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(54) Title: PRODUCTION OF AN ALUMINIUM STRAND

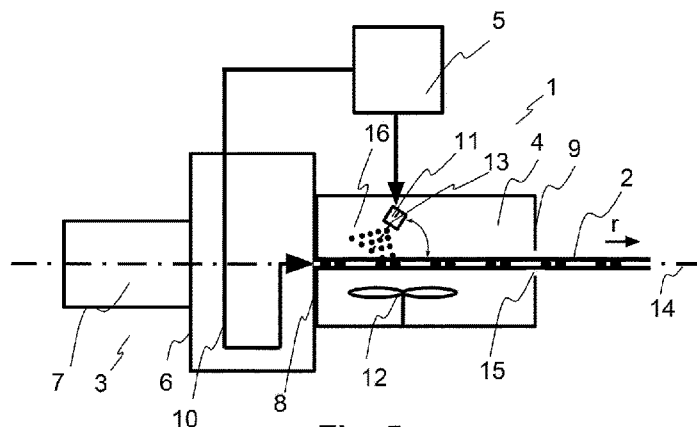


Fig. 5

(57) Abstract: Device (1) for producing an aluminium strand (2), comprising a press (3), a cooling installation (4) and a liquid gas source (5), wherein the press (3) comprises a die (6), wherein a press material (7) is able to be pressed through the die (6) into an aluminium strand (2) in the press (3), wherein the cooling installation (4) for cooling the aluminium strand (2) is directly downstream of the die (6), and wherein the cooling installation (4) is connected to the liquid gas source (5).

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Production of an aluminium strand

The present invention relates to a device and to a method for producing an aluminium strand.

- 5 The extrusion of an aluminium strand is known. A subsequent heat treatment to increase the strength of aluminium is also known.

A plurality of steps are performed for extruding an aluminium strand. First, an aluminium press is heated, then the aluminium press is pressed into an aluminium strand by a die in the extrusion press. The still heated aluminium strand is air-cooled to room
10 temperature. Often a transport to another heat treatment is then carried out in a furnace because the press and the furnace are not present in one place. This heat treatment can in particular be a so-called solution annealing. For heat treatment, the aluminium strand is first heated to a target temperature in a furnace and then quenched with water (quenching). The aluminium strand is heated to a suitable temperature in the furnace so
15 that one or more soluble components in the strand material can transition into a solid solution where they are kept in the supersaturated state after quenching. The heated aluminium strand is quenched with water, as the required critical cooling rate is achieved here, so that the structure no longer changes when cooled by, for example, diffusion processes. After quenching, the aluminium strand has the desired material properties.
20 The extrusion process and heat treatment in the furnace with subsequent quenching are in separate locations in order to prevent liquid water or water vapour from entering the press, causing damage to the press or material defects on the aluminium strand there.

Proceeding therefrom, the object of the present invention is to design the production of aluminium strands to be more efficient and less complex, and to produce the aluminium
25 strands with improved material and surface properties.

This object is achieved by the features of the device claim and the method claim. Further advantageous design embodiments of the invention are specified in the dependent claims. The features individually listed in the dependent claims may be combined with one another in technologically advantageous fashion and may define further
30 embodiments of the invention. Moreover, the features specified in the claims are more

particularly described and elucidated in the description, with further preferred embodiments of the invention being specified.

According to the invention, a device for producing an aluminium strand is presented, which comprises a press, a cooling installation and a liquid gas source, wherein the press
5 comprises a die, wherein a press material in the press is pressable through the die to an aluminium strand, wherein the cooling installation for cooling the aluminium strand is directly downstream of the die, and where the cooling installation is connected to the liquid gas source.

A press material can be heated in the press and by way of a pressing force be pressed
10 through the die into an aluminium strand. The press material can be pre-heated, and be inserted into the press only for pressing. The press preferably has a heating device. The heating device can be used to heat the press material. The press includes a die. This allows the press material to be pressed into the aluminium strand. The press may also include a ram and/or a recipient. The recipient can enclose the press material and the
15 ram can generate a force to push the press material through the opening of the die. For cavities in the aluminium strand, a mandrel can be attached to the die. In the press, forming work is carried out to produce a strand shape with a profile specified by the die from the press material. The press preferably works according to the method of full-forward extrusion and/or hollow-forward extrusion.

