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(54) **HEAT EXCHANGER OF A GAS TURBINE ENGINE OF AN AIRCRAFT**

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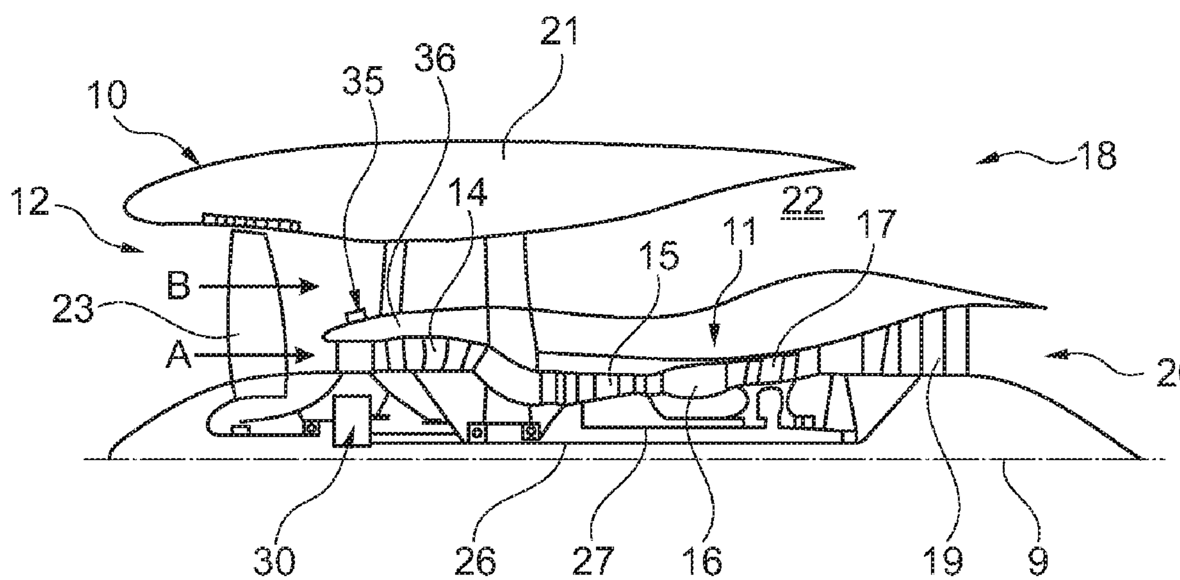
(57) **ABSTRACT**

A heat exchanger of a gas turbine engine includes a casing having a stepped incident-flow profile. An air volume flow is, in the region of the incident-flow profile, diverted such that a recirculation zone with a separation bubble forms in the flow. Downstream of the incident-flow profile, is a further stepped incident-flow profile. The flow is diverted such that, downstream of the further incident-flow profile, a further recirculation zone forms in which a separation bubble is present. In the region of the incident-flow profile and/or the further incident-flow profile, is an inlet of a flow duct which runs in the casing in the direction of a mouth. An air volume flow conducted through the flow duct emerges from the mouth at such an angle relative to the flow direction of the air volume flow that, downstream of the mouth, a recirculation zone with a separation bubble forms.



