult to flexibly control cooling performance and this may cause problems for workpieces for which small distortion must be minimized. On the contrary, in gas cooling the cooling performance is not always high, but such cooling is excellent for controlling cooling speed and is suitable for processing those workpieces for which there may be problems if there is even slight distortion. The advantages and disadvantages of oil and gas cooling are opposite with respect to the other.

The mist cooling technology developed by IHI sprays two types of mist in a controlled manner.

As in oil cooling, this cooling method uses latent heat. By using water as a refrigerant, the mist cooling method provides cooling performance more than twice that of the oil cooling method. A mist of coarse droplets is used to super-quench the components, while a mist of fine droplets is used to control cooling speed. This cooling technology realizes both super-quench and controllability at levels equivalent to that of gas cooling. In other words, our mist cooling method has the advantages of both oil and gas cooling. In addition, it eliminates the need to use oil in degreasing processes.

This method will enable new cooling methods, such as cooling with a pause as well as pulse cooling with on-and-off spraying at 10-second intervals. The former will enable cooling that brings the entire workpiece to a uniform temperature before the hard martensite structure is deposited. The latter will reduce temperature differences in cooling over the entire workpiece and is considered a promising processing technology for suppressing distortion to low levels.

• Easy layout changes

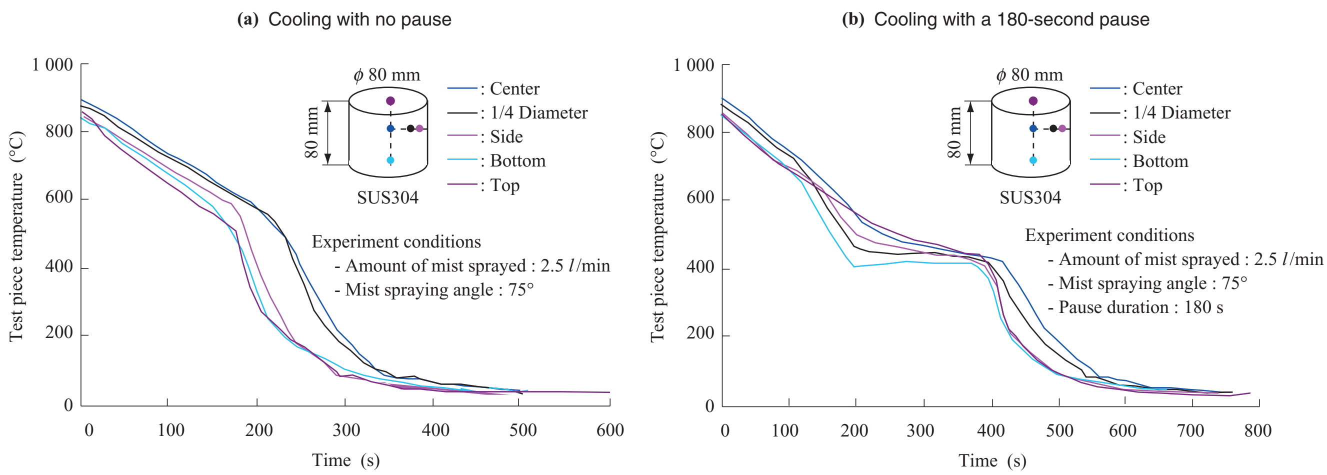
(1) Utility-free

Conventional heat treatment furnaces must connect to supply lines to receive electricity, cooling water, nitrogen gas and acetylene as well as the other reactant gases used to improve surface quality. Our heat treatment system adopts cooling water circulation, including a water cooler, and contains a nitrogen gas generator as well as reactant gas cylinders, thereby eliminating the need to connect to any factory supply lines other than one for the power source.

In addition to the cost of the heat treatment furnace itself, customers have heretofore been required to bear utility expenses, such as those for power source supply construction, cooling water equipment, gas supply equipment and foundation work. With our heat treatment equipment, customers no longer need to worry about construction costs except that of the heat treatment system itself and that for power source supply construction. As the cost of the equipment itself constitutes the majority of the initial cost, it is easier for customers to introduce this equipment.

(2) Portability

Layout planning is an important issue for customers. Conventional equipment cannot be easily relocated. Such relocation results in large expenses for adjustment and reinstallation of utilities. For these reasons, it has been considered difficult to change the layout of



Cooling with a pause

lines containing heat treatment equipment.

However, our heat treatment equipment is assembled onto a base frame that can be easily moved and also requires less installation space, allowing it to be relocated freely.