20 However, it is not relevant here how the force is generated to press the press material through the die.

An aluminium strand is an elongate body with a profile shape defined by the die. Profile shape refers here to the shape of the cross section of the strand. The opening of the die has the negative of the external shape for the aluminium strand to be produced. The
25 device depends neither on the shape of the die nor on the profile shape of the aluminium strand.

The die is preferably interchangeable and can be adapted to the desired profile shape of the aluminium strand.

The press material can be heated to a forming temperature to make it easier to press
30 the press material through the die into an aluminium strand. Furthermore, the forming heat can be used to further heat the press material and/or the aluminium strand. A

temperature reached for solution annealing is preferably suitable for setting a desired microstructure in the aluminium strand. The aluminium after pressing therefore preferably has a sufficient temperature for a sufficient time so that one or more soluble components can transition into a solid solution, where they can be kept in the supersaturated state after quenching. Therefore, the aluminium strand can be produced and solution annealing can be carried out at the same time with the device described. For the device it does not matter whether the press material is heated ahead of or in the press. In any case, the heat present during extrusion and the resulting forming heat can be utilized for solution annealing.

10 The aluminium strand is pressed from the press material through the die by the press. Preferably, at least 0.1 kg of the press material is pressed into the aluminium strand per second. Particularly preferably, at least 1 kg of the press material is pressed into the aluminium strand per second. The aluminium strand is preferably composed of the aluminium alloy ALZnMgCu1,5, preferably AlMgSi0.5 and particularly preferably
15 AlMgSi1.

The produced aluminium strand preferably has a length of at least 10 m, particularly preferably of at least 50 m.

The produced aluminium strand preferably has a mass of at least 10 kg, particularly preferably of at least 100 kg.

20 The liquid gas source is preferably a source for liquid inert gas and/or gaseous inert gas. The liquid gas source can make available a plurality of components. One component herein may be liquid inert gas and/or gaseous inert gas. Particularly preferably, the liquid gas source is a source for supercooled liquid inert gas and/or cooled gaseous inert gas.

The cooling installation is connected to the liquid gas source. The cooling installation can
25 be supplied with one or more components of the liquid gas source. The cooling installation can therefore be operated with liquid gas from the liquid gas source as a coolant. This is particularly preferable to water cooling. Water cooling directly adjacent to the die would be disadvantageous due to the water vapour generated by the water cooling.

30 The cooling installation is used to quench the aluminium strand at a critical cooling rate. The temperature to which the aluminium strand is cooled by the cooling installation is

only of minor importance compared to the cooling rate. For example, the aluminium strand can be cooled by the cooling installation to a temperature in the range of 10 to 50 °C, in particular to room temperature. Since the temperature can vary across the cross section of the aluminium strand, these specifications refer to a core temperature of the aluminium strand. If the aluminium strand is cooled to a temperature above or below the temperature of the ambient air by the cooling installation, the aluminium strand can reach the temperature of the ambient air by contact with the ambient air outside the cooling installation.

The cooling of the aluminium strand at a critical cooling rate in the cooling installation has the advantage that controlled and more homogeneous cooling with liquid gas is possible. This serves to improve the surface quality of the aluminium strand and/or increase the mechanical strength of the aluminium strand. A high surface quality means that the surface hardness is less scattered and more homogeneous. The cooling installation allows the structure of the material, which has been set due to the temperature for solution annealing of the aluminium strand in the press, to be better established and controlled. In particular, at least part of the soluble components can thus be preserved in solid solution. The cooling installation also serves to reduce the thermal stresses in the aluminium strand and thus produce the most rectilinear strand possible.

The cooling installation for cooling the aluminium strand is directly downstream of the die. This has the advantage that the aluminium strand does not have to be transported in a complex manner between the press and a downstream thermal treatment. The heated aluminium strand is hereby cooled in the cooling installation immediately after the press. Furthermore, this arrangement serves an efficient use of energy, since both the aluminium strand and the press material are heated only once. A transportation procedure between the press and the furnace for heat treatment would result in intermittent cooling and would require repeated heating to the temperature for solution annealing. At the same time, at least some of the soluble components can be retained in solid solution in the aluminium strand. Disposing the cooling installation directly adjacent to the die is possible above all due to the use of the liquid gas as a coolant, particularly in comparison to water cooling.

