CONTROL SYSTEM FOR VACUUM FURNACES

Inventors: Carl Bergman; Paul Larsson, both of Vasteras, Sweden
Assignee: Allmanna Svenska Elektriska Aktiebolaget, Vasteras, Sweden

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Primary Examiner—Roy N. Envall, Jr.
Attorney—Jennings Bailey, Jr.

ABSTRACT
A control system for an electrically heated furnace for sintering powder bodies, especially bodies of hard metal, has a vacuum pump connected to the interior of the furnace chamber by a suction conduit. The furnace includes a plurality of heating elements for different zones, a temperature sensitive instrument for each zone and a controlled measuring instrument for one of the zones which is the master zone. These instruments are connected to a master regulator for the furnace and slave regulators for the individual zones. A throttle valve in the vacuum conduit, or a controlled tap connected to the vacuum conduit, make it possible to keep the pressure in the furnace constant despite the fact that the pump runs at a constant speed. A pressure-sensing member connected to the vacuum conduit is also connected to the regulators for the heating elements.

10 Claims, 4 Drawing Figures
CONTROL SYSTEM FOR VACUUM FURNACES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a control system for a vacuum furnace for sintering powder bodies, preferably bodies of hard metal. The control system regulates the heating of the furnace during that part of the heating process when degassing takes place. The control system can be used in furnaces of the type described in Swedish published specification No. 333,437.

2. The Prior Art

Bodies of hard metal are manufactured of powder containing carbides of tungsten, tantalum, titanium or vanadium or a mixture of two or more carbides of these substances and a binder which may consist of cobalt and/or nickel, or possibly iron. The total carbide content is usually 70–99 percent and the content of binder 1–30 percent. The powder has a great tendency to absorb or react with the gases in the atmosphere, mainly oxygen (O₂) and water vapor. These substances are removed by degassing during heating, by performing the heating under vacuum. When hard metal is being degassed it is desirable to keep the pressure below a certain level during the entire degassing process. The heating is usually carried out as quickly as possible, i.e., the heating is performed with the highest power or with the highest permissible temperature gradient tolerated by the furnace and workpiece. The gas emission is usually very irregular, however, for hard metal and it has a pronounced maximum which for many compositions is at about 700°C. If, as is desirable, the gases are to be removed without the pressure rising above a certain level, an extremely large and expensive vacuum equipment is necessary with a constant temperature gradient. Too much gas emission may also cause cracks in the workpiece due to the explosive action of the gases. In certain cases, therefore, the power supply has been controlled in accordance with the temperature.

SUMMARY OF THE INVENTION

According to the invention the heating is controlled depending on the pressure in the furnace equipment is provided with pressure-sensing members to sense the pressure in the furnace or in a suction conduit and power regulating members which, in accordance with the output signal from said pressure sensing member, regulate the power supply to the heating element in the furnace. Further characteristics of the invention include a control system for an electrically heated furnace for sintering powder bodies, especially bodies of hard metal, has a vacuum pump connected to the interior of the furnace chamber by a suction conduit. The furnace includes a plurality of heating elements for different zones, a temperature sensitive instrument for each zone and a controlled measuring instrument for one of the zones which is the master zone. These instruments are connected to a master regulator for the furnace and slave regulators for the individual zones. A throttle valve in the vacuum conduit, or a controlled tap connected to the vacuum conduit, make it possible to keep the pressure in the furnace constant despite the fact that the pump runs at a constant speed. A pressure-sensing member connected to the vacuum conduit is also connected to the regulators for the heating elements.

The invention offers several advantages. The gas emission within the temperature range where it is maximum can be limited to a maximum value adapted to a vacuum equipment and the size of the equipment can be considerably reduced, often to only 25 percent of what was previously considered suitable. The control also makes it possible to very accurately determine the pressure within the temperature ranges where the gas emission is slight, so that the pressure can be held permanently above the level at which damaging gasification of components forming the hard metal is obtained, for example cobalt. In many cases it is suitable to keep a pressure of 1.10⁻⁴ torr in the furnace. The loss of cobalt is then negligible. The control system also makes it possible in a controlled manner to regulate the pressure according to the temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described further with reference to the accompanying drawings.

