



- (51) **International Patent Classification:**
G01N 33/20 (2006.01) *G01N 1/12* (2006.01)
- (21) **International Application Number:**
PCT/SE2016/050585
- (22) **International Filing Date:**
16 June 2016 (16.06.2016)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
1510588.5 16 June 2015 (16.06.2015) GB
- (71) **Applicant:** NOVACAST SYSTEMS AB [SE/SE]; Fridhamsvägen 8, 372 38 Ronneby (SE).
- (72) **Inventor:** ANDERSSON, Robert; Mariebergsvägen 17, 371 43 Karlskrona (SE).
- (74) **Agent:** GIPON KONSULT AB; Brynjevägen 12, 246 34 Löddeköpinge (SE).

- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG,

MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to the identity of the inventor (Rule 4.17(i))
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))
- of inventorship (Rule 4.17(iv))

Published:

- with international search report (Art. 21(3))

- (54) **Title:** APPARATUS AND METHOD FOR ANALYSIS OF MOLTEN METALS

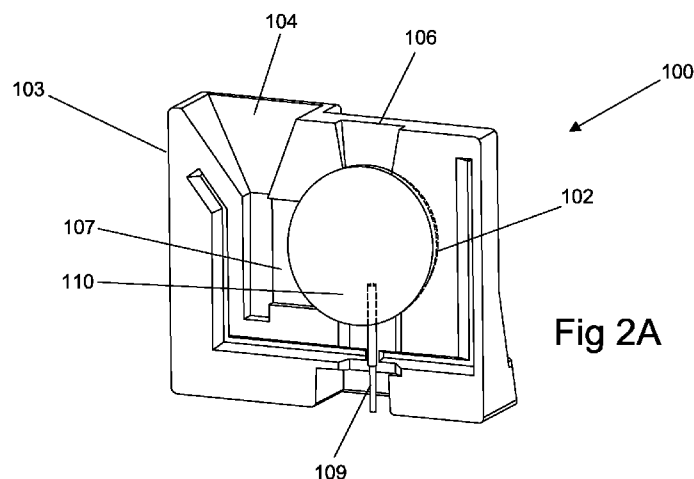


Fig 2A

- (57) **Abstract:** An apparatus (100) for analysis of metals is provided, comprising a mold cavity (102) for receiving a sample of a molten metal, a gating system (104) for allowing the molten metal to be poured, and a vent (106) for allowing gases to escape from the apparatus when the molten metal is poured. The apparatus further comprises at least one chill plate (110), adjacent to the mold cavity (102), for enabling faster cooling and solidification of the sample of the molten metal. The apparatus also comprises a longitudinal slot (108), extending from the mold cavity (102), for allowing a sensor element (109) to be introduced into the sample of the molten metal, the sensor element (109) is a thermocouple wire that is used to monitor a cooling curve of the molten metal, while the molten metal solidifies.



APPARATUS AND METHOD FOR ANALYSIS OF MOLTEN METALS

TECHNICAL FIELD

[0001] The present disclosure relates generally to metal and material analysis; and more specifically, to apparatuses and methods for analysis of metals.

5 BACKGROUND

[0002] There are various evaluation methods for determining a chemical composition of a specimen of cast iron. Most commonly, these evaluation methods employ:

- (i) a spectrometer analysis, for example using an optical spectrometer,
- (ii) a combustion analysis, for example using a Laboratory Equipment Corporation
10 (LECO) machine, or
- (iii) a thermal analysis.

[0003] In the spectrometer analysis, an optical spectrometer (see reference [1]) is used to measure properties of light over a specific portion of the electromagnetic spectrum to determine a composition of a specimen. Typically, the specimen is cast from molten metal
15 into a cylindrical shape, for example, having a diameter ranging between 30 mm and 40 mm and a thickness ranging between 3 mm to 5 mm.

[0004] In order to make an accurate analysis of the specimen, it is important that the specimen has a homogenous microstructure, namely a uniform composition and density, and that each component in the microstructure is as small as possible. An example of a
20 cast iron specimen having a homogeneous microstructure is white iron in which carbon remains interspersed in the metal in a form of a carbide, instead of precipitating out in a form of graphite. Materials like tellurium have been used to prevent formation of graphite in the metal. Such materials are typically coated on inner surfaces of a mold being used for molding the specimen or placed in the mold in a form of an insert.

[0005] During molding, the molten metal undergoes a solidification process that is according to a metastable phase diagram of white iron, namely iron of carbide type. For this purpose, the specimen is cast in a metal mold, which results in a fast cooling and solidification process.

5 [0006] However, there are some challenges when casting a specimen in a metal mold. The specimen may have inner defects arising from formation of slags and oxides and/or may have a rough outer surface quality. Typically, the specimen is grinded or machined before any analysis is performed. Moreover, in several foundries, metal molds are used repeatedly for casting a large number of specimens during a shift. As a result, mold
10 temperatures increase during the shift, and adversely affect a cooling effect of the metal molds. This leads to a formation of an uneven microstructure in the specimens, which, in turn, has a negative effect on the accurateness of the spectrometer analysis.

[0007] Furthermore, in the combustion analysis, a method that is based on combustion technology, for example, such as a LECO type of method, is used. Such a method requires
15 that small pieces of metal be machined out from a given specimen. In some cases, the metal pieces are machined out from the same specimen that has been used for the thermal analysis. The metal pieces may, for example, be obtained using a turning or boring operation, which typically has high demands for hygiene. The metal pieces are then placed in a small ceramic crucible, and reheated and melted under a strictly controlled
20 atmosphere. The specimen is then combusted in the presence of pure oxygen. During this process, carbon and sulphur are oxidized to form carbon dioxide (CO₂) and sulphur dioxide (SO₂), respectively.