The fact that the cooling installation is directly downstream of the die means that the aluminium strand does not pass through any further elements between the cooling

installation and the die. In addition, the disposal of the cooling installation directly downstream of the die is in contrast to the solution known from the prior art, in which the extrusion and thermal treatment with quenching take place as independent processes in separate spaces. Preferably, the cooling installation and the die are not more than 1 m
5 apart. Particularly preferably, the cooling installation and the die are adjacent to each other. Furthermore, it is preferred that the die is disposed on an axis of the cooling installation. Such an arrangement would not make sense if the extrusion and thermal treatment with quenching were carried out as separate processes, as in the prior art.

The device according to the invention further has the synergetic effect of the described
10 advantages. The aluminium strand can be cooled evenly, the time-consuming transport of the aluminium strand from the press for heat treatment is eliminated, the aluminium strand is heated only once, so that a more efficient use of energy takes place and the structure of the material to be set can be better controlled.

In a preferred embodiment, the cooling installation comprises an elongate hollow body,
15 wherein a first end face of the hollow body is disposed directly on the die, and wherein a second end face facing the first end face has an opening.

A cooling installation comprising a hollow body has the advantage that an advantageous atmosphere in terms of convection can be created in the hollow body without the warmer ambient air diminishing the cooling effect of the cooling installation by mixing.
20 Furthermore, this has the advantage that inertization in the hollow body can be ensured and possible undesired reactions and/or undesired diffusion processes of air with the surface of the aluminium strand can be prevented.

The opening serves to feed through the aluminium strand.

The cooling installation preferably has an axis which is aligned along the longitudinal axis
25 of the hollow body. The aluminium strand is preferably on the axle. This has the advantage that the aluminium strand can always be optimally guided through the cooling installation.

The hollow body is preferably formed as a cooling tunnel.

The cooling installation is preferably at least 0.5 m long, particularly preferably at least 2 m long. The cooling installation is preferably not longer than 10 m, particularly preferably not longer than 5m.

5 In another preferred embodiment, the die has a cooling duct which is connected to the liquid gas source.

The cooling duct serves to cool the die. Forming heat in the press, which is not used to heat the press material, can be effectively dissipated via the cooling duct. As a coolant, the liquid gas from the liquid gas source can be passed through the cooling duct.

10 The coolant is preferably present so as to be liquid and/or gaseous in the cooling duct. Liquid coolant, which evaporates to gaseous coolant, has the advantage that the heat can be dissipated particularly effectively.

Preferably, an outlet of the cooling duct is fluidically connected to the cooling installation. This has the advantage that the coolant from the cooling duct can facilitate the cooling of the aluminium strand in the cooling installation.

15 In another preferred embodiment, the cooling installation comprises a two-fluid nozzle and/or a fan.

A liquid and a gaseous component are discharged simultaneously in one spray jet from the two-fluid nozzle. The gaseous component may have a higher flow rate than the liquid component at the nozzle outlet. Due to the high relative velocity between the liquid component and the gaseous component, the liquid component decomposes into ligaments and droplets. Ligaments are elongate fluid threads that can further decompose into droplets. The liquid component can also decompose into drops of identical size. The liquid droplets impacting on the surface of the aluminium strand can cool the aluminium strand by evaporation and/or convection. The gaseous component can cool the aluminium strand by convection. The liquid component and the gaseous components may be formed by the same substance, in particular by nitrogen.

25 The two-fluid nozzle is preferably disposed in the cooling installation. The two-fluid nozzle is preferably a coaxial atomizer, in which a liquid is discharged from the centre of an opening, and a gas flows from a second to the first coaxial opening. Preferably, the two-fluid nozzle discharges drops of different sizes.

A two-fluid nozzle has the advantage that droplets hitting the surface of the aluminium strand at high velocity break through a vapour layer of evaporated liquid which forms, similar to the Leidenfrost effect, and improve cooling.

5 The fan serves to distribute the gas in the cooling installation. One advantage of the fan is that the convective cooling of the aluminium strand is increased.

The present embodiment has the advantage that the critical cooling rate of the aluminium strand is achieved particularly reliably.

