A method for operating a blowing lance for blowing a gas in a metallurgical vessel, wherein the head of the blowing lance includes at least one supersonic nozzle, operating parameter measurement signals used for the purpose of process control are continuously acquired. The inlet pressure and/or the inlet temperature of the gas at the supersonic nozzle and/or the vibration amplitude and/or the vibration frequency of the blowing lance and/or the time at which ignition occurs during the oxygen blowing process and/or the location at which ignition occurs during the oxygen blowing process is detected and/or measured in the head of the lance by a detector or sensor arranged in the head of the lance near the supersonic nozzle during operation of the blowing lance. The measurement signal(s) are transmitted to a control unit connected to the detector or sensor and made available for controlling the operation of the blowing lance.
METHOD FOR OPERATING AN OXYGEN BLOWING LANCE IN A METALLURGICAL VESSEL AND A MEASUREMENT SYSTEM FOR DETERMINING A MEASUREMENT SIGNAL USED IN THE METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority of DE 10 2013 028 079.4, filed May 2, 2013, the priority of this application is hereby claimed and this application is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] The invention pertains to a method for operating a gas-blowing lance, especially an oxygen blowing lance, in a metallurgical vessel, wherein the preferably replaceable head of the blowing lance comprises at least one supersonic nozzle. The invention is also directed to a measurement system for determining measurement signals used during the operation of a gas-blowing lance, especially an oxygen blowing lance, in a metallurgical vessel for the purpose of process control, wherein the measurement system includes a blowing lance, preferably an oxygen blowing lance, with a preferably replaceable head comprising at least one supersonic nozzle, and an evaluation and/or process control unit to receive and process the measurement signals.

[0003] In certain methods of steel production such as the basic oxygen furnace (BOF) method or the argon-oxygen decarburization (AOD) method, it is conventional practice to subject the molten metal in the metallurgical vessel to a flow of a gas, especially a flow of oxygen (O₂) or nitrogen (N₂). For this purpose, a blowing lance is typically lowered into the metallurgical vessel from above, and the gas is blown from it onto the molten metal.

[0004] Gas can also be blown onto the molten metal in processes involving the melting of scrap in an electric-arc furnace (EAF). Gas is usually blown onto the melt at least in the following metallurgical units: BOF converters, AOD converters, the burner and injector nozzles for an electric-arc furnace (EAF) or a CONCARC furnace (CON-converter, ARC-arcing), the burner and injector nozzles for a reducing furnace (SAF-submerged arc furnace), and the nozzles for vacuum treatment systems such as VOD (Vacuum Oxygen Decarburization) or RH (Rahrstahl-Heraeus) units. During the production of steel in a BOF converter, the oxygen is blown onto the metal bath by means of the blowing lance. The head of the lance is typically 1.4-3 m away from the surface of the bath. In the head of a blowing lance of this type there are usually several convergent-divergent nozzles arranged at previously determined angles, which accelerate the gas to supersonic speed. The convergent-divergent nozzles are called “supersonic” or “Laval” nozzles. The gas typically leaves these supersonic nozzles at approximately twice the speed of sound and with a great deal of momentum, whereupon it strikes the metal bath. In the molten metal bath, an oscillating blowing trough is formed, and the blown-on gas ensures an intensive decarburization reaction. A foamy slag forms on the molten metal bath as a result of the gaseous reaction products which rise up.

[0005] According to isentropic stream filament theory, the geometry of a Laval or supersonic nozzle can be designed for only a single value—namely its ideal operating point or “design point”—with respect to any one case of the inlet pressure p₀ of the supersonic nozzle, the inlet temperature T₀ of the nozzle, and the static backpressure pₛ in the metallurgical vessel. The inlet pressure p₀ at this ideal operating point is therefore also called the design pressure, and the inlet temperature T₀ at this ideal operating point is also called the design temperature. Only when the supersonic nozzle is operated at its ideal operating point does the expanded stream of gas lie solidly against the nozzle wall until leaving the nozzle and is the gas accelerated to supersonic speed. As soon as the real flow through the nozzle deviates from the ideal design state or ideal operating point, however, complex flow patterns (diamond wave patterns) in the form of expansion waves or density surges develop both inside and outside the nozzle, which can cause wear of the nozzle edge and lead to premature separation of the jet from the nozzle wall. When the cold gas jet separates from the nozzle wall, a recirculation region develops, which allows hot converter gas to reach the nozzle wall, as a result of which the nozzle suffers wear. To reduce or prevent such wear of the nozzle, the supersonic nozzle must therefore be operated at its operating point as consistently as possible.

[0006] At the tip of a blowing lance there is a replaceable head, which, depending on the application, includes several convergent-divergent supersonic or Laval nozzles to accelerate the gas to supersonic speed. A lance head of this type can be used in the following types of metallurgical vessels or units, among others: in BOF and AOD converters, in SAF (Siemens Injection System) injectors for electric-arc furnaces (EAF), in reducing furnaces (SAF), and in vacuum systems (RH, VOD).

[0007] With respect to both the immediate inlet pressure p₀, i.e., the design pressure of the supersonic nozzle in question, and the inlet temperature T₀, i.e., the associated design temperature of the supersonic nozzle, the geometry of a supersonic or Laval nozzle can be designed for only one optimal operating point of the associated supersonic nozzle at a static backpressure pₛ in the associated metallurgical vessel or unit. Only when both of the process variables, i.e., the design pressure/inlet pressure and the inlet temperature/designtemperature, are maintained during converter operation will the supersonic or Laval nozzle work at its optimal operating point and will the nozzle suffer only minimal wear. Normally, during operation in practice, the upstream pressure pₓ and the volume flow rate of the gas are measured at a valve station where the gas is made available to the blowing lance. These are variables which are usually used in the design of the ultrasonic nozzle. Thus the pressure loss Δpₓ, occurring downstream from the valve station, i.e., in the pipelines and pressure hoses, including the entire blowing lance, is estimated in order to determine the inlet pressure pₓ on the basis of the equation pₓ = p₀ − Δpₓ. The exact pressure loss Δpₓ is difficult to determine theoretically, because to do this it is necessary to perform a compressible pressure loss calculation for all the components, for which purpose the exact layout of the gas lines must be known. For this reason, the process variables pₓ, Tₓ, and pₛ required for nozzle design are always known in the form of approximations. Whether the supersonic or Laval nozzle in question will then in fact work at its design point or ideal operating point during practical use in the steel mill is uncertain. If it does not, the service life of the lance and the stability of the process will become worse.