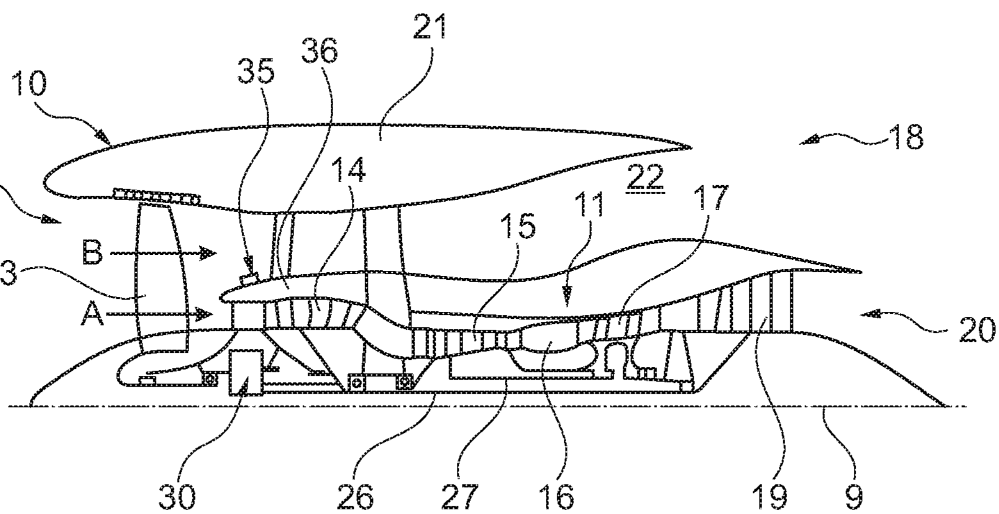


Fig. 1

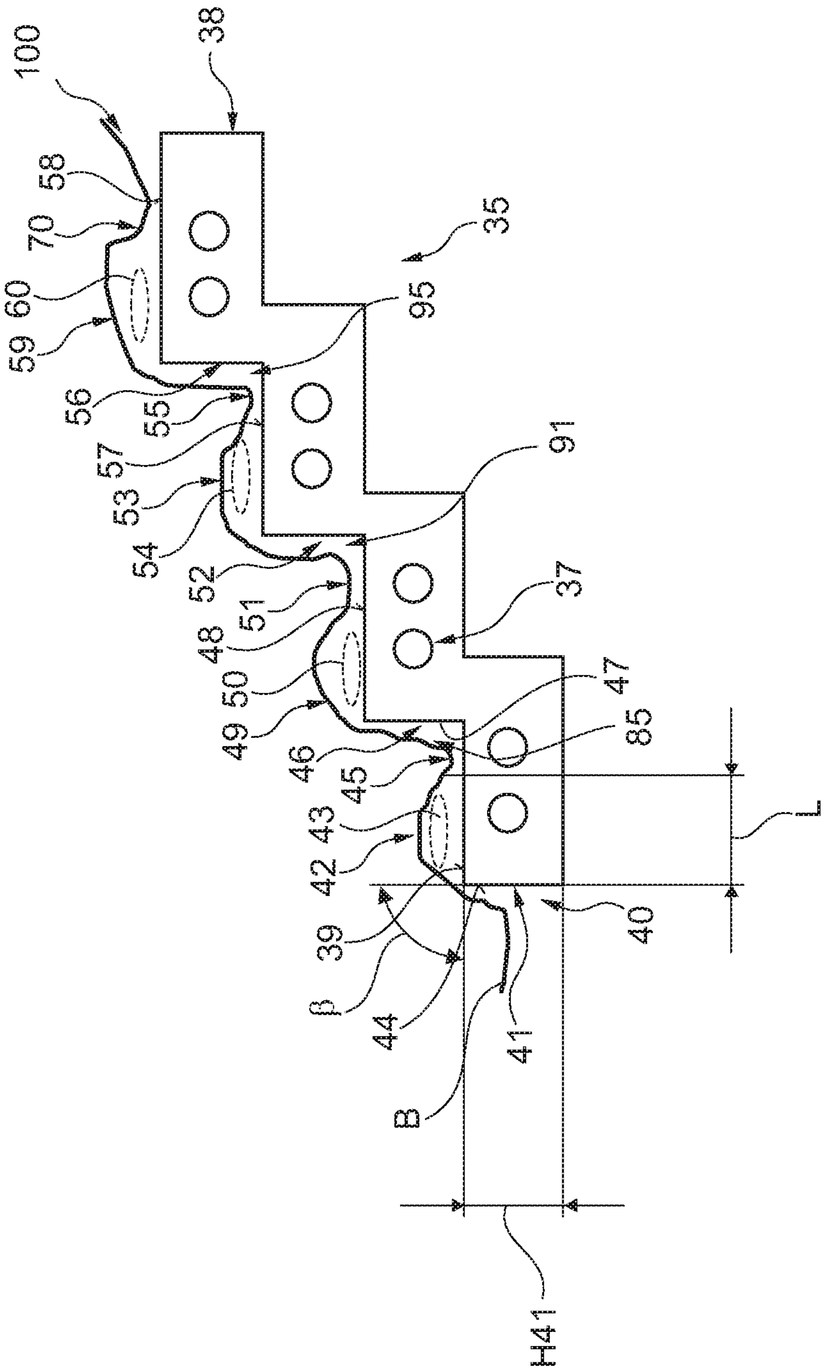

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Fig. 2

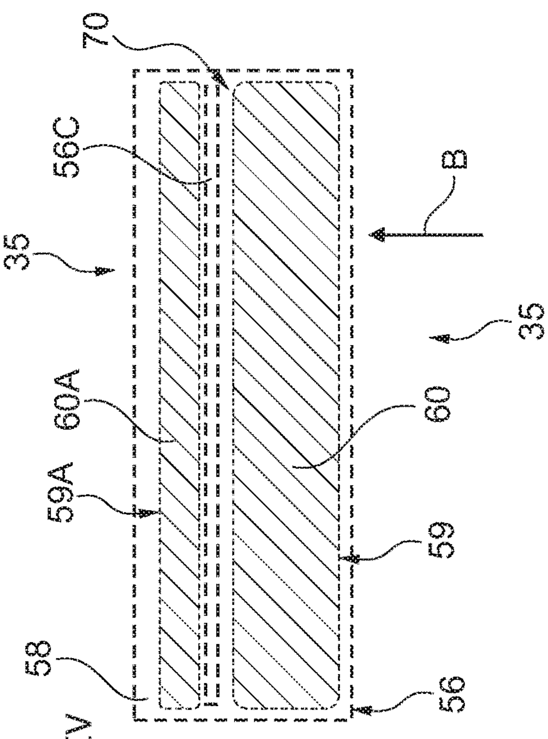
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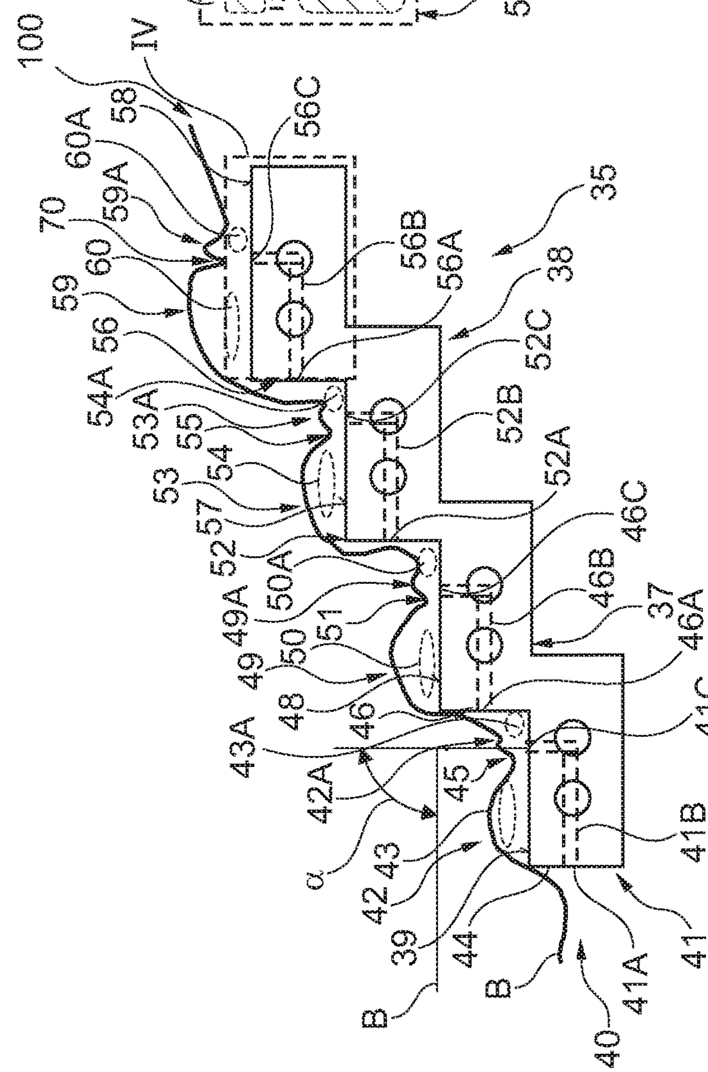
Fig. 4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46C
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46A
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41B
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Fig. 3

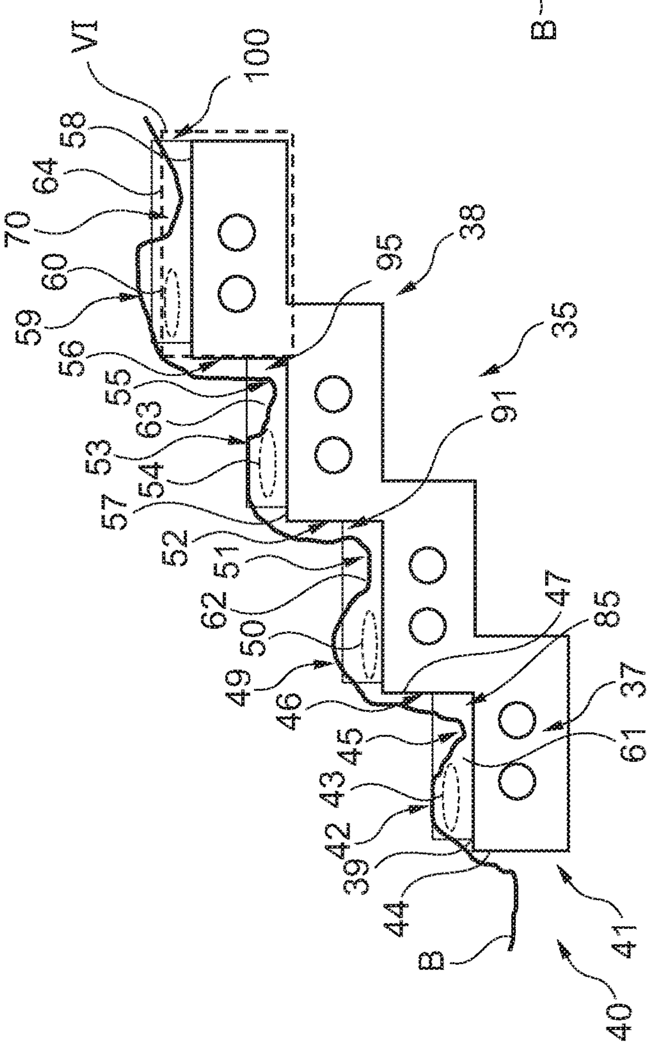
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Fig. 5

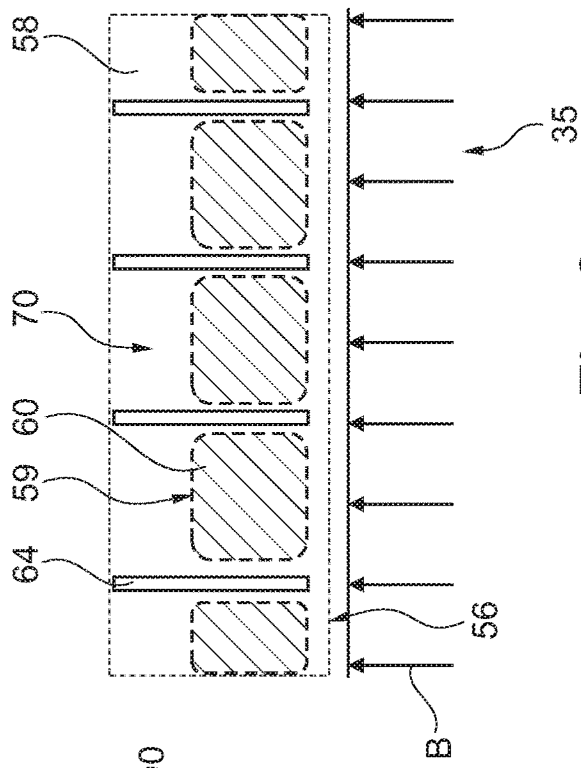
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Fig. 6

