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(54) **Enamelling oven for wire materials**

Emallierofen für fadenförmige Materialien

Four pour l'émaillage de matériaux en fil

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## Description

[0001] The present invention relates to an enamelling oven for wire materials, in particular metal wires for magnetic applications, of the type described in the preamble of claim 1.

[0002] It is known that wires, such as copper or aluminium wires for example, employed in the manufacture of motor windings, transformers or coils for different uses are generally produced by drawing and subsequent covering with insulating material through a multi-layered application process.

[0003] In this connection, enamelling plants are presently employed which consist of several stations operating immediately downstream of the drawing machine supplying the wires adapted to undergo the necessary covering operations for insulation.

[0004] In more detail, the enamelling plants comprise a first station, in which the insulating material is applied in overlaying subsequent layers, a second station, substantially consisting of an enamelling oven arranged to cause evaporation of the solvents contained in the enamels and then carry out polymerization or crosslinking of the enamels themselves, and a third station in which cooling of the wire is carried out on its coming out of the oven.

[0005] That being stated from a general point of view, the structure of the enamelling ovens to which the present invention particularly refers will be now examined in more detail.

[0006] Presently, enamelling ovens of the traditional type comprise a main chamber of elongated conformation which is lengthwise passed through by one or more wires movable from a chamber inlet opening to a chamber outlet opening, in a given feed direction. The traditional ovens are also comprised of a recirculation duct disposed adjacent to the main chamber and associated therewith; said duct has an initial section located close to the inlet opening and provided with a suction fan and an end section, located close to the outlet opening and having a converging configuration so as to produce, by Venturi effect, an air intake from the outside through the same outlet opening of the main chamber. In other words, the recirculation duct and main chamber define a closed circuit along which the fluid flow circulates in countercurrent relative to the wire feeding direction.

[0007] It is to be noted that the different ducts in the oven as well as the fan are conveniently shaped so as to ensure, within the chamber, the existence of a constant vacuum condition relative to the surrounding atmosphere in order to counteract the escape of toxic gases from the inlet and outlet openings. In fact, insulating enamels presently used to cover wires usually have a solid content in the range of 25-40% by weight in the case of polyesther imide (PEI) enamels and in the range of 10-25% by weight in the case of polyurethane (PU) enamels. Therefore, while passing through the main chamber, wires must lose a great amount of solvents.

Said solvents are drawn into the recirculation duct and burnt, as they cannot be discharged to the surrounding atmosphere. It should be finally noted that conventional ovens, in order to be able to keep a steady vacuum condition within the main chamber, ensuring suction of external air both from the wire inlet opening and outlet opening in compliance with the equation of the fluid motion, are necessarily provided with an exhaust conduit commonly referred to as stack, which is placed close to the recirculation duct downstream of the fan. The exhaust conduit too is usually provided with a related suction fan facilitating evacuation of part of the gases produced from solvent combustion.

[0008] While the above described enamelling ovens have been widely used in the art, they however have some drawbacks from an operating point of view.

[0009] In particular, traditional ovens lack in versatility as regards their capability of adjusting the cold air volume drawn in from the main-chamber outlet opening. This volume is in fact closely correlated with the vacuum created, by the Venturi effect, by the end portion of a converging configuration of the recirculation duct. In other words, in order to ensure a good vacuum at the outlet opening, so as to eliminate the possibility of gas escapes to the outside, the occurrence of a strong Venturi effect is necessary, which involves the suction of an important air mass from the outside; said air gives rise to a corresponding disadvantageous cooling of the main chamber.

[0010] In addition to the above considerations, it is to note that in traditional ovens, when one wishes to vary the amount of air to be sucked depending on the different enamel types to be processed, it is obviously possible to act directly on the fan placed in the recirculation circuit. However, this brings about a consequent variation in the fluid flow rate processed by the oven in the unit time and therefore a change in the performance offered by said oven.

[0011] Alternatively, or in addition to the above solution, enamelling ovens have been recently widely used in which, close to the end portion of the recirculation duct, shutoff members such as gate valves, guillotine valves, or others are disposed, which shutoff members are capable of enabling an adjustment of the air velocity at the section where they are installed. While these solutions enable the amount of air entering the outlet openings of the main chamber to be adjusted, they however give rise to a strong resistance increase in the recirculation duct and therefore an increase in the static pressure upstream of the shutoff member, which results in a flow rate variation in the baking chamber. It should be also pointed out that when the Venturi effect is greatly limited there is always the risk that gas escapes from the outlet opening may occur.