[0008] During the blowing process, furthermore, the oxygen jet emerging from the blowing lance ignites when it...
makes contact with the liquid pig iron. Because the converter or the metallurgical vessel in question is often filled not only with pig iron but also with coolants such as steel scrap, the oxygen jet emerging from the blowing lance can also be thrown back by the scrap, if its temperature is not high enough for ignition. Thus very often the combustion of the oxygen does not start immediately, i.e., as soon as the blowing process begins. It is extremely important, however, to know the exact time at which ignition occurs, because knowing when the associated decarburization reaction of the molten metal bath begins is vital to the management of the process. Depending on the position of the scrap and the position of the liquid pig iron in the vessel, furthermore, the ignition time can also be different for each nozzle of a multi-hole blowing lance. Differentiated knowledge of the time and place of ignition would make it possible to achieve a correspondingly exact differentiation according to the oxygen that is used and that which is not.

[0009] Finally, a melt-slag emulsion forms in the converter or metallurgical vessel during conventional blowing processes. As a result of the decarburization reaction, the volume of slag increases enormously, so that slag can actually be ejected, which results in an increase in production costs and the risk of a shutdown. During the blowing process, furthermore, slag and molten metal, especially liquid steel, adhere to the blowing lance, which is usually water-cooled. This soot which forms on a blowing lance is undesirable and must be removed, because the overall mass of the blowing lance increases undesirably and the orifices of the supersonic nozzles can become partially clogged.

[0010] A method for operating an oxygen blowing lance in a metallurgical vessel is known from WO 2012/136608 A1, in which the pressure and the temperature are measured at the entrance to a supersonic nozzle of a blowing lance by means of an independent measurement device, which, without external supply lines or feed lines, performs time-resolved pressure and/or temperature measurements and stores the corresponding measurement values. An independent measuring device of this type, also called a "data logger", is installed in the head of the blowing lance and then measures the pressure and/or the temperature over the course of its (battery-operated) service life and stores these data. The independent measurement device is then removed from the head of the lance and, after the measurement data have been read out, a calibration curve is set up. The operation of the oxygen blowing lance, which no longer carries the independent measuring device, is then controlled on the basis of this calibration curve. The disadvantage of using data loggers is that the pressure loss Δp_{in} or the inlet pressure p_{in} present during the course of operation, and the inlet temperature T_{in} present during the course of operation can be determined only after the fact, i.e., after the lance has been taken out. The inlet pressure p_{in} and the inlet temperature T_{in} are not recorded continuously in real time during the blowing process, which means that it is not guaranteed that the supersonic nozzle of the blowing lance will operate at its ideal operating point during the course of operation.

[0011] It is known from practical experience, furthermore, that conventional vibration sensors mounted on the carriage of the lance can be used to detect vibrations of the blowing lance during operation in a metallurgical vessel. The measurement signals thus acquired can be used to draw conclusions concerning the extent to which slag has formed in the metallurgical vessel and the tendency to eject slag. The vibration measurements are made on the carriage, because the vibration sensors are protected from heat there and because the lance can be replaced without having to worry about the sensors. The disadvantage of this solution is that the vibrations measured on the carriage are much weaker than those which occur at the tip of the lance, which is the area most affected by slag formation, and they can also be influenced by variables which are independent of the process. Thus the acquired measurement signals provide only an imprecise picture of the conditions in the area of the tip of the lance. In addition, in the case of measurements which are conducted above the lance dome, the deflections of the blowing lance are not detected in optimal fashion. Finally, in the case of measurement sensors mounted near the blowing lance dome, there is the danger that they can suffer wear and be damaged as a result of the heat to which they are subjected and the effect of the dust acting on them.

[0012] It is known from WO 2011/151143 A2 that a camera comprising CCD sensors or photodiodes placed in the gap between the converter mouth and the exhaust hood can be used to measure the course of the radiation intensity over time and to determine the time at which a previously determined radiation intensity is reached or at which a previously determined increase in radiation intensity occurs, which is the point in time at which the oxygen jet emerging from the blowing lance ignites. This method for determining the time of ignition during the blowing process on the basis of observation, from the outside, of the light emissions from the arcing zone which forms at the time of ignition suffers from the disadvantage that, as a result of the large amount of smoke generated after ignition, information on the ignition process can be obtained only indirectly via the radiation of this smoke. As a result, the reliability of the measurement result is limited. In addition, it is impossible to determine in a differentiated manner the ignition of the individual oxygen jets, usually five to six, emerging from a multi-hole nozzle.

SUMMARY OF THE INVENTION

[0013] The invention is based on the goal of creating a solution which makes possible the continuous detection of operating parameter measurement signals for the purpose of process control during the operation of a gas-blowing lance, especially an oxygen blowing lance, in a metallurgical vessel.

[0014] In a method of the type described in detail above, this goal is achieved according to the invention in that the inlet pressure p_{in} and/or the inlet temperature T_{in} of the gas at the at least one supersonic nozzle and/or the vibration amplitude A and/or the vibration frequency of the blowing lance and/or the time at which ignition occurs during the oxygen blowing process and/or the location at which ignition occurs during the oxygen blowing process is/are detected and/or measured, preferably continuously, during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process, by means of at least one detector or sensor mounted in the head of the lance in the area of the supersonic nozzle, and that the measurement signal(s) thus obtained during operation of the blowing lance is/are transmitted, preferably on-line, to an evaluation and/or process control unit connected to the at least one detector or sensor and made available for the purpose of controlling the operation of the blowing lance.