10 In a further embodiment, an opening of the two-fluid nozzle is spaced apart from an axis of the cooling installation, wherein the two-fluid nozzle is inclined relative to the axis and/or the two-fluid nozzle is directed towards the aluminium strand.

15 An inclination of the two-fluid nozzle relative to the axis of the cooling installation and/or to the longitudinal axis of the aluminium strand has the advantage that a liquid film on the surface of the aluminium strand can be better removed and/or prevented, and fresh drops of the two-fluid nozzle thus impact the aluminium strand. Furthermore, the relative velocity of the drops hitting the aluminium strand moving at the feed rate can be increased.

Preferably, the two-fluid nozzle has an angle of at least 15°, preferably at least 30°, particularly preferably at least 45°, in relation to the axis of the cooling installation.

20 The cooling installation preferably has a plurality of two-fluid nozzles and/or a plurality of fans. The two-fluid nozzles and fans can be disposed along the cooling zone. The "and" case is preferred.

This has the advantage that the cooling of the aluminium strand can be adjusted flexibly and zone-by-zone. The two-fluid nozzles can spray as required onto the aluminium strand surface to be cooled.

25 In another preferred embodiment, the liquid gas from the liquid gas source is liquid nitrogen and/or gaseous nitrogen. Particularly preferred is the liquid gas from the liquid gas source of supercooled liquid nitrogen (LIN) and/or cooled gaseous nitrogen (GAN).

Supercooled liquid nitrogen can here preferably be generated with a subcooler, and cooled gaseous nitrogen can preferably be generated with a cold gas mixer. In this

embodiment, liquid and/or supercooled liquid nitrogen can be discharged from the two-fluid nozzle and atomized with gaseous nitrogen.

Proposed as a further aspect of the invention is a method for operating the device for producing an aluminium strand. The method is characterized in that

- 5 a) the press material is pressed through the die into an aluminium strand in the press, wherein the press material is heat-treated in the die in that forming heat at least partially heats the press material;
- b) the aluminium strand is guided through the cooling installation, wherein the aluminium strand is quenched at least at a critical cooling rate in the cooling
10 installation.

In a), the press material is preferably present at a temperature for solution annealing. Alternatively, the press material in a) can be heated to a solution annealing temperature.

In a preferred embodiment, the aluminium strand in b) is quenched by liquid or supercooled liquid nitrogen and gaseous or cooled gaseous nitrogen being discharged
15 from a two-fluid nozzle and distributed by a fan.

In another preferred embodiment, the die has a cooling duct through which a coolant is directed in a).

In a) excess heat is dissipated preferably via the cooling duct in the die. This ensures that the die and the aluminium strand do not heat up inadmissibly, causing damage to
20 the press and/or the aluminium strand.

The coolant preferably emanates from the liquid gas source and is liquid and/or gaseous.

This embodiment serves to increase the feed rate of the aluminium strand and thus produce the aluminium strand more quickly.

The invention and the associated technical field are elucidated in detail hereunder with
25 reference to the figures. It should be pointed out that the invention is not intended to be limited by the exemplary embodiments shown. In particular, unless explicitly stated otherwise, it is also possible to extract sub-aspects of the subject matter elucidated in the figures and to combine them with other constituents and knowledge from the present description and/or figures. In particular, it should be pointed out that the figures and
30 especially the size ratios illustrated are merely schematic. Identical reference numerals

denote identical items, such that any elucidations from other figures can be consulted additionally. In the figures:

- Fig. 1: shows a schematic view of a press known from the prior art;
- 5 Fig. 2: shows a schematic temperature curve which is established with the press known from Fig. 1;
- Fig. 3: shows a schematic view of an arrangement for heat treatment known from the prior art;
- Fig. 4: shows a schematic temperature curve which is set with the arrangement for heat treatment known from Fig. 3;
- 10 Fig. 5: shows a schematic view of a design embodiment of a device according to the invention; and
- Fig. 6: shows a schematic temperature profile which is set with the device from Fig. 5 when carrying out a method according to the invention for producing an aluminium strand;
- 15 Fig. 1 shows a schematic view of a press 3 known from the prior art. In the press 3, a press material 7 is pressed through a die 6 into an aluminium strand 2. The aluminium strand 2 is squeezed out at a feed rate in the feed direction r .
- Fig. 2 shows a temperature curve which is set in the press material 7 and after the die 6 in the aluminium strand 2 when the latter is moved through the press 3 from Fig. 1. The illustration of Fig. 2 is schematic. The diagram shows a plotted temperature T over the axial position L . The press material 7 is heated from a first temperature T_A to a second temperature T_B in the press 3. The press 3 has an axial length L_P . The aluminium strand 2 is demoulded from the die 6 at the second temperature T_B . The aluminium strand 2 moves at a feed rate in the feed direction r and cools down in the ambient air to a room temperature T_R . After an axial length of the air cooling L_U , the aluminium strand 2 reaches the room temperature T_R .
- 20
- 25 Fig. 3 shows a schematic view of an arrangement known from the prior art for heat treatment of an aluminium strand 2. The arrangement comprises a furnace 17 and a water cooling installation 18. The aluminium strand 2 is guided in the feed direction r