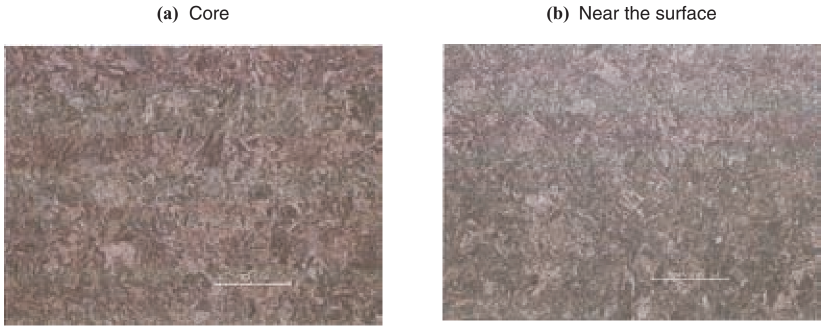
(3) Miniaturization of the system

A multi-chamber structure increases processing speed but also increases the size of the system. We have developed a three-layered structure, which features a heating chamber in the top layer, an intermediate chamber in the middle layer and a cooling chamber in the bottom layer. The three-layer structure complicates the transport mechanism and renders it more likely to cause trouble. To prevent such trouble, we have simplified the moving parts and minimized the functional parts.

For example, we use cylinders for transport such that horizontal movement can be achieved by pushing alone. Each chamber is sealed with a lid connected to an up-and-down cylinder. The heating chamber is sealed with both a vacuum and heat insulation.

This simplified transport mechanism contributes to reductions in the volume of the equipment, evacuation time, and processing time per cycle. As a result, in this system we have decreased the time from the completion of heating to the completion of cooling to approximately 16 seconds. This is more than 3 seconds shorter than the super-quench time requirement of less than 20 seconds. Oil cooling batch equipment can rarely satisfy this time requirement.

Minimizing the number of system components has produced excellent results, including cost reductions.



Composition after SCr420H mist cooling

• Easy maintenance

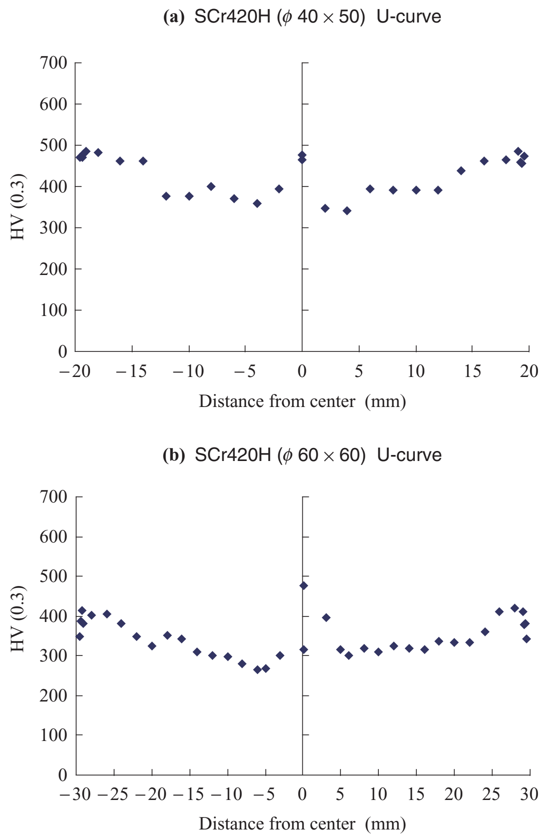
In heat treatment systems, the heating chamber is the main part requiring frequent maintenance. Those of conventional equipment required significant amounts of time and money to implement repair and replacement work. By contrast, this system has a cartridge-type heating chamber as well as a spare heating chamber to facilitate fast replacements.

As described above, our system is superior to conventional equipment in several ways.

The following data was collected from actual use of our heat treatment system.

A super-quench test was conducted on an SCr420H (JIS : Japanese Industrial Standards) specimen, which is a material used for gear parts. The test revealed that the Vickers hardness was approximately 500 HV near the surface and more than 340 HV at the center of the specimen. When we observed the structure, the martensite (quench-hardened layer) was clearly visible near the surface and also in the center. When using the oil cooling method, it is difficult to achieve a Vickers hardness of more than 300 HV and a bainite-type structure is generated rather than martensite. Thus, this test demonstrates the superiority of our mist cooling technology.

With our revolutionary heat treatment system — in-line heat treatment equipment — we will dive into the global market!



Test piece for the hardness test

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