The invention relates to a turbine wheel arrangement for a gas turbine comprising two successive turbine wheels (18, 20) rotating in opposite directions, wherein the first turbine wheel (18) comprises flow channels (42) of a Laval cross-sectional shape, distributed over the circumference and having radially inner gas inlets (43) and radially further out gas outlets (45), in each case with a substantially tangential flow direction component, wherein the gas outlets (45) act as the second axially or radially acting turbine wheel (20) in the direction of flow. This has the effect that the thermal energy and compressive energy of the gas at the nozzle inlet is largely converted into flow energy at the outlet of the turbine stage. The rotational speeds of the two rotors coupled to the turbine wheels can be set as desired, allowing the operational states of the two systems to be optimally set without adjusting systems.
TURBINE WHEEL ARRANGEMENT FOR A GAS TURBINE

[0001] The invention relates to a turbine wheel arrangement for a gas turbine having two successive turbine wheels rotating in opposite directions.

[0002] Currently known gas turbines are designed for the highest possible performance with the highest degree of efficiency, as a consequence of which the components and materials used are strained to the limits of acceptability. This applies in particular to the turbine blades of the first turbine stage which are subjected to the most extreme demands, the result of which is that it is necessary to use very expensive materials and to implement complex cooling measures for cooling the blades. Added to this are loads due to high mechanical stresses caused by high flow velocities, but above all the high centrifugal forces resulting from the high rotational speeds. On the whole, it is difficult with such designs to achieve an overall efficiency of greater than 35%.

[0003] In steam turbine manufacturing, it is known to design stationary guide wheels of axial turbines with Laval nozzle channels that are oriented at an angle of approximately 45° relative to the circumferential direction.

[0004] A gas turbine is known from AT 2395806 in which combustion gases are directed outwardly via two oppositely aligned radial channels and subsequently diverted in the circumferential direction and directed through Laval nozzle-like outlet channels on blades of an oppositely disposed rotating blade wheel.

[0005] The object of the invention is to provide a gas turbine which is distinguished from conventional turbines by lower temperature stress of the turbine stage and which makes possible a high temperature and pressure gradient from the combustion chamber to the turbine blades within a broad power range, so that high thermal efficiency can be achieved thereby.

[0006] The invention arises from the features of the independent claims. Advantageous refinements and embodiments are the subject matter of the dependent claims.

[0007] The advantageous effect of the invention is that the thermal energy and compressive energy of the gas at the nozzle inlet are largely converted into flow energy at the outlet of the turbine stage. The impulse force of the nozzles drives the turbine wheel. The gas exiting the Laval nozzles has a very high flow velocity in excess of Mach 1 and is directed to the blades of the second turbine wheel in the direction of flow, as a result of which a torque and a rotation are produced counter to the direction of rotation of the first turbine wheel. In this configuration, the speed of the gas jet is substantially greater than the peripheral speed of the turbine blade. Thus, the kinetic energy remaining in the flow jet from the first energy conversion in the Laval nozzles is utilized. In this case, the second turbine wheel is designed so that ideally the tangential speed at the outlet virtually disappears.

[0008] By suitably controlling the stresses at each wheel, for example, using generators, the rotational speeds of the two rotors coupled to the turbine wheels can be set as desired, allowing the operational states of the two systems to be optimally set without adjusting systems.

[0009] With the invention it is possible to separate the combined stresses thermally, mechanically and based on centrifugal force. As a result, a relief occurs in Laval nozzles which reduces virtually all the thermal and compressive energy and which converts it into kinetic energy. Thus, the material stresses are reduced substantially to this area. The Laval nozzles themselves may be manufactured from suitable, temperature-resistant materials such as ceramics or metal alloys and are able to withstand the thermal loads. Accordingly, the kinetic energy remaining in the gas jet is fully utilized as a result of the momentum in the second turbine stage. Based on the counter-rotation principle it is possible to reduce by half the required rotational speed, consequently reducing significantly the stresses caused by centrifugal forces.

[0010] Based on the concept according to the invention, it is possible to achieve very high compression ratios of >25, high combustion chamber temperatures of >2,000° C. and, as a result, high thermal efficiency of >60% and overall gas turbine efficiency of >50%.