[0008] A well-serviced combustion analysis successfully detects low levels of carbon, sulphur, nitrogen, oxygen and hydrogen, for example ranging between 0.0002 and 0.05
25 percentage, depending upon a type of specimen. The combustion analysis yields an exact result, but requires a high hygiene, a good service level, a lab atmosphere, and a quite expensive equipment.

[0009] Furthermore, the thermal analysis is based on a fact that, when solidifying according to the metastable phase diagram, solidification characteristics of a cast iron

specimen have a clear relation to the composition of the specimen, namely to Carbon Equivalent Liquidus (CEL) content and Carbon content.

[0010] In the thermal analysis, a ceramic cup with typical dimensions of 35 mm x 35 mm x 40 mm (b x w x h) is filled with molten cast iron. On the bottom or the sides of the cup, a tellurium paste is coated or glued to the cup. Tellurium has a high affinity to sulphur. When sulphur is tied up with tellurium atoms, the cast iron solidifies according to the metastable phase diagram. The weight of the metal ranges between 190 g and 250 g, depending on a fill status of the cup.

[0011] Typically, a thermocouple that extends into the cup or is positioned centrally in the cup is used to monitor a cooling curve of the molten cast iron. A drop in temperature along the cooling curve during the solidification is logged by a measuring device. The measuring is finished after certain time, for example, after 70-180 seconds. The composition of the metal is then determined based on a form of the cooling curve.

[0012] Thermal analysis is a well-established technology, and in most cases, is used in parallel with the spectrometer analysis and/or the combustion analysis. Thermal analysis gives accurate and fast results. Moreover, practical implementation of thermal analysis is easy and robust. However, tellurium used in this process is dangerous for the environment and health of operators. The specimen cannot be re-cycled easily because of the presence of tellurium, and has to be sent for external recycling.

20 SUMMARY

[0013] The present disclosure seeks to provide an improved apparatus and a method for analysis of metals.

[0014] The present disclosure also seeks to provide an improved apparatus and a method for analysis of cast iron without use of tellurium.

25 [0015] A further aim of the present disclosure is to at least partially overcome at least some of the problems of the prior art, as discussed above.

[0016] In one aspect, embodiments of the present disclosure provide an apparatus for analysis of metals, characterized in that the apparatus comprises:

a mold cavity for receiving a sample of a molten metal;

a gating system, extending from the mold cavity, for allowing the molten metal to be
5 poured;

a vent, extending from the mold cavity, for allowing gases to escape from the apparatus when the molten metal is poured;

at least one chill plate adjacent to the mold cavity for enabling cooling and solidification of the sample of the molten metal; and

10 a longitudinal slot, extending from the mold cavity, for allowing a sensor element to be introduced into the mold cavity, the sensor element is a thermocouple wire that is used to monitor a cooling curve of the molten metal, while the molten metal solidifies.

[0017] In another aspect, embodiments of the present disclosure provide a method for analysis of metals, characterized in that the method comprises:

15 pouring a sample of a molten metal into a mold cavity through a gating system extending from the mold cavity;

cooling and solidifying the sample of the molten metal using at least one chill plate adjacent to the mold cavity;

measuring temperature of the cooling and solidifying sample of the molten metal using a
20 sensor element, to be introduced into the molten metal through a longitudinal slot extending from the mold cavity, wherein the sensor element is a thermocouple wire; and

generating a cooling curve of the molten metal using the detected temperature while the molten metal solidifies.

[0018] The apparatus is designed in a manner that a test specimen of a smaller size is
25 produced in a faster cooling and solidification process, as compared to conventional

apparatuses. As a result of the faster cooling and solidification process, materials like tellurium are not required to be used.

[0019] Embodiments of the present disclosure substantially eliminate or at least partially address the aforementioned problems in the prior art, and enable a fast analysis of cast
5 iron and ductile iron, without use of tellurium.

[0020] Additional aspects, advantages, features and objects of the present disclosure would be made apparent from the drawings and the detailed description of the illustrative embodiments construed in conjunction with the appended claims that follow.

[0021] It will be appreciated that features of the present disclosure are susceptible to
10 being combined in various combinations without departing from the scope of the present disclosure as defined by the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The summary above, as well as the following detailed description of illustrative
embodiments, is better understood when read in conjunction with the appended drawings.
15 For the purpose of illustrating the present disclosure, exemplary constructions of the disclosure are shown in the drawings. Moreover, those in the art will understand that the drawings are not to scale. Wherever possible, like elements have been indicated by identical numbers.

[0023] Embodiments of the present disclosure will now be described, by way of example
20 only, with reference to the following diagrams wherein:

FIGs. 1A and 1C are a side view and a top view respectively an apparatus for analysis of
metals, in accordance with an embodiment of the present disclosure;

FIGs 1B and 1D are sections B-B and A-A in FIG 1A and 1C respectively.

FIGs. 2A and 2B are perspective views of a respective mold half of the embodiment in
25 Fig 1 A-D

FIG. 3 is an exploded view of an apparatus in accordance the embodiment in Fig 1 and 2
in which a sample has been molded.

FIG. 4 is an illustration of steps of a method for analysis of metals, in accordance with an embodiment of the present disclosure.

[0024] In the accompanying drawings, a non-underlined number relates to an item identified by a line linking the non-underlined number to the item. When a number is non-underlined and accompanied by an associated arrow, the non-underlined number is used to identify a general item at which the arrow is pointing.

DETAILED DESCRIPTION OF EMBODIMENTS

[0025] The following detailed description illustrates embodiments of the present disclosure and ways in which they can be implemented. Although some modes of carrying out the present disclosure have been disclosed, those skilled in the art would recognize that other embodiments for carrying out or practicing the present disclosure are also possible.