[0012] It is also known from document US-A-4938689 a furnace for firing an enamel-insulated wiring comprising a principal chamber and an auxiliary unit for withdrawing air and solvent vapours from the solvent remov-

al zone of the principal chamber. A part of the withdrawn mixture of air and vapours is mixed with a first volume of air at ambient temperature and returned to the principal chamber in correspondence of the second portion or outlet opening of the main chamber. Another part of said mixture is sent to a heat exchanger in which it gives up part of its thermal energy to a second volume of air at ambient temperature which is heated and sent to the principal chamber in correspondence of the first portion or inlet opening of the main chamber.

**[0013]** Other examples of wire coating apparatuses are shown in US-A-3183605 which, in a first embodiment, shows an oven provided with two recirculating ducts having a common end connected with a central region of the main chamber (where the coated wire is processed) and the other end communicating with terminal opposite portions of the main chamber. According to a second embodiment, document US-A-3183605 shows an oven having only one recirculation duct with one end connected with a central region of the main chamber and the other end communicating with the terminal portion of the curing zone of the main chamber. The oven comprises also a double Venturi duct for regulating air flow into the solvent removal zone of the main chamber preceding the curing zone.

**[0014]** Under this situation, the main object of the present invention is to substantially obviate all the above mentioned drawbacks.

**[0015]** In particular, it is a fundamental object of the invention to provide an enamelling oven in which the volume of the air entering the outlet opening can be adjusted to the most precise degree, said adjustment being made independent of the volume of the hot fluid recirculating within the baking chamber.

**[0016]** Another object of the invention is to provide an oven capable of adapting itself to the various operating requirements and in particular the different requirements encountered when enamels of different physico-chemical properties are to be handled.

**[0017]** Yet another object of the invention is to provide an enamelling oven capable of carrying out adjustment of the gases recirculating in the oven in a quick and efficient manner-, as well as in particular of the cold air entering the outlet opening of the main chamber.

**[0018]** The foregoing and further objects that will become more apparent in the following are substantially achieved by an enamelling oven for wire material according to the characterizing part of claim 1.

**[0019]** Further features and advantages will be best understood from the detailed description of a preferred non-exclusive embodiment of an enamelling oven for wire material in accordance with the present invention.

**[0020]** Such a description is taken hereinafter by way of nonlimiting example with reference to the accompanying drawing in which the only figure diagrammatically shows an enamelling oven for wire material according to the present invention.

**[0021]** With reference to the drawing, the enamelling

oven in question has been generally identified by reference numeral 1. Oven 1 is interposed between a wire enamelling station in which insulating enamel is applied to the wire or wires to be enamelled and which is located upstream of oven 1, and a cooling station for the enamelled wire emerging from the oven, which station is located downstream of the oven itself. These stations are not shown in the figure and will not be further described as they are not of importance to the ends of the present invention.

**[0022]** The oven in question comprises at least one main chamber 2 which is lengthwise passed through by at least one movable wire 3 moving along a predetermined feed direction identifiers by arrows 4. It should be noted that usually the main chamber is simultaneously passed through by several wire portions 3 disposed parallelly to one another. It should be also noted that wire 3 is movable from an inlet opening 5 formed at one end of the main chamber 2 to an outlet opening 6 formed at the other end of said chamber.

**[0023]** In a conventional manner, oven 1 is also comprised of a recirculation duct generally denoted by 7, which has an initial section 8 located close to the inlet opening 5 and in fluid communication with the main chamber 2. The recirculation duct 7 also has an end section 9 which is in fluid communication too with the main chamber 2 close to the outlet opening 6. In other words, as viewed from the figure, the recirculation duct 7 extends adjacent to the main chamber 2 and defines a substantially loop-shaped path therewith; in said path, due to the ventilation means 10 and the geometrical conformation of the different ducts, a gas flow is generated which at the main chamber 2 flows in countercurrent relative to the feed direction of the wire 3 so as to facilitate disposal of vapours from the solvent material and a heat exchange with the wire itself.

**[0024]** The ventilation means 10 preferably comprises a ventilation member or fan operating at the recirculation duct immediately downstream of the initial section 8.

**[0025]** For the sake of completeness it should be pointed out that at a centre section of the recirculation duct 7 provision is made for a first group of heating resistors 11, a catalytic plate 12 and optionally a second heating resistor group 13 for a fine adjustment of the fluid temperature.