through the furnace 17 and heated. The aluminium strand 2 is then guided through the water cooling installation 18 and quenched with water.

Fig. 4 shows a temperature profile which is set in the aluminium strand 2 when the latter is moved through the furnace 17 with a length L_O and the water cooling installation 18 with a length L_{WK} from Fig. 3. The illustration of Fig. 4 is schematic. The diagram shows a plotted temperature T over the axial position L . The aluminium strand 2 is heated from a room temperature T_R to a solution annealing temperature T_G in the furnace 17. Subsequently, the aluminium strand 2 is quenched from the solution annealing temperature T_G to the room temperature T_R in the water cooling installation 18.

The known production of the aluminium strand 2 illustrated by Figures 1 and 2 and the known heat treatment of the aluminium strand 2 illustrated by Figures 3 and 4 can be carried out successively and independently of one another.

Fig. 5 shows a schematic view of a design embodiment of a device 1 according to the invention for producing an aluminium strand 2. The device 1 comprises a press 3, a cooling installation 4 and a liquid gas source 5, wherein the press 3 comprises a die 6, wherein a press material 7 in the press 3 is pressable through the die 6 to an aluminium strand 2, wherein the cooling installation 4 for cooling the aluminium strand 2 is directly downstream of the die 6, and wherein the cooling installation 4 is connected to the liquid gas source 5. The aluminium strand 2 is made of an aluminium alloy.

The liquid gas source 5 is a source for supercooled liquid and cooled gaseous nitrogen. The liquid gas source 5 makes available a plurality of components.

The aluminium strand 2 is squeezed out at a feed rate in the feed direction r .

The cooling installation 4 comprises an elongate hollow body, wherein a first end face 8 of the hollow body is disposed directly on the die 6, and wherein a second end face 9 opposite the first end face 8 has an opening 15. The cooling installation 4 has an axis 14.

The die 6 has a cooling duct 10 which is connected to the liquid gas source 5. The cooling duct 10 is fluidically connected to the cooling installation 4.

The cooling installation 4 has a two-fluid nozzle 11 and a fan 12. In the two-fluid nozzle 11, supercooled liquid nitrogen is atomized by cooled gaseous nitrogen to form a spray

jet 16. An opening 13 of the two-fluid nozzle 11 is spaced apart from an axis 14 of the cooling installation 4. Furthermore, the two-component nozzle 11 is inclined relative to the axis 14 and directed towards the aluminium strand 2. The two-fluid nozzle 11 is inclined by 45° relative to the axis 14.

5 The method for operating a device 1 is characterized in that

- a) the press material 7 is pressed through the die 6 into an aluminium strand 2 in the press 3, wherein the press material 7 is heat-treated in the die 6 in that forming heat at least partially heats the press material 7;
- b) the aluminium strand 2 is guided through the cooling installation 4, wherein the
10 aluminium strand 2 is quenched at least at a critical cooling rate in the cooling installation 4 in that supercooled liquid nitrogen and cooled gaseous nitrogen are discharged from a two-fluid nozzle 11 and distributed by a fan 12.

The die 6 includes the cooling duct 10 through which a coolant is directed in a). Excess heat in the die 6 can be dissipated via the cooling duct 10. The coolant from the liquid
15 gas source 5 is liquid and can evaporate into a gas when excess forming heat is absorbed. The coolant from the cooling duct 10 is discharged into the cooling installation 4 and facilitates the cooling of the aluminium strand 2.