[0026] In one aspect, embodiments of the present disclosure provide an apparatus for analysis of metals, characterized in that the apparatus comprises:

- 15 a mold cavity for receiving a sample of a molten metal;
- a gating system, extending from the mold cavity, for allowing the molten metal to be poured;
- a vent, extending from the mold cavity, for allowing gases to escape from the apparatus when the molten metal is poured;
- 20 at least one chill plate adjacent to the mold cavity for enabling cooling and solidification of the sample of the molten metal; and
- a longitudinal slot, extending from the mold cavity, for allowing a sensor element to be introduced into the molten metal, the sensor element is a thermocouple wire that is used to monitor a cooling curve of the molten metal, while the molten metal solidifies.

25 [0027] In another aspect, embodiments of the present disclosure provide a method for analysis of metals, characterized in that the method comprises:

pouring a sample of a molten metal into a mold cavity through a gating system extending from the mold cavity;

cooling and solidifying the sample of the molten metal using at least one chill plate adjacent to the mold cavity;

- 5 measuring temperature of the cooling and solidifying sample of the molten metal using a sensor element, to be introduced into the molten metal through a longitudinal slot extending from the mold cavity, wherein the sensor element is a thermocouple wire; and generating a cooling curve of the molten metal using the detected temperature while the molten metal solidifies.

- 10 **[0028]** The apparatus and method are susceptible to being used for thermal analysis and spectrometer analysis of metal, such as grey iron, ductile and compacted graphite iron.

- [0029]** The at least one chill plate enables the apparatus to achieve a high cooling and solidification rate, namely a faster process of cooling and solidification of the molten metal (hereinafter referred to as “faster cooling and solidification process”). It will be appreciated that a high cooling and solidification rate is necessary to achieve a TE White state in the metal, without use of materials like tellurium. The term “TE White” used herein refers to a temperature for white solidification of the metal, namely a lower temperature in an eutectic temperature interval of the metastable phase diagram of white iron. In the eutectic temperature interval, the metal is in a form of a mix between melt and solid phases.
- 15
20

[0030] According to an embodiment, the at least one chill plate is implemented in a form of an internal chill.

- [0031]** The at least one chill plate can be formed from various metals or alloys, for example, such as ductile iron, copper, or steel. According to an embodiment, the at least one chill plate is formed from low-grade steel.
- 25

[0032] The gating system and the vent extend from the mold cavity towards outside ending at a bottom and a top, respectively, of the mold cavity of the apparatus, preferably

in slightly different directions with respect to each other. For example, the gating system and the vent may be located at an angle of from 90-170° with respect to each other. Further, the gating system is wide enough to permit a high pouring speed of the molten metal into the mold cavity. Moreover, the configuration of the gating system at the bottom
5 allows the molten metal to be filled in the mold cavity in a bottom up direction.

[0033] Thus, the apparatus is designed in a manner that a test specimen of a smaller size is produced in a faster cooling and solidification process, as compared to conventional apparatuses. As a result of the faster cooling and solidification process, materials like tellurium are not required to be used. This facilitates a decrease in an environmental load
10 with regard to use of tellurium. This also enables the test specimen to be re-melted in a foundry and re-cycled easily.

[0034] Moreover, the test specimen so formed is clean with a high surface quality, and has minimal risks for occurrences of casting defects, such as cold laps and cold shuts.

[0035] According to an embodiment, the apparatus is suitable for casting a test specimen
15 of a thickness ranging from 3 mm to 10 mm, preferably 3,5-4,5mm. In an embodiment, the sample of the molten metal (specimen) may be configured to attain a coin shape, based on the shape of the mold cavity.

[0036] Moreover, the apparatus is suitable for determining a chemical composition of various metals, for example of cast iron or ductile iron or grey iron or ductile compacted
20 graphite iron. The apparatus is particularly suitable for a fast analysis of cast iron and ductile iron without the use of tellurium. It will be appreciated here that the apparatus is suitable for analysis of ductile iron, as it enables a faster cooling and solidification process to be achieved without the use of tellurium. Conventional apparatuses that use tellurium are unsuitable for analysis of ductile iron, as tellurium reacts with ductile iron and is
25 unavailable for tying up sulphur; as a result, ductile iron does not solidify properly, namely according to a metastable phase diagram of white iron.

[0037] Furthermore, according to an embodiment, the apparatus also comprises a longitudinal slot, extending from the mold cavity, for allowing a sensor element to be introduced into the sample of the molten metal. Specifically, the longitudinal slot is

configured at a bottom of the mold cavity. This longitudinal slot also extends from the mold cavity towards the outside of the apparatus. In one embodiment, the longitudinal slot is diametrically opposed to the gating system, i.e. they are located at 180° one from another.

5 **[0038]** In an embodiment, the sensor element is preheated by the molten metal before the mold cavity is filled with the molten metal. In other words, the sensor element is preheated to reach a temperature that of the molten metal prior to be introduced into the mold cavity. This enables or ensures a reliable analysis, i.e. thermal analysis, to be performed with the help of temperature to be measured from cooling and solidifying
10 sample of the molten metal by the sensor element. Specifically, the sensor element is introduced in the bottom of the mold cavity and is preheated by the molten metal before the mold cavity is filled with the molten metal. For example, the sensor element is inserted in the longitudinal slot such that sensor element protrudes in the mold cavity before the start of the pouring the molten metal into the mold cavity. Therefore, when
15 the molten metal enters the cavity and the sensor element is preheated, the sensor element is ready to start the thermal analysis when the mold cavity is completely filled. Further, a part of the sensor protruding in the mold cavity is broken and stays in the solidified sample when released from the apparatus.

[0039] In one embodiment, a steel sleeve may be mounted at the bottom of the mold
20 cavity to receive the sensor therein. This may allow reusability of the sensor element.

[0040] According to an embodiment, the sensor element is a thermocouple wire that is used to monitor a cooling curve of the molten metal, while the molten metal solidifies. This enables a thermal analysis of the metal to be performed. When the metal solidifies, the test specimen is formed in a shape of the mold cavity. The test specimen is then used
25 for a spectrometer analysis.