**[0026]** An exhaust conduit or stack 14, only partly shown, is also provided and it is arranged to discharge part of the hot fluid resulting from combustion. It is to note that the exhaust conduit 14 too is generally equipped with a respective suction fan, not shown as known and conventional.

**[0027]** In an original manner and in accordance with the present invention, oven 1 also comprises an auxiliary channel 15 having one end 15a communicating with the recirculation duct 7 and a second end 15b communicating with the main chamber 2. In more detail, the first end 15a of duct 15 draws fluid from duct 7 preferably

close to the end section 9.

**[0028]** The second end 15b of channel 15, in turn, is connected to the main chamber 2 preferably at an intermediate region thereof between the outlet opening 6 and an insertion section 16 of the end section 9 into the chamber 2.

**[0029]** As viewed from the drawing, the end section 9 of duct 7 has a decreasing area in cross-section as it moves close to the main chamber 2, so that an efficient Venturi effect is achieved and, as a result, a vacuum is created in the main chamber portion included between the outlet opening 6 and said insertion section 16. To this end, the end section 9 opens into the main chamber 2 in a direction substantially tangential to, or in any event slightly inclined to the longitudinal extension direction of the main chamber itself.

**[0030]** On the contrary, the auxiliary channel 15 has a cross-section of substantially constant area and enters the main chamber 2 at right angles thereto.

**[0031]** Preferably, but not necessarily, at the second end 15b of the auxiliary channel 15 provision is made for flow adjusting means 17 comprising at least one valve proportionally operable between a full-closure condition and a full-opening condition so as to substantially offer an infinite number of adjustment possibilities for the flow circulating in the channel 15.

**[0032]** Operation of the enamelling oven 1 according to the invention described above mainly as regards structure, is as follows.

**[0033]** As shown in the drawing, the fan 10 operating in the recirculation duct 7 causes an increase in the kinetic energy of the flow made up of air and solvent vapours (see arrows 20). Then said flow encounters the resistor groups 11 and 13 and the catalytic plate 12 where it is fired. The hot flow goes on until it reaches the section of the recirculation duct 7 where the exhaust conduit 14 is provided. At said conduit, due to the presence of a respective suction fan (not shown), part of the hot gases are sucked out. The remaining and predominant portion of the gases reaches the duct end section 9 and the auxiliary recirculation channel 15. At this point, depending on the operating conditions of the adjustment valve 17, different technical effects to be better analyzed in the following can be achieved,

**[0034]** In any case, the air flow passing through the end section 9 creates a vacuum in the main chamber 2 causing external fresh air to be drawn in through the outlet opening 6. As shown in the drawing, wire 3 moves from the inlet opening 5 to the outlet opening 6 according to the orientation shown by arrows 4, in countercurrent with respect to the gas flow running according to the orientation shown by arrows 20.

**[0035]** Said gases pass through the whole main chamber 2 in which a vacuum condition relative to the external environment constantly exists and they are then recalled through the initial section 8 of the recirculation duct.

**[0036]** It is to note that by virtue of the vacuum condi-

tion existing within the chamber 2, suction of air from the outside also takes place from the inlet opening 5.

**[0037]** Dealing now in greater detail with the fundamental aspects of the present invention, it is pointed out that, due to the presence of the auxiliary channel 15 provided with the adjustment valve 17, a very precise, efficient and quick control on the amount of air entering the chamber from the outlet opening 6 can be carried out. In this connection, it should be noted that positioning of the adjustment valve in a closed condition causes the flow downstream of the exhaust conduit 14 to be completely routed towards the end section 9 of duct 7 so as to give rise to an important Venturi effect bringing about a strong suction of fresh air from the outlet opening 6.

**[0038]** Conversely, assuming that the adjustment valve is positioned in a fully-open condition, a predetermined portion of the hot gas flow also passes through the auxiliary channel 15. Under this situation, the vacuum produced, due to the Venturi effect, by the end section 9 will be only partly reduced as compared with the preceding case, thereby achieving a good vacuum in the main chamber portion between the insertion section 16 and opening 6, and therefore without any risks that gases will escape from said opening.