Fig. 6 shows a temperature profile which is set in the press material 7 and behind the die 6 in the aluminium strand 2 when, as shown in Fig. 5, the press material 7 is formed by the press 3 with the length L_P into an aluminium strand 2 and is discharged from the die
20 6 and quenched at the critical cooling rate in the cooling installation 4 with the length L_K . The illustration of Fig. 6 is schematic. A plotted temperature T is shown over the axial position L . The press material 7 is present at a solution annealing temperature T_G . From the die 6, the aluminium strand 2 is discharged with a feed rate in the feed direction r and moves through the cooling installation 4. In the cooling installation 4, the aluminium
25 strand 2 is quenched from the solution annealing temperature T_G to the room temperature T_R .

List of reference signs

	1	Device
	2	Aluminium strand
	3	Press
5	4	Cooling installation
	5	Liquid gas source
	6	Die
	7	Press material
	8	First end face
10	9	Second end face
	10	Cooling duct
	11	Two-fluid nozzle
	12	Fan
	13	Opening of the two-fluid nozzle
15	14	Axis of the cooling installation
	15	Opening of the cooling installation
	16	Spray jet
	17	Furnace
	18	Water cooling installation
20	r	Feed direction of the aluminium strand
	L	Axial position
	L _K	Axial length of the cooling installation
	L _O	Axial length of the furnace
	L _P	Axial length of the press

	L_U	Axial length of air cooling
	L_{WK}	Axial length of the water cooling installation
	T	Temperature
	T_A	First temperature
5	T_B	Second temperature
	T_G	Solution annealing temperature
	T_R	Room temperature

Claims

1. Device (1) for producing an aluminium strand (2), comprising a press (3), a cooling installation (4) and a liquid gas source (5), wherein the press (3) comprises a die (6), wherein a press material (7) is able to be pressed through the die (6) into an aluminium strand (2) in the press (3), wherein the cooling installation (4) for cooling the aluminium strand (2) is directly downstream of the die (6), and wherein the cooling installation (4) is connected to the liquid gas source (5).
2. Device (1) according to claim 1, wherein the cooling installation (4) comprises an elongated hollow body, wherein a first end face (8) of the hollow body is disposed directly on the die (6), and wherein a second end face (9) facing the first end face (8) has an opening (15).
3. Device (1) according to one of the preceding claims, wherein the die (6) has a cooling duct (10) which is connected to the liquid gas source (5).
4. Device (1) according to one of the preceding claims, wherein the cooling installation (4) comprises a two-fluid nozzle (11) and/ or a fan (12).
5. Device (1) according to claim 4, wherein an opening (13) of the two-fluid nozzle (11) is spaced apart from an axis (14) of the cooling installation (4), and wherein the two-fluid nozzle (11) is inclined relative to the axis (14) and/or the two-fluid nozzle (11) is directed towards the aluminium strand (2).
6. Device (1) according to one of the preceding claims, wherein a liquid gas from the liquid gas source (5) is liquid nitrogen and/or gaseous nitrogen.
7. Method for operating a device (1) according to one of Claims 1 to 6, characterized in that
 - a) the press material (7) is pressed through the die (6) into an aluminium strand (2) in the press (3), wherein the press material (7) is heat-treated in the die (6) in that forming heat at least partially heats the press material (7);
 - b) the aluminium strand (2) is guided through the cooling installation (4), wherein the aluminium strand (2) is quenched at least at a critical cooling rate in the cooling installation (4).

8. Method according to Claim 7, wherein the aluminium strand (2) in b) is quenched in that liquid nitrogen and gaseous nitrogen are discharged from a two-fluid nozzle (11) and distributed by a fan (12).
9. Method according to Claim 7 or 8, wherein the die (6) has a cooling duct (10),
5 through which a coolant is directed in a).