[0041] In operation, the mold cavity is filled with molten metal, thereafter the temperature is measured with a high frequency (minimum 50 times per sec) temperature measuring unit, such as a temperature sensor unit. In an embodiment, the temperature measuring unit may include functional electronic components, which includes but not limited to at
30 least one temperature sensor, a processor, a memory and so forth. In an example, the

temperature sensor unit is operable to define first and second derivatives for each measured temperature value. Thereafter, based on the first and second derivatives a cooling graph of the sample of the molten metal may be determined.

5 [0042] In one embodiment, the temperature sensor unit is further operable to determine liquidus temperature, eutectic temperature and solidus temperature using the cooling curve, the first and second derivatives. For example, an algorithm (stored in the memory) may be executable on the processor using the cooling curve, the first and second derivatives to determine the liquidus temperature, the eutectic temperature and the solidus temperature.

10 [0043] The chill plate in the mold cavity determines a molten metal solidification time which is about 5-17 seconds (s), preferably 13-17s, and most preferably by 15 s by means of a predetermined relationship between a thickness of the chill plate and a depth of the mold cavity. Specifically, the thickness of the chill plate and the depth of the mold cavity are adjusted in a manner such that a faster solidification time (or rate) for the molten metal
15 may be achieved. In an embodiment, the thickness of the chill plate may be in a range of 1.5 mm to 2.5 mm, preferably 2.5 mm. Further, the mold cavity may include a diameter of about 47 mm and a depth in a range of 5.5 mm to 6.5 mm. This predetermined structural relationship may suitably yield a solidified sample of a molten metal having a thickness of about 3.5-4.5 mm. The predetermined relationship between the thickness of
20 the chill plate and the depth of the mold cavity also enables in formation of a layer of white iron on top of the cooled and solidified sample of the molten metal. The sample of the molten metal, having layer of white iron on top, is suitable for a spectrometer analysis. In an example, the faster solidification time (or rate) yields a 1-2 mm thick layer of white iron on top the sample of the molten metal.

25 [0044] Thus, the apparatus enables a same test specimen of metal to be used for the thermal analysis and the spectrometer analysis. This is important for traceability purposes. The thermal analysis facilitates a high precision determination of Carbon Equivalent Liquidus (CEL) content, carbon content and silica content in the test specimen, while the spectrometer analysis facilitates a high precision determination of
30 heavy elements, namely heavy metals, present in the test specimen.

[0045] Another advantage of using the same test specimen for both the analyses is that the analysis of the metal is fast.

[0046] According to an embodiment, a main body of the apparatus is made of a mold material that has a low impact both on the environment and operators handling the apparatus. In an embodiment, the main body of the apparatus is made of sand (or sand composition), which may be an environment-friendly core sand. For example, the environment-friendly core sand may include green sand. It is to be noted here that other suitable “green” core materials could be used instead of green sand.

[0047] The term “green sand” generally refers to wet sand that is used to make a mold's shape. A green sand is not a particular type of sand on its own, but is rather a mixture (see reference [2]). As an example, green sand could comprise 75 to 85 % of silica sand (SiO_2), 5 to 11 % of abentonite (namely, clay), 2 to 4 % of water, 3 to 5 % of an inert sludge, and 0 to 1 % of an anthracite.

[0048] As the apparatus is made from green sand or other suitable “green” core materials, the apparatus is expendable. The green sand could be recycled in a normal recycling system.

[0049] According to an embodiment, the apparatus is made from two mold halves, in a manner that when the two mold halves are separated, the apparatus is split vertically. Further, when halves put together a slot is provided in a periphery of the mold cavity, the slot extends along the periphery of the mold cavity from the gating system into the mold cavity up to the vent. The slot is typically provided opposite the chill plate. A length of the slot may vary based on an overall size of the apparatus. Further, the slot ensures a short fill time for the cavity. Moreover, the short fill time without turbulence in the flow of molten material avoids defects in the sample caused by gas or slag occlusions. Also, the short fill time will also ensure a high surface smoothness. In operation, the mold halves are aligned and clamped together, for example, with a clamp of steel. According to an embodiment, neither ceramic glue nor ceramic paste is used in the apparatus.

[0050] According to an embodiment, the thermocouple wire is made of Chromel-Alumel type.

[0051] According to an embodiment, at least a portion of the thermocouple wire is covered with a protective ceramic material. An example of the ceramic material is an Al₂O₃ material.

[0052] Moreover, optionally, the results of the analyses are saved into a central server.

5 Optionally the results of the analyses are displayed in parallel to a production staff.

DETAILED DESCRIPTION OF DRAWINGS

[0053] Referring now to the drawings, particularly by their reference numbers, FIGS. 1A and 1C are schematic illustrations of an apparatus **100** for analysis of metals, in accordance with an embodiment of the present disclosure.

10 [0054] The apparatus **100** includes a mold cavity **102** for receiving a sample of a molten metal, a gating system **104** for allowing the molten metal to be poured, a vent **106** for allowing gases to escape, and a longitudinal slot **108** for allowing a sensor element to be introduced into the sample of the molten metal.

15 [0055] FIG 1D is a section through the mold cavity and shows specifically a chill plate **110** placed in the mold half **101** and a recess **107** in the other mold half **103**. The recess provides a peripheral slot together with the opposite mold half and contributes to a short fill time of the cavity.

20 [0056] In FIG. 2A, there is shown a perspective view of a mold half **103** of the apparatus **100**. The recess **107** extends along the periphery of the mold half **103** from a point near the bottom of the cavity to a point near the vent **106**. A sensor element **109** is inserted in the bottom of the cavity **102**. When molten metal is inserted in the cavity through the slot between the mold halves the sensor element is preheated.

25 [0057] In FIG. 3, there is shown an exploded view of the apparatus **100**, in which a residue **202** is a result of a solidification of molten metal filled in the apparatus according the showed embodiment of the invention. Unwanted portions of excess metal **207** and **208** of the residue **202** are cut to obtain a test specimen of a coin shape, for example, for spectrometer analysis.