**[0039]** However, the suction effect not only will produce suction of external fresh air from the outlet opening 6, but will also cause a recall of hot gases from the auxiliary channel 15. In other words, the portion of the main chamber 2 included between the auxiliary channel 15 and end section 9 is passed through by a fluid the temperature of which can be adjusted by opening or closing the adjustment valve 17 to a greater or lesser degree, because part of the fluid therein present comes from the auxiliary channel 15.

**[0040]** In addition, note should be taken that, due to the channel 15 and valve 17, a fine and sudden adjustment of the cold air volume drawn in from the outlet opening 6 can be carried out, without on the other hand causing an important change in the flow rate of the baking chamber, in that the flow resistances produced by the adjustment valve are surely lower than in the known art because the fluid velocity in channel 15 is greatly lower than that in the end section 9.

**[0041]** The invention achieves important advantages.

**[0042]** In fact, thanks to the presence of the auxiliary channel 15, it is possible to adjust the volume of the air introduced from the opening 6, independently of the amount of the overall fluid processed in the oven. In addition, the temperature in the main chamber portion included between the channel 15 and end section 9 can be adjusted too, so that the length of the efficient portion of chamber 2 can be adapted by turns to the different requirements, depending on the types of insulating enamels used for covering the wire 3. In fact, it should be noted that, depending on the typologies of the insulating enamels used, the polymerization times can have different durations. However, it is of the greatest importance that the wire on which the covering enamel has

already been completely polymerized should not stay any longer at high temperatures, in that this situation would surely damage the integrity of the insulating layer. On the other hand, is it obvious that the insulating layer must be properly polymerized before letting the wire come out of the oven. Due to the presence of channel 15 and the related adjustment valve, oven 1 is capable of adapting itself to any necessities as it can each time carry out a temperature adjustment in a portion of the main chamber 2, and of ensuring a great operating flexibility.

## Claims

1. An enamelling oven for wire materials comprising:

- at least one main chamber (2) lengthwise passed through by at least one movable wire (3), along a predetermined feed direction, from an inlet opening (5) to an outlet opening (6) of the main chamber;
- at least one recirculation duct (7) having one initial section (8) disposed in fluid communication with said main chamber (2) close to the inlet opening (5) and one end section (9) disposed in fluid communication with the main chamber (2) close to the outlet opening (6);
- ventilation means (10) for generating in said main chamber (2), an air flow in countercurrent to said wire feeding direction (3);
- and an auxiliary channel (15),

characterized in that said auxiliary channel (15) has one end (15a) communicating with said recirculation duct (7) and a second end (15b) communicating with said main chamber (2) at an intermediate region between said outlet opening (6) and said end section (9), flow-adjusting (17) means being operatively associated with the auxiliary channel (15).

2. An oven according to claim 1, characterized in that the first end (15a) of said auxiliary channel (15) draws fluid from the recirculation duct (7) substantially close to the end section (9) of said recirculation duct.

3. An oven according to claim 1, characterized in that said auxiliary channel (15) has a substantially constant cross-section.

4. An oven according to claim 1, characterized in that said second end (15b) of the auxiliary channel (15) opens into said main chamber (2) in a direction substantially perpendicular to the longitudinal extension direction of the main chamber itself.

5. An oven according to claim 1, characterized in that

said adjusting means (17) comprises at least one valve proportionally operable between a fully-closed condition and a fully-open condition.

6. An oven according to claim 1, characterized in that said end section (9) has an area in cross-section that progressively decreases as it approaches said main chamber (2).

7. An oven according to claim 1, characterized in that said ventilation means (10) comprises a ventilation member operating at said recirculation duct (7).

## Patentansprüche

1. Emaillierofen für fadenförmige Materialien, umfassend:

- mindestens eine Hauptkammer (2), die durch mindestens einen beweglichen Faden (3) längs einer vorgegebenen Vorschubrichtung von einer Eintrittsöffnung (5) bis einer Austrittsöffnung (6) der Hauptkammer durchquert wird;
- mindestens eine Rücklaufleitung (7) mit einem Anfangsabschnitt (8), der mit der Hauptkammer (2) nahe der Eintrittsöffnung (5) in fluiden Verbindung steht, und einem Endabschnitt, der mit der Hauptkammer (2) nahe der Austrittsöffnung (6) in fluiden Verbindung steht;
- Lüftungsmittel (10), um in dieser Hauptkammer (2) einen Luftfluß im Gegenstrom zur Vorschubrichtung des Fadens (3) zu erzeugen;
- und einen Hilfskanal (15),

dadurch gekennzeichnet, daß der Hilfskanal (15) ein erstes mit der Rücklaufleitung (7) kommunizierendes Ende (15a) und ein zweites Ende (15b) besitzt, das mit der Hauptkammer (2) in einem zwischen der Austrittsöffnung (6) und dem Endabschnitt (7) liegenden Bereich kommuniziert, wobei dem Hilfskanal (15) Durchflußeinstellmittel (17) wirksam zugeordnet sind.