[0011] A further significant advantage of the invention is that the gap between the wheels has no significant effect on efficiency. Furthermore, the components can be more simply and inexpensively manufactured than is the case with conventional turbines, because a single stage turbine is sufficient for achieving the entire energy conversion. As a further advantage, cooling is required only at the Laval nozzles, while a second turbine wheel does not rely on cooling, with the result that the losses in conventional turbines resulting from the significant amount of bleed air for cooling the turbine are prevented.

[0012] According to an advantageous refinement of the invention, the gas turbine comprises an inner rotor, on the outside of which are mounted multiple first blade rows of a multi-stage axial compressor and the second turbine wheel in the direction of flow, in that said gas turbine further comprises a hollow shaft, on the inside of which are mounted multiple second blade rows of the axial compressor which alternate in the axial direction with the first blade row, in that also mounted on the hollow shaft is at least one combustion chamber and the first turbine wheel. Since the blade rings of the shaft rotating in opposite directions alternate in the axial direction of the compressor, virtually any higher number of stages counter-directional in design are possible. In this configuration, the speed of rotation of the two shafts is preferably the same. However, in certain applications, for example, in booster mode, a difference in speed of rotation between the two shafts is also feasible.

[0013] Further advantages, features and details are set forth in the following description, in which exemplary embodiments are described in detail with reference to the drawings. Features described and/or depicted form per se or in any meaningful combination the subject matter of the invention, if applicable, independently of the claims as well, and in particular may also constitute the subject matter of one or more separate applications. Identical, similar and/or functionally similar parts are identified with similar reference numerals.

[0014] In the drawings

[0015] FIG. 1: is an axial section through a gas turbine in the form of a power generator

[0016] FIG. 2: is a cross-section through the gas turbines according to FIG. 1.

[0017] FIG. 3: is an axial section through a Pelton-designed gas turbine.

[0018] FIG. 4: is a cross-section through the gas turbines according to FIG. 3, and

[0019] FIG. 5: is a perspective view of a gas turbine with an axial turbine stage.

[0020] FIG. 1 shows an axial section of a gas turbine 10a which consists of a multi-stage axial compressor 12, a single stage radial compressor 14, a combustion chamber 16, a first
radial turbine wheel 18 and a second radial turbine wheel 20. Together, the two radial turbine wheels 18, 20 form a single stage counter-rotating turbine.

[0021] Every second blade ring of the axial compressor 12 and the second turbine wheel 20 are jointly mounted on an inner rotor 22 which is supported via a bearing 24 on a stationary axle 26. Also attached to the inner rotor 22 is the rotor 28a of a first generator, the external stator of which is not shown.

[0022] Supported on the inside of a hollow shaft-like outer rotor 30 is the other blade ring of the axial compressor 12, in addition to the blade ring of the radial compressor 14, the combustion chamber 16 and the turbine wheel 18. The outer rotor 30 is supported by a first bearing 32a on the stationary axle 26 and by a second bearing 32b on the inner rotor 22. In addition, the outer rotor 30 is joined via a first blade ring 34 to a rotor hub 36 which is supported by the front bearing 32c on the shaft 26. A rotor 38b of a second generator is attached radially outwardly to the outer rotor 30, the external stator of which is not shown.

[0023] FIG. 2 shows a cross-section through the gas turbine 10a according to FIG. 1 at the axial height of the turbine wheels 18, 20, as depicted by the arrow II. FIG. 2 shows a ring of shaped parts 40 of the first turbine wheel 18 (FIG. 1) each of which is a cross-section in the shape of a Laval nozzle formed between these flow channels 42. The flow channels 42 comprise gas outlets 43 aligned substantially radially and gas outlets 45 arranged substantially in the tangential or circumferential direction. The Laval cross-sectional shape of the flow channels 42 exists preferably in just one direction, namely in the circumferential direction, whereas a non-varying cross-section exists in the axial direction. Alternatively, it is also possible to configure the shape of the shaped parts 40 so that the cross-section varies in the axial direction as well. The shaped parts 40 are preferably formed on an end disk 41 which closes off the flow channel for the gas stream in the axial direction.

[0024] Outer turbine blades (44) of the second turbine wheel 20 are arranged radially outside the shaped parts 40 which are impacted by the supersonic gas flow exiting the flow channels 42 and are thereby caused to rotate in a direction opposite to the first turbine wheel 18.