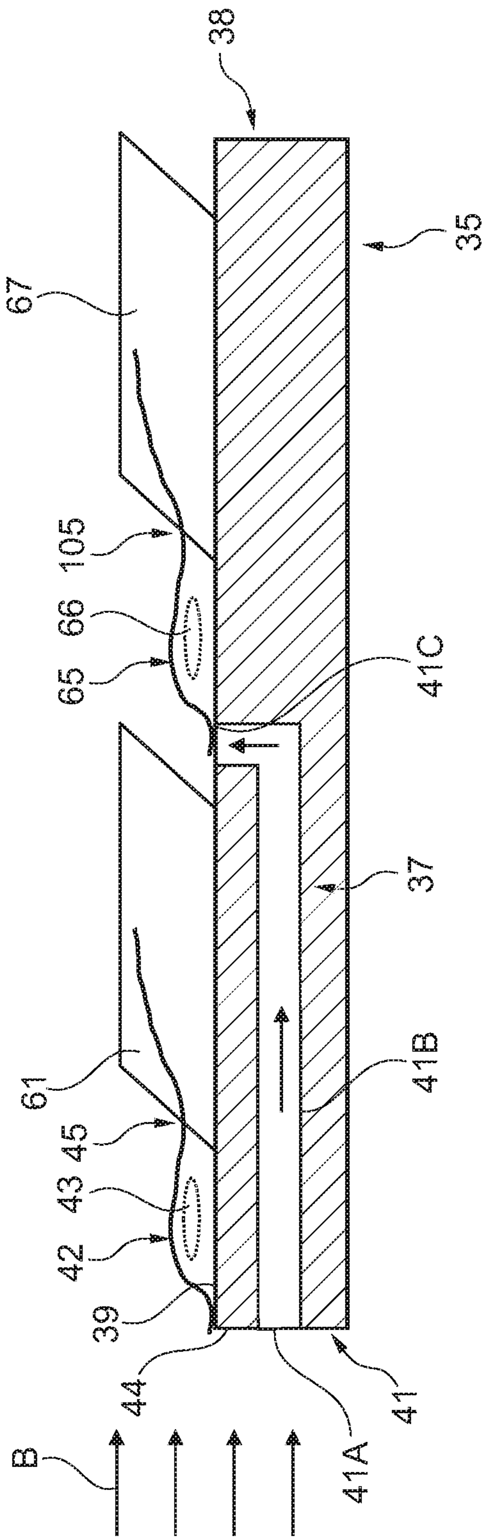

Fig. 7

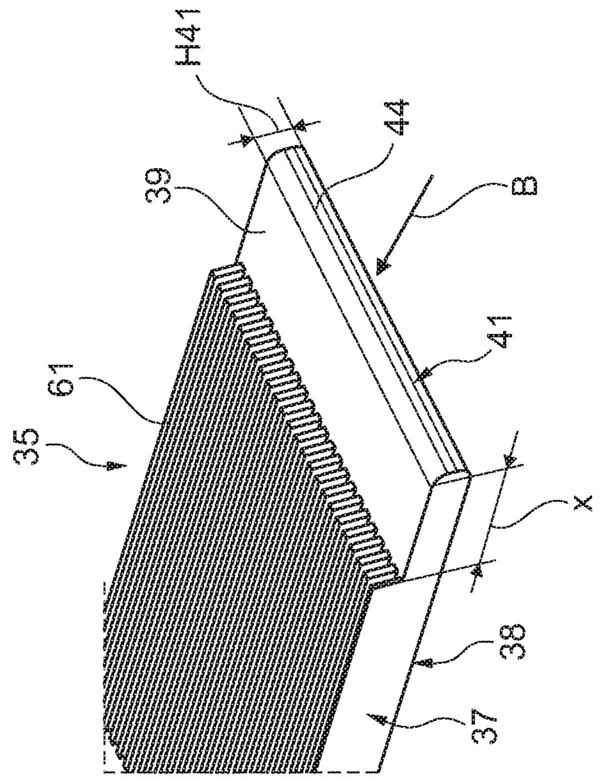

Fig. 9

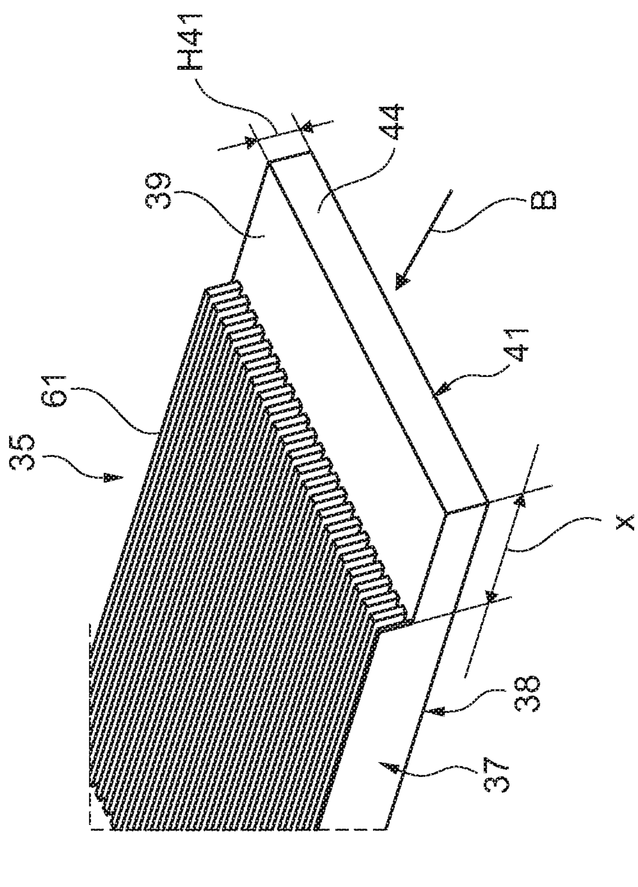

Fig. 8

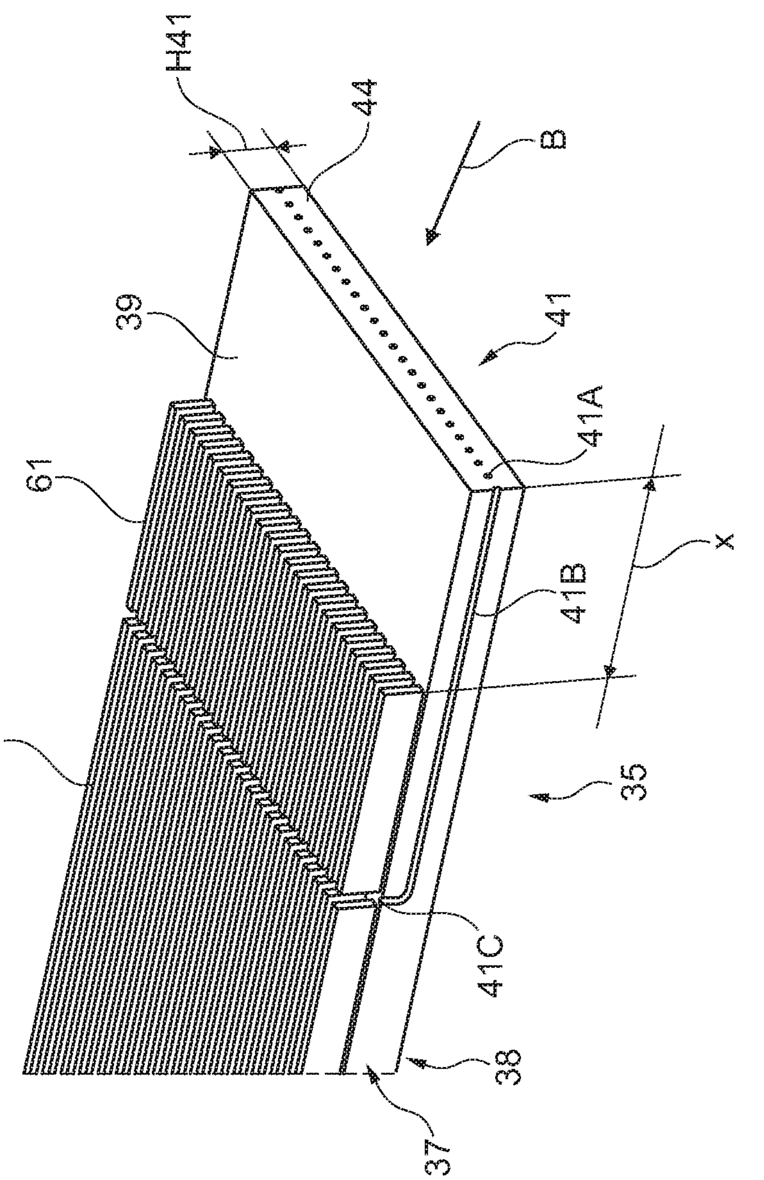

Fig. 10

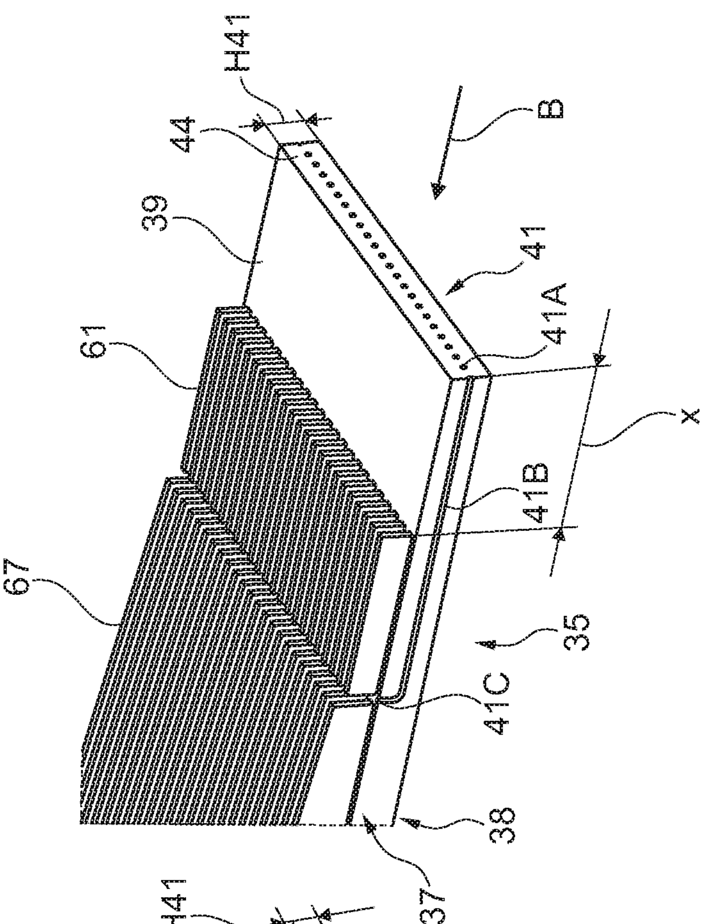

Fig. 12

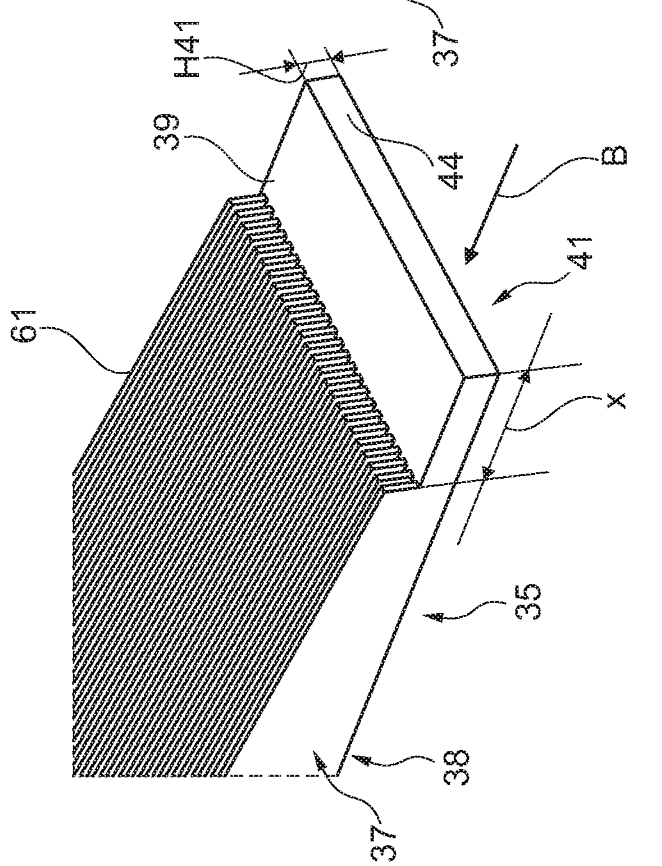

Fig. 11

HEAT EXCHANGER OF A GAS TURBINE ENGINE OF AN AIRCRAFT

[0001] This application claims priority to German Patent Application DE102019126123.6 filed Sep. 27, 2019, the entirety of which is incorporated by reference herein.

[0002] The present disclosure relates to a heat exchanger of a gas turbine engine of an aircraft, which heat exchanger has a casing and serves for controlling the temperature of a fluid, which can be conducted through the casing, by means of an air volume flow which is incident on the casing in an axial direction.

[0003] The waste heat generated by known gas turbine engines or aircraft engines during operation is released to the surroundings by means of known measures. A major part of the waste heat to be dissipated is released to the fuel that is to be burned. Since the heat energy that is transmissible to the fuel in each case is limited, gas turbine engines are designed with so-called oil-air heat exchangers. Oil-air heat exchangers are commonly arranged in the bypass flow duct of a gas turbine engine, at the radially inner side of the bypass flow duct or at the radially outer side of the bypass flow duct. The temperature of the oil conducted through the interior of the oil-air heat exchanger is controlled by means of the air volume flow which is conducted through the bypass flow duct and which flows over the heat exchanger at its outer side which faces toward the flow cross section, through which flow passes, of the bypass flow duct. To increase the surface area of the oil-air heat exchanger, oil-air heat exchangers are generally designed with cooling fins or lamellae which project into the air flow and which are oriented in the flow direction of the air volume flow in the bypass flow duct.

[0004] The efficiencies of such oil-air heat exchangers are however relatively low, because the heat transfer between the surface of the oil-air heat exchanger and the air volume flow impinging on said surface is inhibited after a certain traveling distance of the air volume flow along the surface of the oil-air heat exchanger. This results from the fact that the thickness of the boundary layer of the air volume flow increases along the surface of the heat exchanger, and thus the heat transfer coefficient decreases. The reduced heat transfer coefficient has the result that the surface of the oil-air heat exchanger must be dimensioned to be very large. For this purpose, the oil-air heat exchanger and/or the cooling fins thereof is or are enlarged. This is however in turn possible only to a very restricted extent, because the contact area between the region wetted by oil and the oil-air heat exchanger is under some circumstances limited.