[0015] In the case of a measurement system of the type described in detail above, the previously mentioned goal is again achieved in that a detector or sensor is mounted in the
head of the lance in the area of the at least one supersonic nozzle, which detector or sensor, is connected by appropriate
transmission means to the evaluation and/or process control unit; detects and/or measures, preferably continuously, in the
head of the lance, during the operation of the blowing lance, especially during a blowing process, preferably an oxygen
blowing process: the inlet pressure $p_{in}$ and/or the inlet temperature $T_{in}$ of the gas at the at least one supersonic nozzle
and/or the vibration amplitude $A$ and/or the vibration frequency $\omega$ of the blowing lance and/or the time at which
ignition occurs during the oxygen blowing process and/or the location at which ignition occurs during the oxygen blowing
process; and transmits, preferably on-line, the measurement signal(s) thus acquired during the operation of the blowing
lance are transmitted to the evaluation and/or process control unit connected to the at least one detector or sensor and makes
them available for the purpose of controlling the operation of the blowing lance.

[0016] The invention thus proceeds from the central idea of
mounting, in the head of the blowing lance, one or more
detectors and/or sensors, which detect operating parameters
by suitable measurement technology during operation, that is
especially during the time that the blowing lance is in its
working or operating position in the metallurgical vessel and
is delivering the gas, and transmit the acquired measurement
signals continuously and on-line during operation to an evalu-
ation and/or process control unit and thus make them avail-
able for the purpose of controlling the operation of the blowing
lance. The measurement signals obtained in this way,
which represent the current operating state in relation to the
operating parameters in question, can then be used directly
for the purpose of process control during ongoing operation
of the blowing lance.

[0017] According to one aspect of the invention, the current
inlet pressure $p_{in}$ of the gas at the entrance to the at least one
supersonic nozzle of the blowing lance is detected and/or
measured by means of at least one detector and/or sensor.
According to a second aspect of the invention, the inlet tem-
perature $T_{in}$ of the gas at the entrance to the at least one
supersonic nozzle of the blowing lance is detected and/or
measured during the blowing process in the head of the lance,
especially continuously, by means of at least one detector
or sensor.

[0018] The operating parameter measurement signals
acquired in the first aspect and/or in the second aspect of the
invention are then transmitted to an evaluation and/or process
control unit directly, preferably on-line, and made available
for the purpose of controlling the operation of the blowing
lance. Thus it is possible, for example, to adjust the valve
pressure $p_v$ and thus regulate the inlet pressure $p_{in}$ currently
being reached at the entrance to the supersonic nozzle in the
head of the lance, this inlet pressure being set to a value which
corresponds at least essentially and/or approximately, i.e.,
with perhaps only a small deviation, to the design pressure $p_0$.
It is therefore possible in this way, by means of the invention,
to operate a supersonic nozzle—and in the case that a detector
or sensor is provided at the entrance to each supersonic nozzle
or Laval nozzle of a blowing lance—to operate all of the
supersonic nozzles at all times at a point which is at least close
to their design point, that is, in or at their ideal operating point.
As a result, stable process conditions for the gas-blowing
process are obtained, especially for oxygen blowing, which
leads to a significant increase in durability and to a longer
service life of the preferably replaceable head of the lance.

Continuous detection of the inlet pressure $p_{in}$ and of the inlet
temperature $T_{in}$ during a blowing process therefore makes it
possible to adjust the pressure $p_{in}$ dynamically at the valve
station during the blowing process, so that the head of the
lance can be operated at its design point and nozzle wear can
be minimized.

[0019] According to the invention, therefore, the current
inlet pressure $p_{in}$ and the current inlet temperature $T_{in}$ present
at the moment in question in the interior of the blowing lance,
that is, in the head of the lance, are measured during the
blowing process. This time-dependent pressure and tempera-
ture measurements are carried out by means of detectors
and/or sensors. The measurement data are transmitted over a
cable or possibly wirelessly to a connected evaluation and/or
process control unit such as a PC. The power required to
operate the detectors and/or sensors can be supplied over the
cable or by a battery or by means of an energy-harvesting
module.

[0020] According to these first two aspects of the invention,
therefore, pressure and possibly temperature sensors for
determining the current inlet pressure $p_{in}$ and the current inlet
temperature $T_{in}$ of the oxygen or of the blowing gas in the
blowing lance are installed in the blowing lance or directly in
the head of the lance. At the same time that the pressure
measurement(s) is/are being carried out in the blowing lance
or in the head of the lance, the pressure or upstream pressure
$p_{ua}$ at the valve station supplying the blowing gas or the
oxygen should also be measured. This makes it possible to
perform an on-line calculation of the pressure loss $\Delta p_{up}=p_{ua}-p_{in}$ and to monitor the deviation of the current inlet
pressure $p_{in}$ and the current inlet temperature $T_{in}$ of the
blowing gas or of the oxygen from the corresponding design vari-
able of the supersonic nozzle in question, namely, from the
design pressure $p_{in}$ and the design temperature $T_{in}$ during
the blowing process. The upstream pressure $p_{ua}$ at the valve
station can thus be adjusted in such a way that an inlet pressure
$p_{ua}$ which corresponds to the design pressure $p_0$ is present at
the entrance to one or all of the supersonic or Laval nozzles
of the blowing lance. This has the effect of minimizing the wear
of the head of the lance. The variable $T_{in}$ is not necessary for
actual operation, but the design temperature $T_{in}$ is required as
a theoretical design variable for the nozzle design. It is not
possible to determine the static pressure $p_{in}$ in the metallur-
gical vessel in this way. For the design of the nozzle, however,
this parameter plays only a subordinate role, because the
pressure $p_{in}$ deviates only slightly from the ambient pressure
of 1.01 bars. The measurement data, i.e., the acquired oper-
ing parameter measurement signals, can be transmitted by
cable or wirelessly, in the latter case by means of a radio
module, for example, installed in the blowing lance, to an
evaluation and/or process control unit such as a computer,
especially a PC, which is available to the operating personnel.
The process variables inlet pressure $p_{in}$ and inlet temperature
$T_{in}$ directly at the Laval nozzle necessary for the correct theo-
etical design of a supersonic nozzle according to the isentro-
ic flow filament theory and the static (back) pressure $p_{in}$
in the metallurgical vessel can now be detected continuously by
means of the inventive method and the inventive measure-
ment system as the actual time-dependent values at the
moment in question. These variables $p_{in}$ and $T_{in}$ can be mea-
sured continuously during the blowing process by means of
the detectors and/or sensors mounted in the head of the lance.
The static pressure $p_{in}$ in the metallurgical vessel plays only a
subordinate role in the design process and thus in the auto-
matic regulation of the operation of the supersonic nozzle(s) in or at their ideal operating point, because it usually fluctuates only moderately around the ambient pressure (1.01 bars = 0.2 bar). When the pressure $p_{out}$ at the valve station is also measured continuously, the pressure loss $\Delta p_{valve}$ between the valve station and entrance of the gas into the head of the blowing lance can also be determined continuously during the blowing process.