FIG. 1 shows schematically one embodiment of the invention,

FIG. 2 a variant of a regulating means included in the means shown in FIG. 1,

FIG. 3 gas emission from a hard metal body weighing 150 kg when heated with constant supply of power, i.e., with an approximately constant temperature gradient and

FIG. 4 shows the temperature of the workpiece as a function of the time when using the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIGS. 1 and 2, 1 designates a sintering furnace which is sealed with respect to the surroundings so that a vacuum can be maintained therein. The furnace is connected by a conduit 2 to a pump 3. In the furnace is a workpiece 4 which has been formed by compacting powder. The furnace is a 1 is divided into four different zones, each with its own heating element 5a, 5b, 5c and 5d which through a cable 6 are supplied with electric power from a current source, not shown, by way of regulators 7a, 7b, 7c and 7d. The cable contains conductor pairs 6a, 6b, 6c and 6d for the elements in each of the heating zones. The regulator can be constructed of AC regulators with thyristors, for example ASEa type YQNA and of power regulators comprising PI regulators, multipliers and summating means made by ASEa and designated QRTN 201, QRTF 205 and QRTF 201 and measuring units for voltage and current to the heating elements.

One zone in the furnace is the master zone and the others are slave zones. In all the zones there are thermoelements 8a, 8b, 8c and 8d which give the real value to the control equipment for the temperature in the four zones of the furnace. Furthermore, in one zone, the master zone, there is a thermoelement 9 which sets the desired value for the temperature in the slave zones, which is equal to the real value in the master zone. Through conduits 10a, 10b, 10c, 10d and 10e in the conductor bundle 10 the thermoelement is in communication with a temperature regulator 11 which is a master regulator and temperature regulators 12a, 12b and 12c which regulate the temperatures in the different zones of the furnace. As master regulator a regulator can be used which has a scale 13 on which a desired value can be set for the final sintering temperature to
be reached. The real value is obtained from the thermoelement 8d in the master zone in the furnace. A regulator of the make Eurotherm 0°–1800°C type PID can be used. Temperature regulators of the make Eurotherm –3–3mV type PID can be used as slave regulators. The slave regulators regulate the temperature in the respective slave zones so that it is as close to the temperature in the master zone as possible. The desired value for the slave regulators comes from the thermoelement 9 in the master zone and the real value from the thermoelements 8a, 8b and 8c in each zone. A pressure gauge 15, for example of a type having a logarithmic scale, is connected to the conduit 2 and emits a signal dependent on the value shown on the indicator. The signal is supplied to a vacuum regulator 16.

A PI regulator sold by ASEA under the designation QALB may be used. The regulator 16 activates a servomotor 17 in FIG. 1 to set a throttle valve 18 in the vacuum conduit 2 so that the pressure in the furnace 1 can be kept constant in spite of a constant speed of the pump 3. The equipment also includes a regulator 19 which can either be directly actuated by the output signal from the regulator or by a member which senses the position of the valve 18. In this way the regulator senses how much of the pump capacity is being used and delivers a signal dependent on this, this signal being delivered through the conduit 20 to the regulators 7a, 7b, 7c and 7d so that these increase the power supply to the furnace when the pump capacity is not fully exploited. The regulator 19 may be a PI regulator, make ASEA, type QALB 210.

If a furnace with high power is used, the use of all the available power may cause too rapid heating for certain types of material if the capacity of the vacuum pump does not limit the heating rate. It may therefore be suitable to use a power limiter 21 which senses the temperature derivative. This may be provided with a setting device for the desired value. The real value can be obtained by measuring the alteration of resistance in the heat coils in the master zone. When the real value exceeds the desired value the power limiter emits an output signal which is supplied to the regulators 7a, 7b, 7c and 7d so that they decrease the power supplied to the furnace. The power limiter may be built up of resistance measuring units, a motor operating device for reference comparison and a PI regulator, make ASEA, type QALB 210.