[0005] The present disclosure is based on the object of providing a heat exchanger, which is favorable in terms of structural space and which is distinguished by high efficiency, of a gas turbine engine of an aircraft.

[0006] This object is achieved by a heat exchanger having the features of Patent claim **1**.

[0007] According to a first aspect, a heat exchanger of a gas turbine engine of an aircraft having a casing is provided in order to be able to control the temperature of a fluid, which can be conducted through the casing, by means of an air volume flow which is incident on the casing in an axial direction. The casing has a step-like incident-flow profile in a region facing toward the flow of the air volume flow. The air volume flow is, in the region of the incident-flow profile, diverted in relation to an outer side of the casing such that the flow of the air volume flow grows above the outer side of the casing at least approximately perpendicularly with respect to the outer side, over which flow passes, of the casing, or, in relation to the main flow direction of the air volume flow upstream of the incident-flow profile, downstream of the incident-flow profile expands at least approximately in a radial direction above the outer side, in such a way that, downstream of the incident-flow profile and above the outer side of the casing, a recirculation zone with at least one separation bubble forms in the air volume flow.

[0008] Downstream of the incident-flow profile, there is provided a further step-like incident-flow profile which, in relation to the outer side of the casing and in relation to the inner region of the casing, rises outwardly, is impinged on by the air volume flow and diverts the air volume flow. Here, the air volume flow is diverted in the region of the further incident-flow profile such that, downstream of the further incident-flow profile and above the outer side of the casing, a further recirculation zone forms in which in each case at least one separation bubble is present.

[0009] In addition or as an alternative to the further incident-flow profile, in the region of the incident-flow profile and/or in the region of the further incident-flow profile, there may be provided an inlet of at least one flow duct which runs in the casing in the direction of a mouth. The air volume flow conducted through the flow duct or the air volume flows conducted through the flow ducts emerges from the mouth or emerge from the mouths in each case at such an angle relative to the flow direction of the air volume flow that, downstream of the mouth or downstream of the mouths, in each case one recirculation zone with at least one separation bubble forms above the outer side(s) of the casing.