[0021] Especially for the realization of the first two aspects of the invention described above, an advantageous embodiment of the inventive method is characterized in that, the inlet pressure $p_{in}$ of the gas at the entrance to the at least one supersonic nozzle is detected and/or measured, especially continuously, by means of at least one pressure sensor mounted in the head of the lance in the area of the at least one supersonic nozzle during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process; and in particular in that the inlet temperature $T_{in}$ of the gas at the entrance to the at least one supersonic nozzle is detected and/or measured, especially continuously, by means of at least one temperature sensor mounted in the head of the lance in the area of the at least one supersonic nozzle during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process.

[0022] It is especially advisable in this case for the feed pressure $p_{in}$ of the gas at a gas feed station installed a certain distance away from the at least one supersonic nozzle to be detected and/or measured simultaneously, especially continuously.

[0023] In a similar manner, an embodiment of the inventive measurement system is characterized in that a pressure sensor is mounted in the head of the lance in the area of the at least one supersonic nozzle, which sensor is connected by appropriate transmission means to the evaluation and/or process control unit; detects and/or measures, especially continuously, the inlet pressure $p_{in}$ of the gas at the entrance to the at least one supersonic nozzle during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process; and transmits, preferably on-line, the measurement signal(s) thus acquired during the operation of the blowing lance to the evaluation and/or process control unit connected to the at least one pressure sensor and thus makes them available for the purpose of controlling the operation of the blowing lance; and/or in that at least one temperature sensor is mounted in the head of the lance in the area of the at least one supersonic nozzle, which sensor is connected by appropriate transmission means to the evaluation and/or process control unit; detects and/or measures, especially continuously, the inlet temperature $T_{in}$ of the gas at the entrance to the at least one supersonic nozzle during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process; and transmits, preferably on-line, the measurement signal(s) thus acquired during the operation of the blowing lance to the evaluation and/or process control unit connected to the at least one pressure sensor and thus makes them available for the purpose of controlling the operation of the blowing lance.

[0024] According to a third aspect of the invention, it is provided that, by means of at least one vibration sensor installed directly in the head of the lance, the vibration amplitude $A$ and/or the vibration frequency $\omega$ of the blowing lance, especially an oxygen blowing lance, is detected and measured during the operation of the blowing lance. As a result of the measurement by means of detectors and/or sensors mounted in the head of the lance, it is possible to achieve a reliable, maintenance-free and efficient vibration measurement at the blowing lance in the metallurgical vessel, especially a converter, so that the increase in the level of the slag and the possible ejection of slag from the vessel can be recognized as well as the presence of skull on the blowing lance. It is therefore possible to measure the vibrations of the blowing lance, especially an oxygen blowing lance or BOF lance, by means of a sensor system mounted inside the blowing lance. The measurement is made in the head of the lance at a point as close as possible to the orifice, that is, at the “low point” of the blowing lance, and as a result the measurement signals are highly significant, in fact more significant than those according to the prior art. The measurement is preferably carried out by means of a wireless sensor system (detectors and/or sensors), wherein, however, a hardwired system or system with transmission lines is also possible. The latter possibility, however, is associated with certain problems, namely, that, if the lower part of the lance, that is, the head of the lance located above the sensor system formed by the detectors and/or sensors, is damaged, the feed lines and possibly the sensor system itself may have to be replaced, which is expensive. In the case of vibration sensors as well, power can be supplied to the wireless sensor system by batteries, accumulators, or an energy-harvesting module.

[0025] For the realization of this third aspect of the present invention, the third aspect is characterized in that the vibration amplitude $A$ and/or the vibration frequency $\omega$ of the blowing lance is detected and/or measured in the head of the lance, especially continuously, by means of at least one vibration sensor mounted in the head of the lance in the area of the at least one supersonic nozzle during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process.

[0026] In a similar manner, it is provided in accordance with an embodiment of the measurement system, that at least one vibration sensor is mounted in the head of the lance in the area of the at least one supersonic nozzle, which sensor is connected by appropriate transmission lines to the evaluation and/or process control unit; detects and/or measures in the head of the lance, preferably continuously, the vibration amplitude $A$ and/or the vibration frequency $\omega$ of the blowing lance during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process; and transmits, preferably on-line, the measurement signal(s) thus acquired during the operation of the blowing lance to the evaluation and/or process control unit connected to the at least one vibration sensor and thus makes them available for the purpose of controlling the operation of the blowing lance.

[0027] By means of the vibration sensors mounted in the head of the lance to determine the vibration amplitude $A$ and/or the vibration frequency $\omega$ of a gas blowing lance, especially an oxygen blowing lance, it is possible to measure the amplitude and/or frequency of the vibrations continuously and, in association with that, to monitor the height of the slag in the converter or metallurgical vessel. When the level of the slag is low, the frequency spectrum is dominated by the natural harmonic vibrations of the blowing lance. When the level of the slag is high, the lance is enclosed by the slag. A stochastic component of the vibrations, caused by the slag, now develops and increases. The formation of skull on the tip
of the lance also changes the mass of the lance. The amount of adhering slag or steel can be estimated by measuring the natural frequencies, and an early decision can be made about replacing the lance. The measured vibration amplitudes $A$ and/or vibration frequencies $\omega$ are also transmitted, especially in a wireless manner and in particular by radio, to the evaluation and/or process control unit, especially a computer, preferably a PC, which is available for the operator for use. At least one radio module is assigned to the associated vibration sensor or sensors and is connected to it or to them.