[0058] FIGs. 1 to 3 are merely examples. A person skilled in the art will recognize many variations, alternatives, and modifications of embodiments of the present disclosure.

[0059] FIG. 4 is an illustration of steps of a method **300** for analysis of metals, in accordance with an embodiment of the present disclosure.

5 [0060] Specifically, those skilled in the art would recognize that the method **300** illustrates steps involved in the functioning of an apparatus, such as apparatuses **100** and **200**, explained in conjunction with the FIGs. 1 to 3.

[0061] At step **302**, a sample of a molten metal is poured into a mold cavity through a gating system extending from the mold cavity.

10 [0062] At step **304**, the sample of the molten metal is cooled and solidified using at least one chill plate adjacent to the mold cavity.

[0063] At step **306**, temperature of the cooling and solidifying sample of the molten metal is measured using a sensor element. The sensor element is operable to be introduced into the sample of the molten metal through a longitudinal slot extending from the mold cavity.

15 The sensor element is a thermocouple wire.

[0064] At step **308**, a cooling curve of the molten metal is generated using the detected temperature as the molten metal solidifies.

[0065] The steps **302** to **308** are only illustrative and other alternatives can also be provided where one or more steps are added, one or more steps are removed, or one or
20 more steps are provided in a different sequence without departing from the scope of the claims herein. For example, the method **300** may further include venting gases from the mold cavity by a vent extending from the mold cavity.

[0066] Further, the method **300** may include preheating the sensor element prior to introducing into the sample of the molten metal. Moreover, in the method **300**, the
25 measuring of the temperature of the cooling and solidifying sample may include defining first and second derivatives for each measured temperature value, and thereafter determining liquidus temperature, eutectic temperature and solidus temperature using the

cooling curve, the first and second derivatives. The method **300** may also include defining carbon content, silica content and carbon equivalent liquidus content by using the cooling curve. The method **300** may further include performing spectrometer analysis on the cooled and solidified sample of the molten metal. The method **300** may also include
5 grinding the cooled and solidified sample of the molten metal prior to the spectrometer analysis.

[0067] Embodiments of the present disclosure are susceptible to being used for various purposes, including, though not limited to, enabling a fast analysis of cast iron and ductile iron, without use of tellurium. Further, embodiments of the present disclosure are
10 susceptible to being used for thermal analysis and spectrometer analysis of such metal.

[0068] Modifications to embodiments of the present disclosure described in the foregoing are possible without departing from the scope of the present disclosure as defined by the accompanying claims. Expressions such as “including”, “comprising”, “incorporating”, “have”, “is” used to describe and claim the present disclosure are intended to be construed
15 in a non-exclusive manner, namely allowing for items, components or elements not explicitly described also to be present. Reference to the singular is also to be construed to relate to the plural.

CLAIMS

What is claimed is:

1. An apparatus for analysis of metals, characterized in that the apparatus comprises:
 - a mold cavity for receiving a sample of a molten metal;
 - 5 a gating system, extending from the mold cavity, for allowing the molten metal to be poured;
 - a vent, extending from the mold cavity, for allowing gases to escape from the apparatus when the molten metal is poured;
 - 10 at least one chill plate, adjacent to the mold cavity, for enabling cooling and solidification of the sample of the molten metal; and
 - a longitudinal slot, extending from the mold cavity, for allowing a sensor element to be introduced into the mold cavity, the sensor element is a thermocouple wire that is used to monitor a cooling curve of the molten metal, while the molten metal solidifies.
 - 15
2. An apparatus as claimed in claim 1, characterized in that the at least one chill plate is implemented in a form of an internal chill.
3. An apparatus as claimed in claims 1 or 2, characterized in that the gating system
 - 20 ends at a bottom of the mold cavity to allow the molten metal to be filled in the mold cavity in a bottom up direction.
4. An apparatus as claimed in any one of the preceding claims, characterized in that the sensor element is introduced in the bottom of the mold cavity and is preheated by the
 - 25 molten metal before the mold cavity is filled with the molten metal.
5. An apparatus as claimed in any one of the preceding claims, comprise mold halves when put together a slot is provided in a periphery of the mold cavity, the slot extends

along the periphery of the mold cavity from the gating system into the mold cavity up to the vent.

6. An apparatus as claimed in any one of the preceding claims, characterized in that
5 a thickness of the chill plate is associated with a depth of the mold cavity to enable fast solidification and a layer of white iron on the sample of the molten metal.
7. An apparatus as claimed in any one of the preceding claims, characterized in that
10 the apparatus is suitable for casting a test specimen of a thickness ranging from 3 mm to 10 mm.
8. An apparatus as claimed in any one of the preceding claims, characterized in that the apparatus is suitable for analyzing cast iron.
- 15 9. An apparatus as claimed in any one of the preceding claims, characterized in that the apparatus is suitable for analyzing ductile iron.
10. An apparatus as claimed in claim 1, characterized in that the apparatus enables a
20 same test specimen of metal to be used for thermal analysis and spectrometer analysis.
11. An apparatus as claimed in any one of the preceding claims, characterized in that a main body of the apparatus is made of sand.
12. An method for analysis of metals, characterized in that the method comprises:
25 pouring a sample of a molten metal into a mold cavity through a gating system extending from the mold cavity;
cooling and solidifying the sample of the molten metal using at least one chill plate adjacent to the mold cavity;
measuring temperature of the cooling and solidifying sample of the molten metal
30 using a sensor element, to be introduced into the mold cavity through a longitudinal slot extending from the mold cavity, wherein the sensor element is a thermocouple wire; and

generating a cooling curve of the molten metal using the detected temperature while the molten metal solidifies.

13. The method as claimed in claim 12, further comprising venting gases from the
5 mold cavity by a vent extending from the mold cavity.