[0010] The targeted generation of recirculation zones with separation bubbles in accordance with the present disclosure gives rise in each case to a transition from a laminar flow profile to a turbulent flow profile of the flow of the air volume flow. This increases the heat transfer coefficient at the outer side of the heat exchanger after only a relatively short traveling distance. Furthermore, the average quantity of heat transferred in relation to the surface area of the heat exchanger required for this is increased in relation to solutions known from the prior art.

[0011] The turbulent boundary layer which attaches to the surface of the heat exchanger again after the recirculation phase significantly improves the heat transfer between the air volume flow and the fluid conducted through the casing.

[0012] By means of the heat transfer coefficient increased in the manner described in more detail above, it is in turn possible to design the heat exchanger to be smaller without reducing the temperature control performance thereof. In this way, weight savings and material savings and an oil circuit which can under some circumstances be dimensioned to be smaller in the region of the heat exchanger are possible. Furthermore, it is also possible for the fluid which is conducted through the casing, such as oil or the like, to release a greater quantity of heat to the air volume flow flowing past if the heat exchanger has approximately similar dimensions to conventionally designed heat exchangers.

[0013] The recirculation zone or the separation bubble may have a defined length in the flow direction of the air volume flow, which length is dependent on a height of the effective area of the incident-flow profile. Here, the effective area of the incident-flow profile corresponds to an area of the incident-flow profile projected into a plane which is perpendicular to the flow direction of the air volume flow.

[0014] According to a further aspect of the present disclosure, the air volume flow is, in the region of the incident-flow profile or in the region of the incident-flow pro-files and/or in the region of the mouth or in the region of the mouths, diverted relative to the outer side of the casing in a growing or expanding manner such that, in the flow direction of the air volume flow, the recirculation zones are adjoined by in each case one reattachment region. In this way, an improvement of the heat transfer coefficient is achieved in a simple manner.

[0015] Here, the mouth may be arranged at least approximately in the region of the outer side of the casing or the mouths may be arranged in each case in the region of the outer sides of the casing in which the recirculation zone ends in each case or in which the recirculation zones end in each case.

[0016] Furthermore, it may be provided that the mouth or the mouths is arranged in each case at least approximately in the region of the outer side or are arranged in each case in the region of the outer sides of the casing in which the reattachment region is present or in which the reattachment regions are present.

[0017] In a further embodiment of the heat exchanger according to the present disclosure, the air volume flow is, in the region of the incident-flow profile or in the region of the incident-flow profiles and/or in the region of the mouth or in the region of the mouths, diverted relative to the outer side of the casing in a growing or expanding manner such that, in the flow direction of the air volume flow, the reattachment regions are adjoined by in each case one turbulent flow region. In other words, the growing boundary layer of the air flow in the region of the incident-flow profiles and/or in the region of the mouth or in the region of the mouths in relation to the outer side of the casing is utilized in that, in the flow direction of the air volume flow, the reattachment regions are adjoined by in each case one turbulent flow region of the air volume flow. In this way, again, an improvement of the heat transfer coefficient is achieved in a simple manner.

[0018] Furthermore, on the outer side of the casing, there may be provided cooling fins which extend outward in relation to the outer side of the casing and which run at least approximately in the flow direction of the air volume flow and which are spaced apart from one another in a direction which is perpendicular to the flow direction of the air volume flow or which corresponds to a transverse direction of the casing. In this way, again in a manner which is favorable in terms of structural space, the surface area of the heat exchanger is enlarged, and a level of performance of the heat exchanger is improved.

[0019] In advantageous refinements of the heat exchanger according to the present disclosure, the incident-flow profile or the incident-flow profiles and/or the outer sides of the casing are arranged, in the flow direction, upstream of or at least regionally between the cooling fins.

[0020] In order to be able to maximize an efficiency of the heat exchanger in particular in the region of the cooling fins, a height of the cooling fins proceeding from the outer side or proceeding from the outer sides of the casing may be designed to be constant, or to increase at least regionally in the flow direction, over the length of the cooling fins.

[0021] In a manner dependent on the respectively present usage situation, it is possible for the height of the ribs to be configured to rise in linear or parabolic fashion.

[0022] If a spacing between in each case two incident-flow profiles in the flow direction of the air volume flow lies in a range between one and ten times the height of the in each case front incident-flow profile in the flow direction of the air volume flow, it is possible, in the region of the heat exchanger, to attain a high heat transfer capacity with simultaneously small dimensions of the heat exchanger. Here, it may be provided that the spacing between in each case two incident-flow profiles lies in a range between four and five times the height of the front incident-flow profile.

[0023] The cooling fins may end, in the flow direction of the air volume flow, upstream of those regions of the outer sides of the casing in which the mouths of the flow ducts are arranged, and/or begin downstream of the regions. In this way, it is achieved in a simple manner that the recirculation zones with separation bubble, generated as a result of the passive injection, are not impaired by the presence of cooling fins.

[0024] In a structurally simple embodiment of the heat exchanger according to the present disclosure, the step-like incident-flow profiles extend at least approximately transversely with respect to the flow direction of the air volume flow.

[0025] In a further structurally simple embodiment of the heat exchanger according to the present disclosure, the step-like incident-flow profiles are formed at least regionally with a convex and/or planar face area directed counter to the flow direction of the air volume flow, which face areas enclose in each case an angle of between 0° and 90° with the outer sides of the casing. It is thus possible in a simple manner for relatively long or relatively short recirculation zones or separation bubbles to be generated in a manner dependent on the respectively present structural form of the heat exchanger. Here, the length of the recirculation zones or of the separation bubbles can be controlled or generated by means of the geometrical shape of separation edges between the face areas of the incident-flow profiles and the outer areas of the casing.

[0026] The casing of the heat exchanger, in the assembled operating state, may extend in a circumferential direction of the gas turbine engine and be of curved form in the circumferential direction and, in the circumferential direction, delimit a flow region of the air volume flow. This is advantageous for example in the case of an arrangement of the heat exchanger in the bypass flow duct.

[0027] Furthermore, the casing of the heat exchanger may be designed as a closed ring-shaped body or as a ring segment.

[0028] Irrespective of whether the heat exchanger delimits the flow region of the air volume flow in the circumferential direction entirely or only partially radially to the inside or radially to the outside, the casing of the heat exchanger may be of ring-shaped, elliptical or circular design. Furthermore, it is possible for multiple heat exchanger portions or heat exchangers to be provided which are arranged so as to be distributed over the circumference and which are spaced apart from one another in the circumferential direction of the flow region.

[0029] It is self-evident to a person skilled in the art that a feature or parameter described in relation to one of the above aspects can be applied to any other aspect, unless these are mutually exclusive. Furthermore, any feature or any parameter described here may be applied to any aspect and/or combined with any other feature or parameter described here, unless these are mutually exclusive.

[0030] Embodiments will now be described, by way of example, with reference to the figures.

IN THE FIGURES

[0031] FIG. **1** shows a highly schematic longitudinal section through a gas turbine engine of an aircraft having a heat exchanger;

[0032] FIG. **2** shows a sectional view of a first embodiment of the heat exchanger of the gas turbine engine as per FIG. **1**;

[0033] FIG. **3** shows an illustration corresponding to FIG. **2** of a further embodiment of the heat exchanger;

[0034] FIG. **4** shows a plan view of a region IV of the heat exchanger as per FIG. **3**;

[0035] FIG. **5** shows an illustration corresponding to FIG. **2** of a further embodiment of the heat exchanger;

[0036] FIG. **6** shows a plan view of a region VI of the heat exchanger as per FIG. **5**;

[0037] FIG. **7** shows a longitudinal sectional view of a further embodiment of the oil-air heat exchanger;

[0038] FIG. **8** shows a three-dimensional partial illustration of a further embodiment of the oil-air heat exchanger;

[0039] FIG. **9** shows an illustration corresponding to FIG. **8** of a further embodiment of the heat exchanger;

[0040] FIG. **10** shows an illustration corresponding to FIG. **8** of a further embodiment of the heat exchanger;

[0041] FIG. **11** shows an illustration corresponding to FIG. **8** of a further exemplary embodiment of the heat exchanger; and

[0042] FIG. **12** shows an illustration corresponding to FIG. **8** of a further embodiment of the heat exchanger.