According to a fourth aspect, photodiodes, photodetectors, or light sensors, especially CCD (Charge-Coupled Device) sensors or CMOS (Complementary Metal Oxide Semiconductors; metal-oxide semiconductors) are arranged inside the head of the lance to detect, in the head of the lance, the optical emissions which occur during a blowing process upon ignition of the oxygen jets. This makes it possible to detect in real time when an oxygen blowing lance ignites, wherein the photodiode or the at least one optical sensor or detector is arranged inside the blowing lance in such a way that the optical emissions of the arcing zone caused by the ignition of the oxygen jets can be detected by the sensor inside the blowing lance. The measurement signals thus obtained can then be subjected to further processing in the assigned evaluation and/or process control unit. In this case as well, the measurement signals and data are transmitted over a cable or wirelessly by radio. Again, power can be supplied to the wireless optical sensor system by means of batteries, accumulators, or an energy-harvesting module.

The light sensors (CCD sensors, CMOS sensors) or a camera comprising such sensors, diodes, or detectors for determining the time when ignition occurs during the oxygen blowing process are installed directly in the head of the lance. It is provided in this case that one or more light sensors are arranged in the interior of the blowing lance, preferably in the head of the lance, in order that the exact time of ignition can be determined. The optical emission associated with the ignition of the oxygen jets is detected by the sensor or sensors inside the head of the blowing lance, and the measurement signals and the associated information thus acquired are transmitted to the evaluation and/or process control unit, especially to a computer or PC, either in hardwired fashion over a cable or wirelessly by radio.

To implement the above-described fourth aspect of the invention, one embodiment of the method is characterized in that the optical emission(s) which occur when the oxygen jets are ignited is/are detected in the head of the lance by means of at least one light sensor, especially a CCD or CMOS sensor, or by at least one camera equipped with such a sensor arranged in the head of the lance in the area of the at least one supersonic nozzle during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process. In an embodiment of the measurement system, it is similarly provided that at least one light sensor, especially a CCS or CMOS sensor, or at least one camera equipped with such a sensor is arranged in the head of the lance in the area of at least one supersonic nozzle, which sensor or sensor-equipped camera is connected by appropriate transmission means to the evaluation and/or process control unit; detects and/or measures in the head of the lance the optical emission(s) which occur when the oxygen jets ignite during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process, and transmits, preferably on-line, the measurement signal(s) thus obtained during the operation of the blowing lance to the evaluation and/or process control unit connected to the at least one light sensor, especially a CCS or CMOS sensor, or to the at least one camera and thus makes them available for the purpose of controlling the operation of the blowing lance.

With the inventive embodiment according to the fourth aspect, an accurate determination of the time of ignition can be made; and if a sensor/detector is assigned to each supersonic nozzle of a multi-hole blowing lance, the ignition time can also be differentiated with respect to the individual oxygen jets.

A fifth aspect of the invention has the goal of detecting and/or measuring the place where ignition occurs during the oxygen blowing process. In this regard, light sensors, especially CCD or CMOS sensors or detectors, photodiodes, or photodetectors or a camera equipped with such components should be arranged directly in the head of the lance, and the sensor surfaces receiving the incident light should be aimed optically through an orifice of the blowing lance and especially the orifice of an assigned supersonic nozzle. The light sensors installed in this way in the head of the lance serve to determine the place where ignition occurs during the oxygen blowing process. When several properly aimed optical sensors are used or when a camera is used, it is possible to determine not only the time of ignition but therefore also, in the case of the multi-hole blowing lances conventionally used, the places where ignition occurs. Because, in the normal case, the head of a blowing lance contains several supersonic nozzles, a light sensor can be assigned to each nozzle. In this way, it becomes possible to recognize the ignitions of the oxygen jets in a differentiated manner, because, when an oxygen jet strikes the liquid pig iron, an arcing zone is formed, whereas, when the arcing zone strikes scrap, no arcing zone is formed, so that the areas detected in the case in question will differ with respect to their optical emission(s). The advantage of the installation in the interior of the blowing lance is that the sighting opening of the camera or of the sensors is continuously flushed clean by the flow of oxygen. The measurement signals obtained can then be transmitted over a cable or by radio to the evaluation and/or process control unit, especially a computer or PC, and used there for the purpose of process control. This fifth aspect of the invention therefore consists in detecting the place where the oxygen jet ignites by installing an optical sensor or detector inside the blowing lance in such a way that it can detect, from inside the blowing lance, the optical emissions of the arcing zone caused by the ignition of the oxygen jets, and thus so that the measurement signals or data thus obtained can then be subjected to further processing in the assigned evaluation and/or process control unit. The data are transmitted either in hardwired fashion over a cable or in wireless fashion by radio. In this case as well, the power can be supplied to the wireless optical sensor system by means of batteries, accumulators, or an energy-harvesting module, wherein the detector(s) or sensor(s) is/are supplied with electric power by means of a energy-harvesting module installed in the blowing lance.

To realize this fifth aspect of the invention, the inventive method is characterized in that the optical emissions occurring outside the lance are detected in the head of the lance by means of at least one light sensor, especially a CCD or CMOS sensor, or at least one camera equipped such a sensor arranged in the head of the lance in the area of the at least one supersonic nozzle and aimed optically through an
orifice of the blowing lance during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process.