2. Emaillierofen nach Anspruch 1, dadurch gekennzeichnet, daß das erste Ende (15a) des Hilfskanals (15) das Fluid der Rücklaufleitung (7) im wesentlichen nahe des Endabschnittes (9) der Rücklaufleitung entnimmt.

3. Emaillierofen nach Anspruch 1, dadurch gekennzeichnet, daß der Hilfskanal (15) einen im wesentlichen konstanten Querschnitt aufweist.

4. Emaillierofen nach Anspruch 1, dadurch gekennzeichnet, daß das zweite Ende (15b) des Hilfskanals (15) in die Hauptkammer (2) gemäß einer Richtung einmündet, die zur Richtung der Längsabwick-

lung der Hauptkammer selbst senkrecht steht.

5. Emaillierofen nach Anspruch 1, dadurch gekennzeichnet, daß die Einstellmittel (17) mindestens ein Ventil umfassen, das proportional zwischen einer vollständigen Schließstellung und einer vollständigen Offenstellung steuerbar ist.
6. Emaillierofen nach Anspruch 1, dadurch gekennzeichnet, daß der Endabschnitt (9) eine Querschnittsfläche besitzt, die schrittweise unter Annäherung an die Hauptkammer (2) verkleinert wird.
7. Emaillierofen nach Anspruch 1, dadurch gekennzeichnet, daß die Lüftungsmittel (10) ein Lüftungsorgan umfassen, das im Bereich der Rücklaufleitung (7) wirkt.

#### Revendications

1. Four pour l'émaillage de matériaux en fil comprenant:

- au moins une chambre principale (2) traversée en sens longitudinal par au moins un fil (3) mobile, le long d'une direction d'avance prédéterminée, depuis une ouverture d'entrée (5) jusqu'à une ouverture de sortie (6) de la chambre principale;
- au moins un conduit de remise en circulation (7) ayant une portion initiale (8) mise en communication de fluide avec ladite chambre principale (2) à proximité de l'ouverture d'entrée (5) et une portion finale (9) mise en communication de fluide avec la chambre principale (2) à proximité de l'ouverture de sortie (6);
- des moyens de ventilation (10) pour engendrer dans ladite chambre principale (2) un écoulement d'air en contre-courant par rapport à ladite direction d'avance du fil (3);
- et un canal auxiliaire (15),

caractérisé en ce que ledit canal auxiliaire (15) a une première extrémité (15a) communiquant avec ledit conduit de remise en circulation (7) et une deuxième extrémité (15b) communiquant avec ladite chambre principale (2) à une zone intermédiaire entre ladite ouverture de sortie (6) et ladite portion finale (9), des moyens de réglage de l'écoulement (17) étant associés de manière opérationnelle au canal auxiliaire (15).

2. Four selon la revendication 1, caractérisé en ce que la première extrémité (15a) dudit canal auxiliaire (15) enlève du fluide du conduit de remise en circulation (7) essentiellement à proximité de la portion finale (9) dudit conduit de remise en circulation.

3. Four selon la revendication 1, caractérisé en ce que ledit canal auxiliaire (15) a une section transversale sensiblement constante.

4. Four selon la revendication 1, caractérisé en ce que ladite deuxième extrémité (15b) du canal auxiliaire (15) débouche dans ladite chambre principale (2) selon une direction sensiblement perpendiculaire à la direction d'extension longitudinale de la chambre principale elle-même.

5. Four selon la revendication 1, caractérisé en ce que lesdits moyens de réglage (17) comportent au moins une soupape susceptible d'être actionnée proportionnellement entre une conditions complètement fermée et une condition complètement ouverte.

6. Four selon la revendication 1, caractérisé en ce que ladite portion finale (9) a une aire en section transversale qui diminue progressivement au fur et à mesure qu'elle se rapproche de ladite chambre principale (2).

7. Four selon la revendication 1, caractérisé en ce que lesdits moyens de ventilation (10) comportent un organe de ventilation agissant en correspondance dudit conduit de remise en circulation (7).

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