[0043] FIG. **1** shows a gas turbine engine **10** with a main axis of rotation **9**. The gas turbine engine **10** comprises an air inlet **12** and a fan **23** that generates two air flows: a core air flow A and a bypass air flow B. The gas turbine engine **10** furthermore comprises an engine core **11** that receives the core air flow A. In the axial flow direction, the engine core **11** comprises a low-pressure compressor **14**, a high-pressure compressor **15**, a combustion device **16**, a high-pressure turbine **17**, a low-pressure turbine **19**, and a core thrust nozzle **20**. An engine nacelle **21** surrounds the gas turbine engine **10** and defines a bypass duct **22** and a bypass thrust nozzle **18**. The bypass air flow B flows through the bypass duct **22**. The fan **23** is attached to and driven by the low-pressure turbine **19** by way of a shaft **26** and an epicyclic gear box **30**.

[0044] During operation of the gas turbine engine **10**, the core air flow A is accelerated and compressed by the low-pressure compressor **14** and directed into the high-pressure compressor **15**, where further compression takes place. The compressed air expelled from the high-pressure compressor **15** is directed into the combustion device **16**, where it is mixed with fuel and the mixture is combusted. The resulting hot combustion products then propagate through the high-pressure and the low-pressure turbines **17**, **19** and thereby drive said turbines, before they are expelled through the nozzle **20** to provide a certain propulsive thrust. The high-pressure turbine **17** drives the high-pressure compressor **15** by means of a suitable connecting shaft **27**. The fan **23** generally provides the major part of the propulsive thrust. The epicyclic gear box is a reduction gear box.

[0045] Attention is drawn to the fact that the expressions "low-pressure turbine" and "low-pressure compressor", as used herein, can be taken to mean the lowest-pressure turbine stage and lowest-pressure compressor stage (i.e. not including the fan **23**), respectively, and/or the turbine and compressor stages that are connected together by the connecting shaft with the lowest rotational speed in the gas turbine engine (i.e. not including the gear box output shaft that drives the fan **23**). Alternatively, there is furthermore also the possibility that the low-pressure turbine and the low-pressure compressor to which reference is made here are the medium-pressure turbine and the medium-pressure compressor. Where such alternative nomenclature is used, the fan can be referred to as a first, or lowest-pressure, compression stage.

[0046] Other gas turbine engines in which the present disclosure can be used may have alternative configurations. For example, such engines may have an alternative number of compressors and/or turbines and/or an alternative number of connecting shafts. As a further example, the gas turbine engine shown in FIG. **1** has a split flow nozzle **20**, **22**. This means that the flow through the bypass duct **22** has a dedicated nozzle which is separate from the engine core nozzle **20** and radially on the outside thereof. However, this is not restrictive, and any aspect of the present disclosure can also apply to engines in which the flow through the bypass duct **22** and the flow through the core **11** are mixed or combined before (or upstream of) a single nozzle, which may be referred to as a mixed flow nozzle. One or both nozzles (whether mixed or split flow) can have a fixed or variable area. Although the example described relates to a turbofan engine, the disclosure can be applied, for example, to any type of gas turbine engine, such as, for example, an open rotor engine (in which the fan stage is not surrounded by an engine nacelle) or a turboprop engine. In some arrangements, the gas turbine engine **10** may not comprise a gear box **30**.

[0047] The geometry of the gas turbine engine **10**, and components thereof, is or are defined using a conventional axis system which comprises an axial direction (which is aligned with the axis of rotation **9**), a radial direction (in the direction from bottom to top in FIG. **1**), and a circumferential direction (perpendicular to the view in FIG. **1**). The axial, radial and circumferential directions run so as to be mutually perpendicular.

[0048] Additionally, the gas turbine engine **10** as per FIG. **1** comprises a heat exchanger **35**, which is arranged in the present case on the inner diameter of the bypass duct **22** on an intermediate casing **36** and surrounds the intermediate casing **36** in a circumferential direction of the gas turbine engine **10**.

[0049] As an alternative to this, the heat exchanger **35** may also be arranged in the region of the outer diameter of the bypass duct **22**, which is the same as the diameter of the inner side of the engine nacelle **21**. Furthermore, it is also possible for at least one heat exchanger **35** to be provided both on the inner diameter and on the outer diameter of the bypass duct **22**.

[0050] FIG. **2** to FIG. **12** show various embodiments of the heat exchanger **35**, which in the present case is designed as an oil-air heat exchanger. Here, oil of an oil circuit of the gas turbine engine **10** is conducted through an inner region **37** of a casing **38** of the heat exchanger **35**. An outer side **39** of the heat exchanger **35** is impinged on by the bypass air flow B. The heat exchanger **35** may be designed as a concurrent-flow, counterflow or cross-flow heat exchanger, or else may have any desired combination of the latter structural forms. In the present case, the oil is, in relation to the main flow direction of the bypass air flow B through the bypass channel **22**, oil conducted transversely or in a cross-flow configuration with respect to the bypass air flow B or the air volume flow through the casing **38**.

[0051] The heat exchanger **35** constitutes a device of the gas turbine engine **10**, in the region of which the fluid or oil that can be conducted through the casing **38** is temperature-controlled by means of the bypass air flow B impinging on the housing **38** or by means of the air volume flow conducted through the bypass duct **22**.

[0052] The casing **38** has a first step-like incident-flow profile **41** in a region **40** facing toward the flow of the air volume flow B. Here, the air volume flow B is, in the region of the incident-flow profile **41**, diverted outward in relation to the inner region **37** or the outer side **39** of the casing **38** such that a recirculation zone **42** with at least one separation bubble **43** forms downstream of the incident-flow profile **41** and above the outer side **39** of the casing **38** in the air volume flow B.

[0053] In the present case, the flow of the air volume flow B is, downstream of the incident-flow profile **41**, diverted radially outward in relation to the main axis of rotation **9** and the outer side **39** of the casing **38**.

[0054] If the heat exchanger **35** is arranged in the region of the outer diameter of the bypass channel **22**, the air volume flow B is, downstream of the incident-flow profile **41** in relation to the main axis of rotation **9** and in relation to the then radially inwardly directed outer side **39** of the heat exchanger **35**, diverted radially inward in relation to the main axis of rotation **9** and the outer side **39** of the casing **38**.

[0055] The separation bubble **43** and the recirculation zone **42** have a defined length L. The defined length L of the recirculation zone **42** and of the separation bubble **43** is dependent on a height H**41** of the effective area of the incident-flow profile **41**. The effective area of the incident-flow profile **41** corresponds to an area **44** of the incident-flow profile **41** projected into a plane which is perpendicular to the flow direction of the air volume flow B. The recirculation zone **42** is adjoined by a reattachment region **45**. In the reattachment region **45**, the flow of the air volume flow B re-attaches to the outer surface **39** of the heat exchanger **35**. Additionally, the reattachment region **45** is adjoined by a turbulent flow region **85**, in which the flow of the air volume flow B, above the outer side **39** of the casing **38**, expands again or grows over the further flow path.

[0056] Downstream of the incident-flow profile **41**, there is provided a further step-like incident-flow profile **46**. The further step-like incident-flow profile **46** rises, relative to the outer side **39** between the incident-flow profile **41** and the further incident-flow profile **46**, outwardly in relation to the inner region **37** of the casing **38**. The further incident-flow profile **46** or the area **47** thereof is impinged on by the air volume flow B and diverts the air volume flow B outward to the extent illustrated in FIG. **2**. Here, the air volume flow B is diverted by the further incident-flow profile **46**, which is designed substantially similarly to the incident-flow profile **41**, such that, downstream of the further incident-flow profile **46**, above a further outer side **48** of the casing **38**, there is formed a further recirculation zone **49** with a defined length L in the flow direction, in which in turn there is situated a separation bubble **50**.