14. The method as claimed in claim 12, further comprising preheating the sensor element prior to introducing into the sample of the molten metal.

10 15. The method as claimed in claim 12, characterized in that the measuring of the temperature of the cooling and solidifying sample comprise:

defining first and second derivatives for each measured temperature value, and determine liquidus temperature, eutectic temperature and solidus temperature using the cooling curve, the first and second derivatives.

15

16. The method as claimed in claims 12 to 15, further comprising defining carbon content, silica content and carbon equivalent liquidus content by using the cooling curve.

17. The method as claimed in claim 12, characterized in that further comprises
20 performing spectrometer analysis on the cooled and solidified sample of the molten metal.

18. The method as claimed in claim 17, characterized in that further comprises grinding the cooled and solidified sample of the molten metal prior to the spectrometer analysis.

25

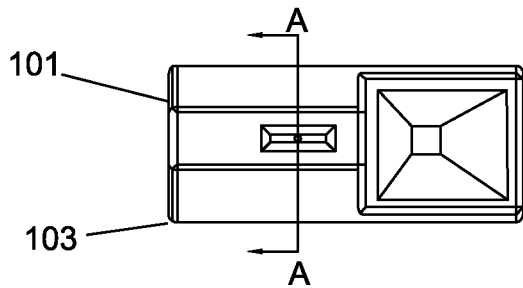


Fig 1C

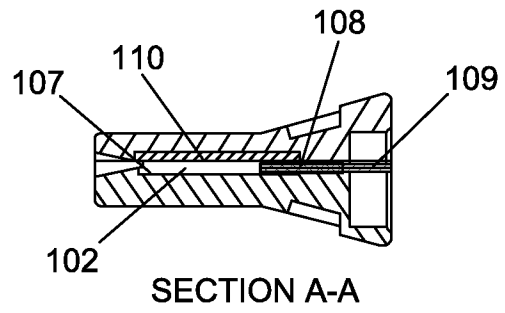