[0034] The measurement system for realizing this fifth aspect of the invention is characterized similarly in that at least one light sensor, especially a CCD or CMOS sensor, or at least one sensor-equipped camera is arranged in the head of the lance, in the area of the at least one supersonic nozzle, which sensor or sensor-equipped camera is optically aimed directly through an orifice of the blowing lance; is connected in hardwired fashion to the evaluation and/or process control unit; detects and/or measures, in the head of the lance, the optical emissions occurring outside the blowing lance during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process; and transmits, preferably on-line, the measurement signal(s) thus obtained during the operation of the blowing lance to the evaluation and/or process control unit connected to the at least one light sensor or the at least one camera and makes them available for the purpose of controlling the operation of the blowing lance.

[0035] In the case of a multi-hole lance comprising several supersonic nozzles, it is especially advisable for at least one detector or sensor to be assigned to each supersonic nozzle or assigned in the case of a corresponding blowing lance of the measurement system.

[0036] According to a further elaboration of the method and of the measurement system, one or more detectors or sensors from the group consisting of pressure sensors, temperature sensors, vibration sensors, and/or light sensors are assigned to the blowing lance, or the blowing lance comprises one or more detectors or sensors from the group consisting of pressure sensors, temperature sensors, vibration sensors, and/or light sensors.

[0037] The transmission of the measurement data to the evaluation unit such as a PC and the power supply to the measuring sensors or detectors can be provided over a cable, for example. When the blowing lance is replaced, however, the head of the lance or the lower part of the lance is usually cut off because of wear, the presence of skull, or damage. In the case of a hardwired power supply, there is the danger that the cable will also be cut. A wireless method of measurement signal and measurement data transmission is therefore especially advantageous. This can be done, for example, by means of radio transmission. In this case, the sensor or detector in question can be equipped with a battery or an energy-harvesting module to guarantee the power supply. In a further elaboration, therefore, the inventive method is characterized in that the measurement signal(s) originating from the detector and/or sensor is/are transmitted to the evaluation and/or process control unit in hardwired fashion by means of a cable arranged in or on the blowing lance or in wireless fashion by means of a radio module connected to the detector and/or sensor and arranged in the blowing lance.

[0038] It is also advantageous in this case for the detector(s) or sensor(s) to be supplied with electric power by an energy-harvesting module arranged in the blowing lance.

[0039] In an advantageous elaboration of the invention, the measurement system is characterized, finally, in that the detector(s) or sensor(s) is/are connected in hardwired fashion to the evaluation and/or process control unit by means of a cable arranged in the blowing lance or in wireless fashion by means of a radio module arranged in the blowing lance, wherein in particular the detector(s) or sensor(s) connected in wireless fashion to the evaluation and/or process control unit is/are preferably connected to an energy-harvesting module arranged in the blowing lance.

[0040] The above-mentioned detectors and/or sensors can thus be equipped with a wireless data and/or power transmission system inside the blowing lance. As a result, the effort required to install new sensors and/or detectors is less than it would be in the case of hardwired or cables sensors or detectors. This reduced effort for reinstallation is especially advantageous when the blowing lance must be cut off above the sensors because of, for example, the presence of skull on the blowing lance, so that a new lance part can be welded on. The sensors, designed as wireless components in this sense, can be equipped with an energy-harvesting source or energy-harvesting module to avoid the need to replace the power source. A generator, for example, can serve as an energy source in the lance, which extracts its energy from the flow of gas or from the vibration of the lance. In cases where vibrations are being measured and an energy-harvesting module is used, the energy can be derived from the vibrations of the blowing lance.

[0041] When several properly oriented optical sensors or detectors or a camera equipped with such sensors is used, it is possible to determine not only the time when ignition occurs but also, in the case of the conventional multi-hole blowing lances, the locations where the ignitions occur. Because the head of a blowing lance usually contains several supersonic nozzles, a corresponding light sensor or detector can be assigned to each supersonic nozzle. In this way, there is the possibility of detecting the ignitions of the oxygen jets in a differentiated manner.

[0042] With the help of the evaluation and/or process control unit, the measurement signals detected or measured and determined by the sensors and/or detectors or the data derived from those signals can be evaluated and used for the purpose of controlling the process and the operation of the model on which the process is based.

[0043] The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of the disclosure. For a better understanding of the invention, its operating advantages, specific objects attained by its use, reference should be had to the drawings and descriptive matter in which there are illustrated and described preferred embodiments of the invention.

**BRIEF DESCRIPTION OF THE DRAWING**

[0044] In the drawing:

[0045] FIG. 1 shows a schematic cross section of a blowing lance with an associated metallurgical vessel and gas supply;

[0046] FIG. 2 shows a schematic diagram of the area of the head of a lance with a hardwired sensor arranged therein;

[0047] FIG. 3 shows a schematic diagram of the area of the head of a lance with a wireless sensor arranged therein; and

[0048] FIG. 4 shows a schematic diagram of a sensor system for detecting the locations where the ignitions occur.

**DETAILED DESCRIPTION OF THE INVENTION**

[0049] FIG. 1 shows a blowing lance 2, especially an oxygen blowing lance, which has been introduced from above into a metallurgical vessel 1 designed as a converter; when in operation in the working position shown in FIG. 1, the lance blows gas onto a metal bath 3 in the metallurgical vessel 1. At the end of the blowing lance 2 located at the bottom in the
diagram of FIG. 1, a replaceable head 4 is mounted, which forms the tip of the blowing lance. Inside the head 4 of the lance are several supersonic nozzles, which are indicated by the dashes proceeding from the head 4 of the lance.

Through a feed line 5 consisting of pipes or hoses, the blowing lance 2 is connected to a gas feed station 6, which comprises a valve station 7, by means of which the gas 8 to be blown out from the head 4 of the lance can be supplied in regulated fashion to the feed line 5. In the exemplary embodiment, the gas 8 is a gas used in oxygen blowing processes, that is, oxygen or an oxygen-containing gas mixture such as an argon-oxygen gas. It is also possible, however, to supply nitrogen or a nitrogen-containing gas mixture to the feed line 5.

When gas 8 is flowing into the feed line 5, a pressure \( p_{\text{up}} \) called the upstream pressure, can be adjusted and automatically regulated at the valve station 7. The pressure \( p_{\text{up}} \) is measured continuously during the operation of the blowing lance 2 for process control purposes.