[0057] The recirculation zone **49** and the separation bubble **50** are adjoined firstly in turn by a reattachment region **51** and, adjoining this, in turn, a turbulent flow region **91**. The further turbulent flow region **91** extends as far as an additional incident-flow profile **52**, which in turn substantially corresponds to the incident-flow profile **41**. The additional incident-flow profile **52** is in turn impinged on by the air volume flow B and diverts this to the extent described in more detail above, such that, downstream of the incident-flow profile **52**, in turn, there is formed a recirculation zone **53** with a separation bubble **54**. Downstream of the recirculation zone **53**, in turn, there is formed firstly a further reattachment region **55** and, adjoining this, a further turbulent flow region **95**, which extends as far as a further incident-flow profile **56**.

[0058] The heat exchanger **35** is thus formed with incident-flow profiles **41**, **46**, **52** and **56** which follow one another at least approximately in a stepped or staircase-like manner, in order to generate, downstream of each of the incident-flow profiles **41**, **46**, **52** and **56**, recirculation zones **42**, **49**, **53**, **59** and separation bubbles **43**, **50**, **54**, **60** and, adjoining each of these, reattachment regions **45**, **51**, **55**, **70** and, adjoining these, turbulent flow regions **85**, **91**, **95** and **100**, which in each case improve a heat transfer coefficient.

[0059] Here, the heights of the incident-flow profiles **41**, **46**, **52** and **56** and also the axial spacings between the incident-flow profiles **41**, **46**, **52** and **56** are in the present case of equal magnitude. In a manner dependent on the respectively present usage situation, it is however also possible for the heights of the incident-flow profiles **41**, **46**, **52** and **56** and also the axial spacings between the incident-flow profiles **41**, **46**, **52** and **56** to differ from one another in each case, or to be only partially identical.

[0060] FIG. **3** shows an illustration corresponding to FIG. **2** of a further exemplary embodiment of the heat exchanger **35**. The heat exchanger **35** as per FIG. **3** has substantially the same construction as the heat exchanger **35** as per FIG. **2**. However, the heat exchanger **35** as per FIG. **3** is, in the region of the incident-flow profiles **41**, **46**, **52** and **56**, formed in each case with an inlet **41**A, **46**A, **52**A and **56**A of flow channels **41**B, **46**B, **52**B and **56**B. The flow channels **41**B to **56**B run in the casing **38** of the heat exchanger **35** in each case in the direction of mouths **41**C, **46**C, **52**C and **56**C which are arranged at least approximately in regions of outer sides **39**, **48**, **57** and **58** of the heat exchanger **35** in which the recirculation zones **85**, **91**, **95** and **100** are respectively present.

[0061] Via the inlets **41**A to **56**A of the flow channels **41**B to **56**B, in each case one air volume flow is conducted in the direction of the mouths **41**C to **56**C. In the exemplary embodiment considered here, the air volume flows in the flow channels **41**B to **56**B are each diverted through 90° in relation to the main flow direction of the air volume flow B in the bypass duct **22** and introduced into the turbulent boundary layers or flow regions **45**, **51**, **55**, **70** of the air volume flow B above the outer sides **39** to **58** at a defined angle α relative to the main flow direction of the air volume flow B which the air volume flow B has in particular upstream of the incident-flow profile **41**. This so-called passive injection has the effect that respective further recirculation zones **46**A, **49**A, **53**A and **59**A with separation bubbles **43**A, **50**A, **54**A and **60**A form downstream of the mouths **41**C to **56**C. Thus, the heat transfer coefficient is further improved in each case in the region of the outer sides **39**, **48**, **57** and **58** of the heat exchanger **35**.

[0062] Here, the defined angle α may have values between 80° and 140°.

[0063] In further embodiments of the heat exchanger, it is possible for the air volume flows in the flow channels **41**B to **56**B to be diverted by angular values greater than or less than 90° between the inlets **41**A to **56**A and the mouths **41**C to **56**C.

[0064] FIG. **4** shows a plan view of a region IV, indicated in more detail in FIG. **3**, of the heat exchanger **35**, which region comprises the incident-flow profile **56**, the mouth **56**C and the two recirculation zones **59** and **59**A.

[0065] FIG. **5**, shows, in turn, an illustration corresponding to FIG. **2** of a further exemplary embodiment of the heat exchanger **35**, which in turn substantially corresponds to the heat exchanger **35** as per FIG. **2**. The heat exchanger **35** as per FIG. **5** comprises respective cooling fins **61** to **64** in each case on the outer sides **39**, **48**, **57** and **58**. The cooling fins **61** to **64** extend in each case outward in relation to the inner region **37** or the outer sides **39** to **58** of the casing **38** of the heat exchanger **35**, and run at least approximately in the flow direction of the air volume flow B. Additionally, the cooling fins **61** to **64** are spaced apart from one another in the circumferential direction of the heat exchanger **35** in the manner illustrated in more detail in FIG. **6**. Here, FIG. **6** shows the cooling fins **64** and a region VI, indicated in more detail in FIG. **5**, in a view from above. It can be seen from the illustrations as per FIG. **5** and FIG. **6** that the recirculation zones **42**, **49**, **53**, **59**, the reattachment regions **45**, **51**, **55** and **70** and the turbulent flow regions **85**, **91**, **95** and **100** are divided in the circumferential direction of the heat exchanger **35**, or in the flow direction of the oil in the casing **38**, by the cooling fins **61** to **64**.

[0066] FIG. **7** shows a further exemplary embodiment of the heat exchanger **35** in a schematic longitudinal sectional view. Here, the heat exchanger **35** as per FIG. **7** is formed only with the incident-flow profile **41**. The recirculation zone **42** and the separation bubble **43** form, in turn, downstream of the incident-flow profile **41**. The recirculation zone **42** is adjoined, in turn, by the reattachment region **45**. In the reattachment region **45**, there are provided first cooling fins **61**, which extend in the main flow direction of the air volume flow B as far as a short distance upstream of the mouth **41**C of the flow channel **41**B. The air volume flow B which emerges through the mouth **41**C substantially perpendicularly outward from the casing **38** in relation to the outer side **39** of the casing **38** leads, in turn, to a breakup of the boundary layer of the air volume flow B downstream of the cooling fins **61**, which in turn generates a further recirculation zone **65** and a further separation bubble **66**. In a further reattachment region **105**, there are provided further cooling fins **67**, the height of which, like the height of the cooling fins **61**, is substantially constant in the main flow direction of the air volume flow B.

[0067] FIG. **8** shows a schematic three-dimensional partial view of a further exemplary embodiment of the heat exchanger **35**. The heat exchanger **35** as per FIG. **8** is designed with an incident-flow profile **41**, the area **44** of which encloses, with the outer side **39**, an angle β which corresponds to approximately 90°. Thus, the heat exchanger **35** has an obtuse-angled edge at the transition between the area **44** and the outer side **39**.

[0068] By contrast to this, the heat exchanger **35** as per FIG. **9** is formed with a rounded edge between the area **44** of the incident-flow profile **41** and the outer side **39**, whereby the area **44** encloses an angle β equal to 0° with the outer side **39** in the transition region. The configuration of the heat exchanger **35** as per FIG. **8** has the effect that the recirculation zone **42** adjoining the incident-flow profile **41**, and the separation bubble **43**, have a greater length L than the recirculation zone **42** and the separation bubble **43** downstream of the incident-flow profile **41** of the heat exchanger **35** as per FIG. **9**.

[0069] An axial spacing x in the main flow direction of the air volume flow B between the incident-flow profile **41** and the start of the cooling fins **61** is equal, in both embodiments of the heat exchanger **35** as per FIG. **8** and FIG. **9**, to the product of the height H**41** of the incident-flow profile **41** and a factor, which in the present case is equal to 4.5.

[0070] FIG. **10** is a three-dimensional partial view of the heat exchanger **35**, the design of which substantially corresponds to the embodiment described in more detail with regard to FIG. **7**.

[0071] FIG. **11**, in turn, shows an illustration, corresponding to FIG. **8**, of a further exemplary embodiment of the heat exchanger **35**, which differs from the exemplary embodiment of the heat exchanger **35** illustrated in FIG. **8** by the fact that a height of the cooling fins **61** increases linearly in the main flow direction of the air volume flow B.

[0072] Additionally shown in FIG. **12** is a further exemplary embodiment of the heat exchanger **35**, which substantially corresponds to the exemplary embodiment of the heat exchanger **35** illustrated in FIG. **10**. That region of the cooling fins **61** of the heat exchanger **35** which extends between the incident-flow profile **41** and the mouth **41**C in FIG. **12** is formed with a height which is constant in the main flow direction of the air volume flow B. That region of the cooling fins **69** which adjoins the mouth **41**C in a downstream direction rises in the present case linearly in the main flow direction of the air volume flow B. As an alternative to this, it is in turn possible for the height of the cooling fins **67** to rise parabolically in the main flow direction of the air volume flow B.