Fig 1D

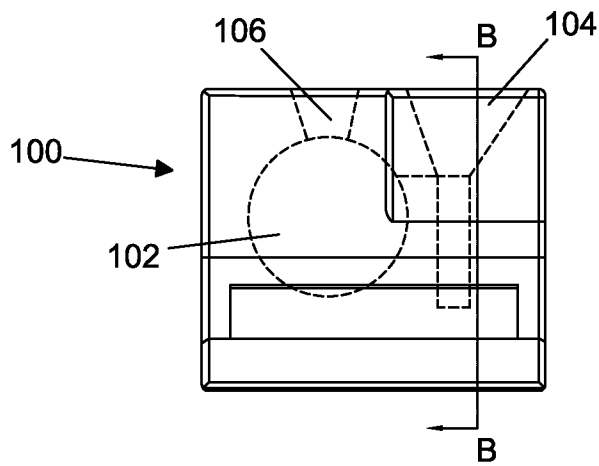


Fig 1A

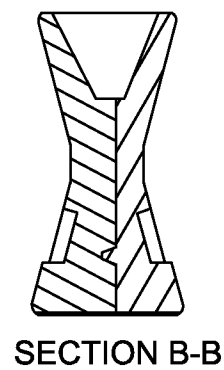


Fig 1B

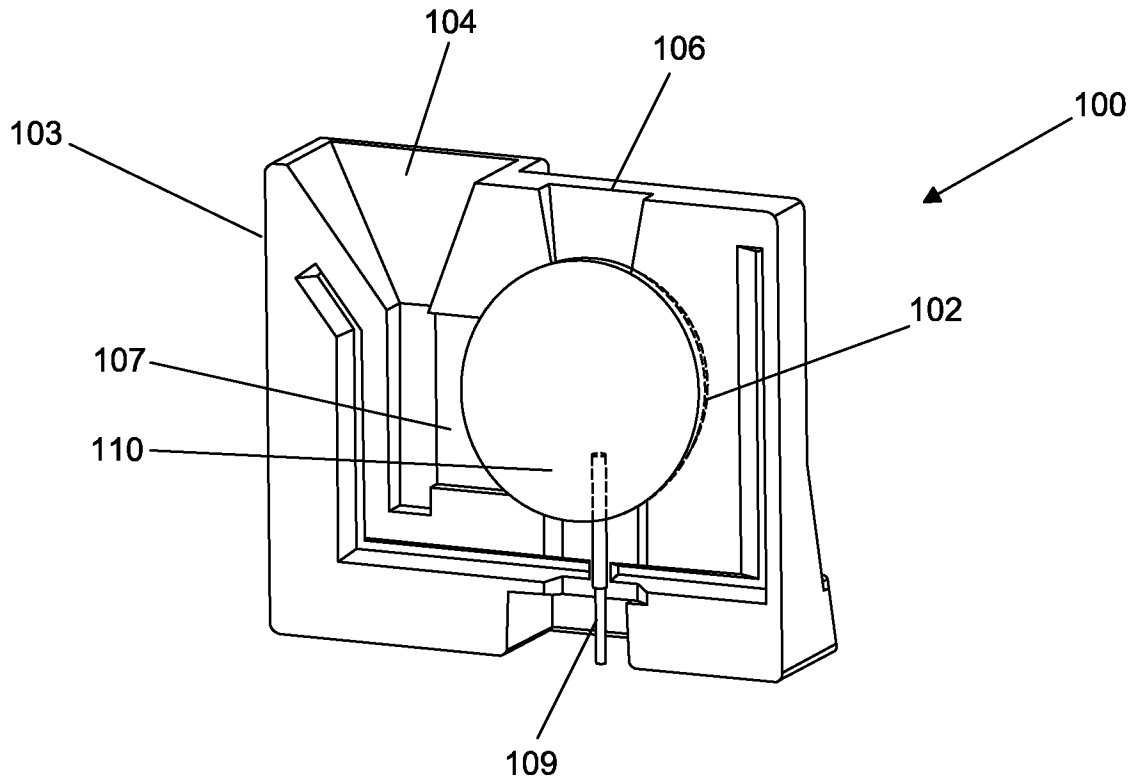


Fig 2A

3/5

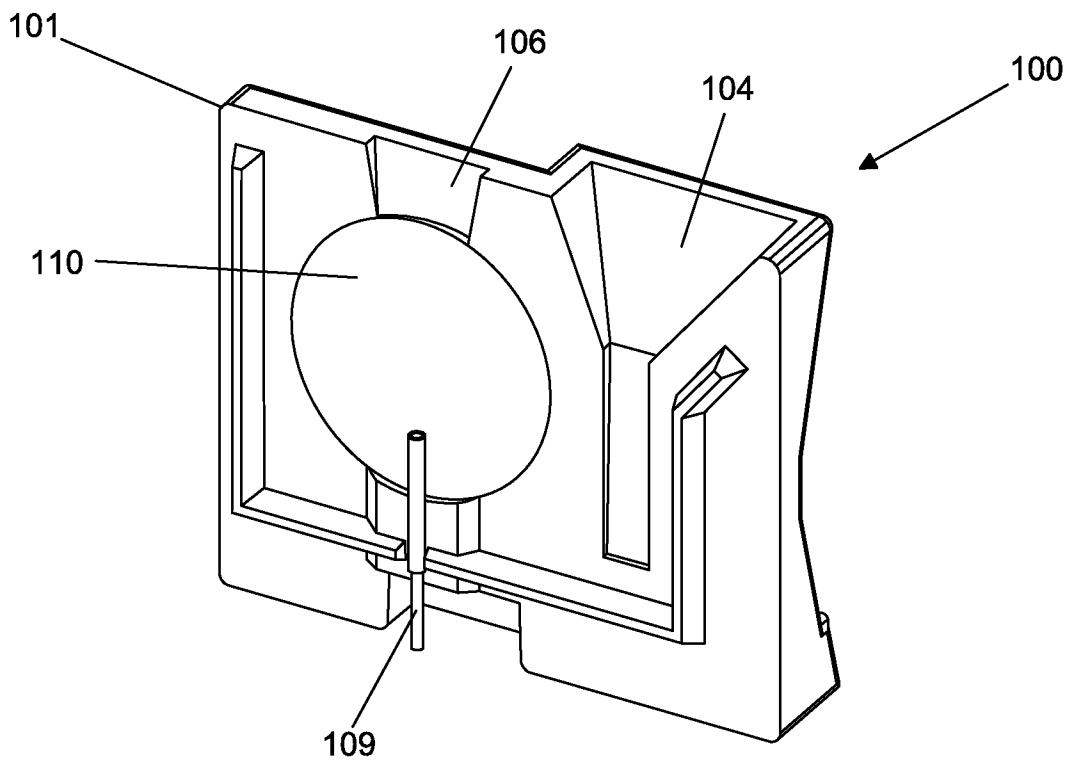


Fig 2B

4/5

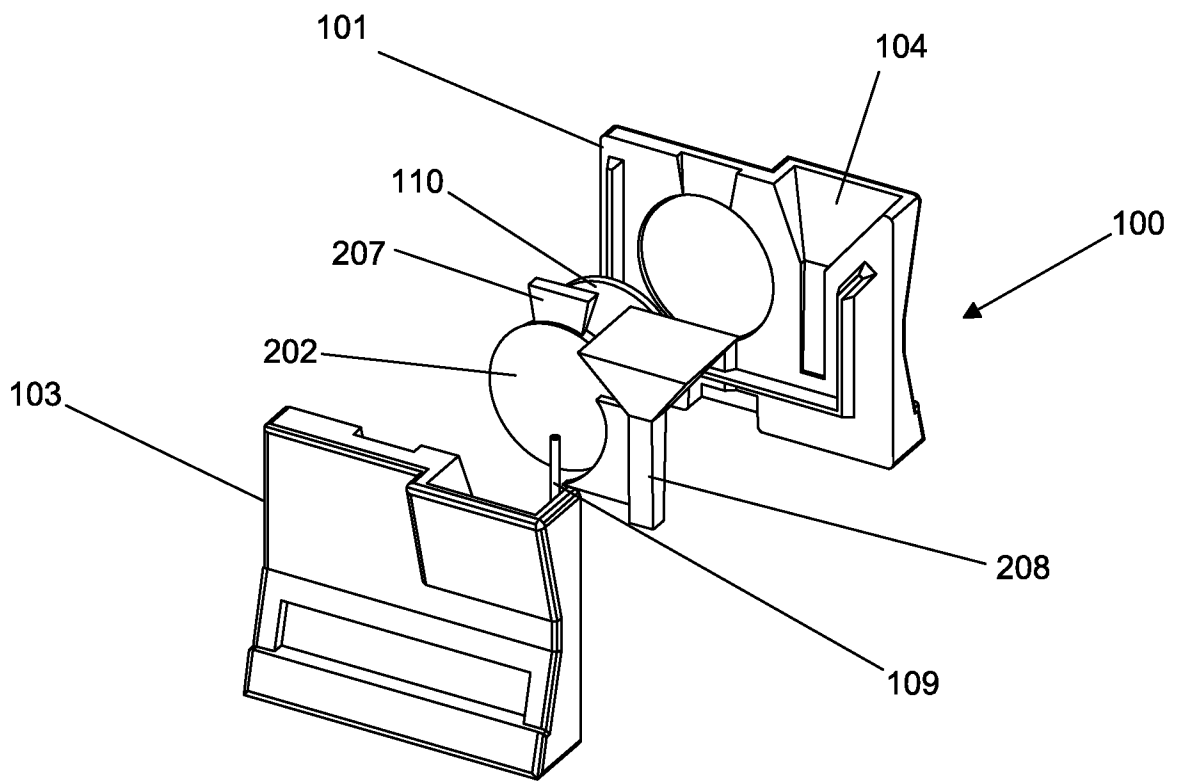


Fig 3

5/5

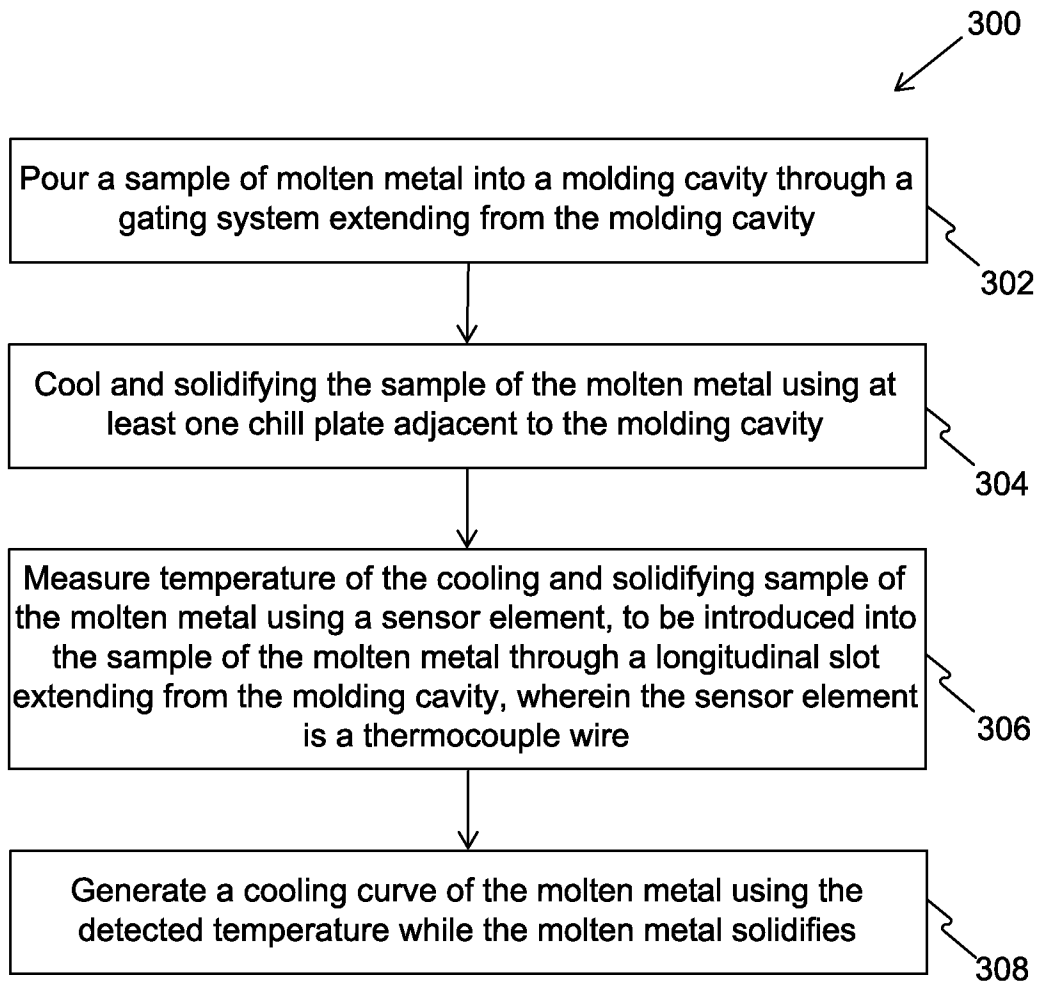


Fig 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2016/050585

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N33/20 G01N1/12
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 699 014 A (BORON JOSEPH J [US]) 13 October 1987 (1987-10-13)	12,14-17
Y	column 2, line 52 - column 3, line 33; figures	1-11,13, 18
Y	----- US 6 200 520 B1 (MORINAKA MAYUKI [JP] ET AL) 13 March 2001 (2001-03-13)	1-11,13
Y	column 1, last paragraph - column 2, paragraph 3; figure	
Y	----- KR 2009 0103244 A (WOOJIN ELECTRO NITE INC [KR]) 1 October 2009 (2009-10-01)	18
A	abstract; figure 3	1,2,11, 12
A	----- US 2010/142585 A1 (POPELAR PATRIK [SE] ET AL) 10 June 2010 (2010-06-10)	4
	figure 1	
	----- -/--	

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 12 September 2016	Date of mailing of the international search report 21/09/2016