In the metallurgical vessel 1 or converter, a static (back)pressure \( p_0 \) is present during the operation of the blowing lance 2. The individual supersonic or Laval nozzles in the head 4 of the lance are designed for an ideal operating point (design point), at which the design pressure \( p_d \) and the design temperature \( T_d \) are present at the entrance to each of the supersonic nozzles. During the operation of the blowing lance 2, the inlet pressures \( p_{\text{in}} \) and the individual inlet temperatures \( T_{\text{in}} \) currently prevailing at the entrance to each of the supersonic or Laval nozzles are continuously detected and/or measured. Because the pressure loss \( \Delta p_{\text{up}} \) from the valve station to the entrance area of each supersonic nozzle is determined by the relationship \( \Delta p_{\text{up}} = p_{\text{up}} - p_0 \), it is possible to perform an on-line calculation of the pressure loss \( \Delta p_{\text{up}} \) and thus to monitor the deviation between the inlet pressure \( p_{\text{in}} \) and the inlet temperature \( T_{\text{in}} \) of the oxygen supplied to the individual supersonic nozzles from the design variables \( p_d \) and \( T_d \) during the blowing process. In this way, the upstream pressure \( p_{\text{up}} \) at the valve station 7 can be adjusted in such a way that the correct design pressure \( p_d \) is present at the inlet pressure \( p_{\text{in}} \) at the entrance to each supersonic or Laval nozzle.

The inlet pressure \( p_{\text{in}} \) and the inlet temperature \( T_{\text{in}} \) are acquired by means of a detector or sensor 9a, 9b, which is arranged in head 4 of the lance in such a way that it detects and/or measures, at the entrance to all or at least one of the supersonic nozzles assigned to it, the inlet pressure \( p_{\text{in}} \) and/or the inlet temperature \( T_{\text{in}} \) of the gas 8 to be blown. If a detector or sensor 9a, 9b is assigned to the entrance of each supersonic nozzle, then the number of detectors and/or sensors 9a, 9b arranged in the head 4 of the lance will be the same as the number of Laval or supersonic nozzles.

FIGS. 2 and 3 show schematically the arrangement of the least one sensor or detector 9a, 9b. FIG. 2 shows a detector or sensor 9a arranged by means of a bracket 10 in the head 4 of the lance; the sensor or detector is connected to an evaluation and/or control unit (not shown) by a transmission line, especially a cable 11.

In the case of the exemplary embodiment according to FIG. 3, a detector or sensor 9b is used, which is connected to an assigned radio module 12, by means of which the measurement signals detected and/or measured by the detector or sensor 9b are transmitted in wireless fashion, especially by radio, to the evaluation and/or control unit (not shown). The radio module 12 comprises here a power source in the form of a battery or energy-harvesting module.

The measurement signals acquired by means of the at least one detector or sensor 9a, 9b are transmitted continuously, on-line, during the operation of the blowing lance 4 in the blowing process to the connected evaluation and/or process control unit (not shown), where they are made available for the purpose of controlling the operation of the blowing lance 2 and then used in fact to control the blowing process.

The at least one detector or sensor 9a, 9b is a pressure sensor for determining the inlet pressure \( p_{\text{in}} \). It is also quite possible, however, for several detectors or sensors 9a, 9b or multi-function detectors or sensors to be arranged in the head 4 of the lance; these components being selected from the group consisting of pressure sensors, temperature sensors, vibration sensors, and/or light sensors.

Vibration sensors installed in the head 4 of the lance detect and/or measure the vibration amplitude \( A \) and/or the vibration frequency \( \omega \) of the blowing lance 2.

Detectors or sensors 9a, 9b designed as light sensors detect the optical emissions caused by the ignition of oxygen jets as the oxygen is being blown into the vessel. The light sensors can be CCD sensors, CMOS sensors, photodiodes, photodetectors, or cameras equipped with these sensors or detectors. In the head 4 of the lance, they detect the radiation or optical emission occurring when an oxygen jet ignites; or they detect, in the head 4 of the lance, the change in the radiation intensity or in the optical emissions occurring when an oxygen jet ignites. The individual detector or sensor 9a, 9b designed in the form of a light sensor can also be equipped and aimed in such a way that, as indicated schematically in FIG. 4, it can detect or recognize the location where the ignition occurs, i.e. the ignition spot 13. In cases where at least one, preferably several, aimed optical sensors 9a, 9b are used or when a camera is used as an optical sensor system, it is possible to determine not only the time when ignition occurs but also, in the case of conventionally used multi-orifice blowing lance, the ignition spot 13. Here, use is made of the effect that, when an oxygen jet 8b emerging from the head 4 of the lance strikes the metal bath 3 in the metallurgical vessel 1, an arcing zone is formed upon ignition of the oxygen jet 8b at the ignition spot 13, whereas, when an oxygen jet 8a strikes scrap 14 present in the metal bath 3, an arcing zone is not formed. The point of contact of the oxygen jet 8a then shows a different radiation intensity and thus optical emission than the contact point of the oxygen jet 8a. Advantage can be taken of this effect to detect the arcing zone and thus the ignition spot 13.

While specific embodiments of the invention have been shown and described in detail to illustrate the inventive principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

We claim:

1. A method for operating a blowing lance for blowing a gas in a metallurgical vessel, wherein a replaceable head of the blowing lance comprises at least one supersonic nozzle, the method comprising the steps of: detecting and/or measuring inlet pressure and/or inlet temperature of the gas at the at least one supersonic nozzle and/or vibration amplitude and/or vibration frequency of the blowing lance and/or a time at which ignition occurs during an oxygen blowing process and/or a location at which ignition occurs during the oxygen blowing process, in the head of the lance with a detector or sensor arranged in the head of the lance in an area of the supersonic nozzle during operation of the blowing lance; and transmitting measurement signal(s) thus acquired during the
operation of the blowing lance, to an evaluation and/or process control unit connected to the detector or sensor and making the signals available for controlling the operation of the blowing lance.