If the equipment is to operate at different pressures at different furnace temperatures it may be provided with a program mechanism 24 into which the desired value for the pressure is programmed. This program mechanism delivers an output signal dependent on the program, this signal being supplied to the vacuum regulator 16.

In the embodiment according to FIG. 2 the pressure in the furnace 1 is regulated when the quantity of gas emitted is less than the pump capacity at the desired pressure. Temperature setting of the servomotor 26 of the same type as the servomotor 17. Otherwise the equipment is in agreement with that shown in FIG. 1 and the function is the same.

The curve 30 in FIG. 3 shows the relationship between the quantity of gas emitted from the workpiece per time unit and the temperature upon heating with constant temperature increase per time unit. The time t hours and the temperature TC are indicated along the abscissa. while along the ordinate the gas quantity emitted Q torr l/sec is indicated. As can be seen from the values on the abscissa, the workpiece is being heated 100°C/h. The curve 30 shows that the gas emission has a pronounced maximum at about 750°C. The gases emitted are mainly carbon monoxide (CO), carbon dioxide (CO2), water vapor (H2O) and hydrogen (H2). According to the invention, the heating of the furnace is dependent on the furnace pressure in such a way that the temperature gradient in the range 600°C to 850°C is limited to such a value that the gas emission corresponds to the maximum capacity of the vacuum pump at the furnace pressure selected.

FIG. 4 shows an example of the relationship between the time t in hours and the temperature T in °C. As can be seen from the drawing, the curve representing the temperature gradient is extremely flat in the range between 600°C and 800°C.

We claim:

1. Method of controlling a vacuum furnace system comprising a vacuum furnace having an electrical heating element, regulating means between said element and an electric power source controlling the heating effect of said elements, a vacuum pump, and a suction conduit element having a gas flow regulating means therein joining the furnace to the vacuum pump, which method comprises sensing the vacuum in said suction conduit element and controlling said gas flow regulating means in response to variations of such vacuum to maintain the pressure in the furnace substantially constant.

2. Method according to claim 1, which comprises controlling the heating effect of the furnace elements in response to variations of said vacuum.

3. Method according to claim 1, which comprises supplying gas from a gas source to the conduit element between the furnace and the vacuum pump by a gas flow regulating means, said supplying of gas maintaining the vacuum pressure level within the preselected level.

4. Method according to claim 1, which comprises controlling the heating effect of the furnace elements in response to the setting of the gas flow regulating means.

5. Vacuum furnace equipment which comprises an electrically heated furnace element, a vacuum pump, a suction conduit element joining the furnace to the vacuum pump, heating means in said furnace, a current source, power control equipment arranged between the current source and the furnace element to regulate the heat supplied to the furnace, which includes a pressure sensing member, which senses the pressure in the furnace or conduit element and includes means to deliver an output signal dependent on the pressure, and a gas flow regulating member, and means connected to said pressure sensing member for setting the flow regulating member in a position in accordance with said pressure dependent signal to maintain the vacuum in said suction conduit element substantially constant.

6. Vacuum furnace equipment according to claim 5, including means responsive to said pressure sensing member to control the heat supplied to the furnace.

7. Vacuum furnace equipment according to claim 5, in which said gas flow regulating member comprises a throttling member in the suction conduit, and means setting said throttling member in response to the output...
signal of said pressure sensing member to maintain the pressure in the suction conduit above a minimum pre-selected value.

8. Vacuum furnace equipment according to claim 7, which comprises a unit which senses the setting of the throttling member and includes means to emit an output signal dependent on the setting of said member, which influences the power control equipment regulating the heat effect supplied to the furnace.

9. Vacuum furnace equipment according to claim 5, which comprises a valve with an adjustable throttling member connected to the suction conduit element between the furnace element and the vacuum pump, and means responsive to the output signal of the pressure sensing member to control said throttling member to supply gas to the suction conduit when the pressure in this conduit falls below a minimum preselected value.

10. Vacuum furnace equipment according to claim 5, which comprises a unit which senses the setting of the throttling member and includes means to emit an output signal dependent on the setting of said member, which influences the power control equipment regulating the heat effect supplied to the furnace.