--	--

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Wilhelm-Shalgunov, J
--	--

INTERNATIONAL SEARCH REPORT

International application No

PCT/SE2016/050585

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 1 565 215 A (KOLBO G; MANNESMANN AG) 16 April 1980 (1980-04-16) figure 4 -----	3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/SE2016/050585

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
US 4699014	A	13-10-1987	JP S6332370 A US 4699014 A	12-02-1988 13-10-1987

US 6200520	B1	13-03-2001	BE 1013620 A5 BR 9905603 A CN 1254091 A DE 19951618 A1 FR 2785391 A1 JP 2000131311 A US 6200520 B1	07-05-2002 12-09-2000 24-05-2000 25-05-2000 05-05-2000 12-05-2000 13-03-2001

KR 20090103244	A	01-10-2009	NONE	

US 2010142585	A1	10-06-2010	EP 1925936 A1 JP 2010510510 A KR 20090086222 A US 2010142585 A1 WO 2008062065 A1	28-05-2008 02-04-2010 11-08-2009 10-06-2010 29-05-2008

GB 1565215	A	16-04-1980	BE 849515 A1 DE 2558092 B1 FR 2335837 A1 GB 1565215 A IT 1065968 B JP S52101632 A	15-04-1977 23-06-1977 15-07-1977 16-04-1980 04-03-1985 25-08-1977