2. The method according to claim 1, wherein the inlet pressure of the gas at an entrance to the at least one supersonic nozzle is detected and/or measured in the head of the lance by at least one pressure sensor arranged in the head of the lance in the area of the at least one supersonic nozzle during operation of the blowing lance.

3. The method according to claim 1, wherein the inlet temperature of the gas at an entrance to the at least one supersonic nozzle is detected and/or measured in the head of the lance by at least one temperature sensor arranged in the head of the lance in the area of the at least one supersonic nozzle during the operation of the blowing lance, especially during a blowing process, preferably an oxygen blowing process.

4. The method according to claim 1, further comprising simultaneously detecting and/or measuring feed pressure of the gas at a gas feed station located a distance away from the at least one supersonic nozzle.

5. The method according to claim 1, wherein the vibration amplitude and/or the vibration frequency of the blowing lance is detected and/or measured in the head of the lance by at least one vibration sensor arranged in the head of the lance in the area of the at least one supersonic nozzle during the operation of the blowing lance.

6. The method according to claim 1, further comprising detecting optical emission(s) occurring upon ignition of oxygen jets in the head of the lance by at least one light sensor arranged in the head of the lance in the area of the at least one supersonic nozzle during the operation of the blowing lance.

7. The method according to claim 1, further comprising detecting optical emissions occurring outside the blowing lance in the head of the lance by at least one light sensor or at least one camera equipped with a light sensor, which is arranged in the head of the lance in the area of the at least one supersonic nozzle and is optically aimed directly through an orifice open of the blowing lance.

8. The method according to claim 1, wherein the lance is a multi-hole lance comprising several supersonic nozzles, at least one detector or sensor being assigned to each supersonic nozzle.

9. The method according to claim 1, wherein at least one detector or sensor selected from the group consisting of pressure sensors, temperature sensors, vibration sensors, and/or light sensors, is assigned to the blowing lance.

10. The method according to claim 1, including transmitting the acquired measurement signal(s) from the detector or sensor to the evaluation and/or process control unit in hardwired fashion by a cable arranged in or on the blowing lance or in wireless fashion by a radio module connected to the detector and/or sensor and arranged in the blowing lance.

11. The method according to claim 1, including supplying the detector(s) or sensor(s) with electric power by an energy-harvesting module arranged in the blowing lance.

12. A measurement system for determining measurement signals used for process control during operation of a blowing lance for blowing gas in a metallurgical vessel, wherein the measurement system comprises: a blowing lance with a replaceable head having at least one supersonic nozzle; an evaluation and/or process control unit for receiving and processing measurement signals; and a detector or sensor arranged in the head of the lance in an area of the at least one supersonic nozzle, which detector or sensor is connected to the evaluation and/or process control unit, detects and/or measures in the head of the lance during the operation of the blowing lance inlet pressure and/or inlet temperature of gas at the at least one supersonic nozzle and/or vibration amplitude and/or vibration frequency of the blowing lance and/or a time when ignition occurs during an oxygen blowing process and/or a location where ignition occurs during the oxygen blowing process, and transmits the measurement signal(s) acquired during operation of the blowing lance to the evaluation and/or process control unit connected to the at least one detector or sensor so that the signals are available for controlling operation of the blowing lance.

13. The measurement system according to claim 12, wherein the detector or sensor is at least one pressure sensor arranged in the head of the lance in the area of the at least one supersonic nozzle, which sensor detects and/or measures, in the head of the lance, the inlet pressure of the at least one supersonic nozzle during operation of the blowing lance, and transmits the measurement signal(s) to the evaluation and/or process control unit for controlling the operation of the blowing lance.

14. The measurement system according to claim 12, wherein the detector or sensor is at least one temperature sensor arranged in the head of the lance in the area of the at least one supersonic nozzle, which sensor detects and/or measures, in the head of the lance, the inlet temperature of the gas at an entrance to the at least one supersonic nozzle during operation of the blowing lance, and transmits the measurement signal(s) to the evaluation and/or process control unit for controlling the operation of the blowing lance.

15. The measurement system according to claim 12, wherein the detector or sensor is a vibration sensor arranged in the head of the lance in the area of the at least one supersonic nozzle, which sensor detects and/or measures, in the head of the lance, the vibration amplitude and/or the vibration frequency of the blowing lance during operation of the blowing lance, and transmits the measurement signal(s) to the evaluation and/or process control unit for controlling the operation of the blowing lance.

16. The measurement system according to claim 12, wherein the detector or sensor is at least one light sensor or at least one camera equipped with a light sensor arranged in the head of the lance in the area of the at least one supersonic nozzle, which sensor or sensor-equipped camera detects and/or measures, in the head of the lance, optical emission(s) occurring when oxygen jets ignite during the operation of the blowing lance, and transmits the measurement signal(s) to the evaluation and/or process control unit for controlling the operation of the blowing lance.

17. The measurement system according to claim 12, wherein the detector or sensor is at least one light sensor or at least one camera equipped with a light sensor arranged in the head of the lance in the area of the at least one supersonic nozzle, which sensor or sensor-equipped camera is optically aimed directly through an orifice of the blowing lance, detects and/or measures, in the head lance, optical emissions occurring outside the lance during the operation of the blowing lance, and transmits the measurement signal(s) to the evaluation and/or process control unit for controlling the operation of the blowing lance.

18. The measurement system according to claim 12, wherein the blowing lance is a multi-hole lance with multiple
supersonic nozzles, wherein at least one detector or sensor is assigned to each of the supersonic nozzles.

19. The measurement system according to claim 12, wherein the blowing lance comprises at least one detector or sensor selected from the group consisting of pressure sensors, temperature sensors, vibration sensors, and/or light sensors.

20. The measurement system according to claim 12, wherein the detector or sensor is connected to the evaluation and/or process control unit in a hardwired manner by a cable arranged in or on the blowing lance or in a wireless manner by a radio module arranged in the blowing lance, wherein when the detector or sensor is wirelessly connected to the evaluation and/or process control unit the detector or sensor is connected to an energy-harvesting module installed in the blowing lance.

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