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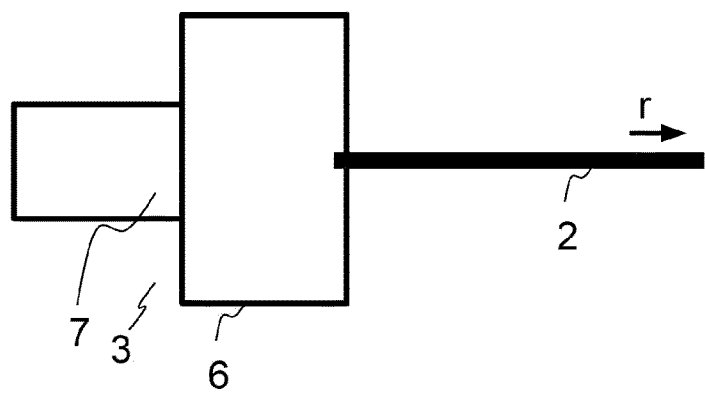


Fig. 1 Prior art

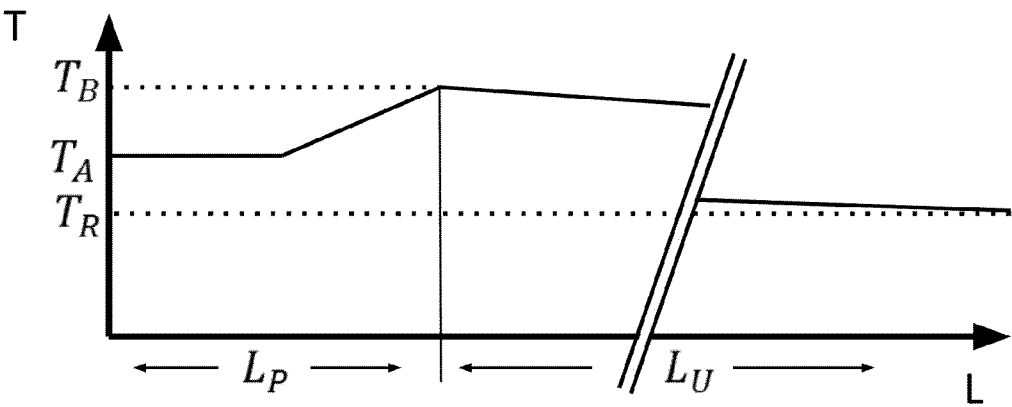


Fig. 2 Prior art

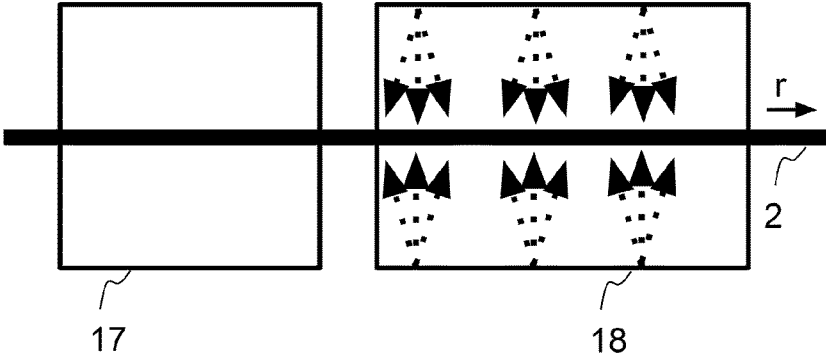


Fig. 3 Prior art

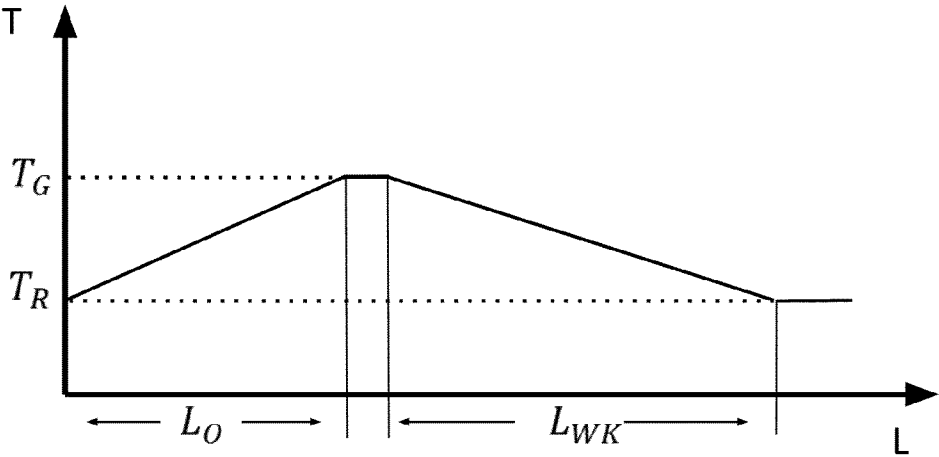


Fig. 4 Prior art

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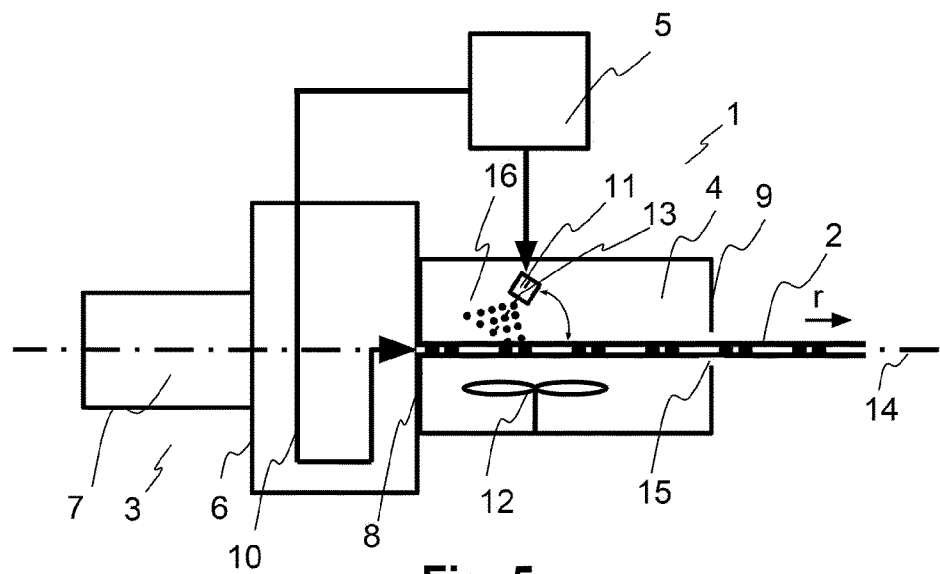


Fig. 5

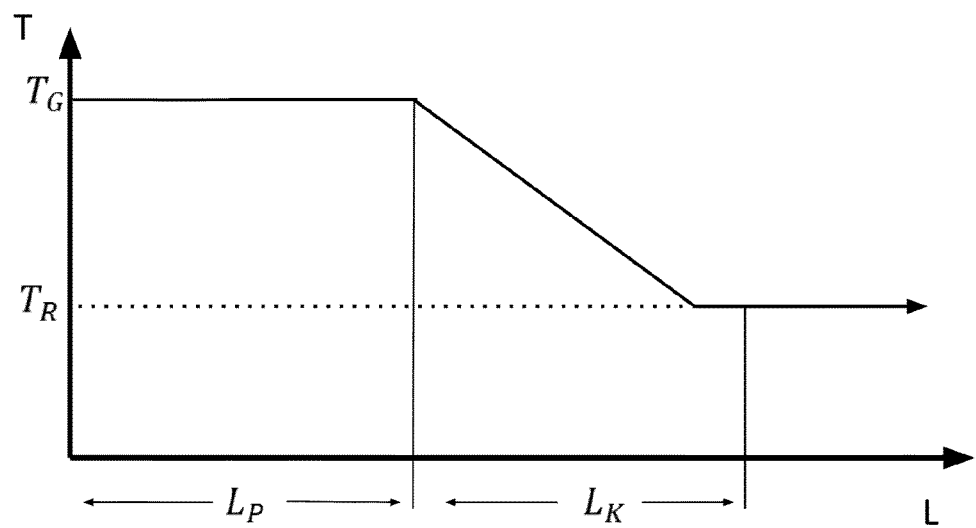


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2024/066377

A. CLASSIFICATION OF SUBJECT MATTER

INV. B21C29/00 B21C29/04
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)

B21C

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	KR 102 243 544 B1 (ALCORE CO LTD [KR]) 22 April 2021 (2021-04-22)	1-7,9
Y	paragraphs [0024] - [0050]; figures -----	8
X	EP 0 210 568 B1 (LINDE AG [DE]) 9 March 1994 (1994-03-09) column 3, line 55 - column 5, line 9; figures -----	1-6
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Further documents are listed in the continuation of Box C.



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