LIST OF REFERENCE SIGNS

[0073] **9** Main axis of rotation
[0074] **10** Gas turbine engine
[0075] **11** Engine core
[0076] **12** Air inlet
[0077] **14** Low-pressure compressor
[0078] **15** High-pressure compressor
[0079] **16** Combustion device
[0080] **17** High-pressure turbine
[0081] **18** Bypass thrust nozzle
[0082] **19** Low-pressure turbine
[0083] **20** Core thrust nozzle
[0084] **21** Engine nacelle
[0085] **22** Bypass duct
[0086] **23** Fan
[0087] **26** Shaft
[0088] **27** Shaft
[0089] **30** Epicyclic gear box
[0090] **35** Heat exchanger
[0091] **36** Intermediate casing

[0092] **37** Inner region of the casing of the heat exchanger
[0093] **38** Casing of the heat exchanger
[0094] **39** Outer side of the casing
[0095] **40** Region
[0096] **41** Incident-flow profile
[0097] **41**A Inlet of the flow duct
[0098] **41**B Flow duct
[0099] **41**C Mouth
[0100] **42** Recirculation zone
[0101] **42**A Further recirculation zone
[0102] **43** Separation bubble
[0103] **43**A Further separation bubble
[0104] **44** Area of the incident-flow profile **41**
[0105] **45** Reattachment region
[0106] **46** Further incident-flow profile
[0107] **46**A Inlet
[0108] **46**B Flow duct
[0109] **46**C Mouth
[0110] **47** Effective area of the further incident-flow profile
[0111] **48** Outer side of the casing
[0112] **49** Further recirculation zone
[0113] **49**A Further recirculation zone
[0114] **50** Separation bubble
[0115] **50**A Further separation bubble
[0116] **51** Further reattachment region
[0117] **52** Additional incident-flow profile
[0118] **52**A Inlet
[0119] **52**B Flow duct
[0120] **52**C Mouth
[0121] **53** Recirculation zone
[0122] **53**A Further recirculation zone
[0123] **54** Separation bubble
[0124] **54**A Further separation bubble
[0125] **55** Further reattachment region
[0126] **56** Further incident-flow profile
[0127] **56**A Inlet
[0128] **56**B Flow duct
[0129] **56**C Mouth
[0130] **57** Outer side
[0131] **58** Outer side
[0132] **59** Recirculation zone
[0133] **59**A Further recirculation zone
[0134] **60** Separation bubble
[0135] **60**A Separation bubble
[0136] **61** to **64** Cooling fins
[0137] **65** Further recirculation zone
[0138] **66** Further detachment bubble
[0139] **67** Cooling fins
[0140] **70** Reattachment region
[0141] **85**, **91**, **95**, **100** Turbulent flow region
[0142] **105** Reattachment region
[0143] A Core flow
[0144] B Bypass flow
[0145] L Length of the recirculation zone or of the detachment bubble
[0146] H**41** Height of the incident-flow profile **41**
[0147] x Axial spacing
[0148] α, β Angle

1. A heat exchanger of a gas turbine engine of an aircraft having a casing, wherein the casing has a step-like incident-flow profile in a region facing toward a flow of an air volume flow, and

the air volume flow is, in the region of the incident-flow profile, in relation to an outer side of the casing, diverted perpendicularly with respect to the outer side, over which flow passes, of the casing in a growing manner

in such a way that, downstream of the incident-flow profile and above an outer side of the casing, a recirculation zone with at least one separation bubble forms in the air volume flow,

and wherein, downstream of the incident-flow profile, there is provided at least one further step-like incident-flow profile

which, in relation to the outer side downstream of the step-like incident-flow profile and in relation to the outer side of the casing, rises outwardly, is impinged on by the air volume flow at least in an axial direction, and diverts the air volume flow in such a way

that, downstream of the further incident-flow profile, above a further outer side of the casing, a further recirculation zone forms in which in each case at least one separation bubble is present, and/or,

in the region of the incident-flow profile and/or in the region of the further incident-flow profile, there is provided an inlet of at least one flow duct which runs in the casing in the direction of a mouth

which is arranged at least approximately in the region of the outer side or which are arranged in each case in the region of the outer sides of the casing,

wherein the air volume flow conducted through the flow duct or the air volume flows conducted through the flow ducts emerges from the mouth or emerge from the mouths in each case at such an angle relative to the flow direction of the air volume flow that, downstream of the mouth or downstream of the mouths, in each case one recirculation zone with at least one separation bubble forms above the outer side(s) of the casing.

2. The heat exchanger according to claim **1**, wherein the recirculation zones each have a defined length in the flow direction of the air volume flow, which lengths are dependent on heights of the effective areas of the incident-flow profiles, which correspond in each case to an area of the incident-flow profiles in each case projected into a plane which is perpendicular to the flow direction of the air volume flow.

3. The heat exchanger according to claim **1**, wherein the air volume flow is, in the region of the incident-flow profile or in the region of the incident-flow profiles and/or in the region of the mouth or in the region of the mouths, diverted relative to the outer side of the casing in a growing or expanding manner such that, in the flow direction of the air volume flow, the recirculation zones are adjoined by in each case one reattachment region of the air volume flow.

4. The heat exchanger according to claim **3**, wherein the mouth or the mouths is arranged in each case at least approximately in the region of the outer side or are arranged in each case in the region of the outer sides of the casing in which the reattachment region is present or in which the reattachment regions are present.

5. The heat exchanger according to claim **4**, wherein the air volume flow is, in the region of the incident-flow profile or in the region of the incident-flow profiles and/or in the region of the mouth or in the region of the mouths, diverted relative to the outer side of the casing in a growing or expanding manner such that, in the flow direction of the air volume flow, the reattachment regions are adjoined by in each case one turbulent flow region.

6. The heat exchanger according to claim **1**, wherein, on the outer side of the casing, there are provided cooling fins which extend substantially outward in relation to the outer side of the casing and which run at least approximately in the flow direction of the air volume flow and which are spaced apart from one another in a direction which is perpendicular to the flow direction of the air volume flow.

7. The heat exchanger according to claim **6**, wherein the incident-flow profile or the incident-flow profiles and/or the outer side or the outer sides of the casing is or are arranged, in the flow direction, upstream of or at least regionally between the cooling fins.

8. The heat exchanger according to claim **6**, wherein a height of the cooling fins proceeding from the outer side or proceeding from the outer sides of the casing is in each case constant, or increases at least regionally in the flow direction of the air volume flow, over the length of the cooling fins.

9. The heat exchanger according to claim **8**, wherein the height of the fins increases linearly or parabolically.

10. The heat exchanger according to claim **1**, wherein a spacing between in each case two incident-flow profiles in the flow direction of the air volume flow lies in a range between one and ten times the height of the effective area of the in each case front incident-flow profile in the flow direction of the air volume flow, preferably in a range between four and five times the height of the effective area of the front incident-flow profile.

11. The heat exchanger according to claim **6**, wherein the cooling fins end, in the flow direction of the air volume flow, upstream of that region of the outer side or upstream of those regions of the outer sides of the casing in which the mouth of the flow duct is arranged or in which the mouths of the flow ducts are arranged, and/or begin downstream of the region or downstream of the regions.

12. The heat exchanger according to claim **1**, wherein the step-like incident-flow profiles extend at least approximately transversely with respect to the flow direction of the air volume flow.

13. The heat exchanger according to Clam **1**, wherein the step-like incident-flow profiles are formed at least regionally with a convex and/or planar face area directed counter to the flow direction of the air volume flow, which face areas enclose in each case an angle of between 0° and 90° with the outer sides of the casing.

14. The heat exchanger according to claim **1**, wherein the casing of the heat exchanger, in the assembled operating state, extends in a circumferential direction of the gas turbine engine and is of curved form in the circumferential direction and, in the circumferential direction, delimits a flow region of the air volume flow.

15. The heat exchanger according to claim **14**, wherein the casing of the heat exchanger is formed as a closed ring-shaped body or as a ring segment.

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