[0025] During operation, air is drawn into the inlet of the gas turbine 10a depicted in FIGS. 1 and 2 located at the first blade ring 34 and compressed by the axial compressor 12. The axial compressor 12 compresses the air by way of the two shafts 22 and 30 rotating in opposite directions, to which the alternating arrangement of blade rows are attached. Downstream of the axial compressor 12, the air stream is diverted radially outwardly and arrives in the blade ring of the single stage radial compressor 14, by way of which the pressure is further increased. Behind the outlet of the radial compressor 14, the air stream is again diverted radially inwardly and arrives at the inlet of the rotating combustion chamber 16, into which fuel is injected and the air-fuel mixture is combusted. Downstream of the combustion chamber 16 the gas stream is again diverted radially outwardly and arrives in the first turbine wheel 18. The flow channels 42 of a Laval nozzle cross-sectional shape (FIG. 2) of the first turbine wheel 18 accelerate the gas stream to greater than mach 1, divert the former in the circumferential direction, then expel the gas stream predominantly in the circumferential direction. With the angular momentum produced, the first turbine wheel 18 in FIG. 2, when viewed counterclockwise, is caused to rotate. The supersonic gas stream subsequently hits the outer turbine blades 44 of the second turbine wheel 20 and is diverted at that point, the blades then accordingly rotating counter to the first turbine wheel 18.

[0026] The rotation of the first turbine wheel 18 is transmitted via the outer shaft 30 to the radial compressor 14 as well as to the blade row of the axial compressor 12 on the outside of the rotor and to the generator rotor 28a. The counter rotation of the second turbine wheel 20 is transmitted to the generator rotor 28a and via the inner rotor 22 to the compressor blades of the axial compressor 12 on the inside of the rotor.

[0027] The gas turbine shown in FIGS. 1 and 2 is used to generate electric power. Alternatively, it can also be used for other applications, for example as a power train for a motor vehicle, watercraft or aircraft. The shafts 22, 30 can also be operated as starter motors for the shafts 22, 30.

[0028] FIGS. 3 and 4 show a gas turbine 10b in which, unlike the embodiment shown in FIGS. 1 and 2, only a single stage Pelton turbine is used. Reference numerals similar to those in FIGS. 1 and 2 identify similar components.

[0029] The gas turbine embodiment 10b also comprises a multi-stage axial compressor 12, which in turn comprises a hollow shaft 30a, to which every other blade row is attached in the axial direction. Provided between these blade rows that are attached to a main rotor 52. The main rotor 52 is mounted by means of bearing 24 on the one hand on an axle 26 and on the other hand on a housing not shown. Further, a Pelton turbine wheel 54 is molded onto the main rotor 52, represented in cross-section in FIG. 4 and described in greater detail below. Also provided on the main rotor 52 is a mounting flange 56 for discharging the output generated.

[0030] The hollow shaft 30a comprises a blade ring of a radial compressor 14 and is joined to a rotating combustion chamber 16 and to a nozzle wheel 58. A first blade ring 34 connects the hollow shaft 30a to a hub shaft 60, in which turn is supported by a front bearing 32a on a housing not shown. At the other end the nozzle wheel 58 is supported by a bearing 32b on the main rotor 52. Provided on the hub shaft 60, as on the main rotor 52, is a mounting flange 62 for discharging the output generated.

[0031] FIG. 4 shows a cross-section of nozzle wheel 58 which includes a plurality of nozzles 64 with a predominantly tangential outflow direction. Opposite the nozzles the Pelton turbine 54 includes a plurality of Pelton blades 66 distributed over the circumference that are impacted by the nozzles 64.

[0032] During operation, the air stream enters the multi-stage axial compressor 12 through the first blade ring 34 where it is compressed. Subsequently, further compression takes place in the radial compressor 14, from where the air stream is fed to the co-rotating combustion chamber 16. There, fuel is added and the mixture is combusted. The combustion gases flow through the nozzles 64 where they act on the Pelton blades 66. As a result, the nozzle wheel 58 rotates counterclockwise as seen in FIG. 4, while the Pelton turbine wheel 54 rotates clockwise. The rotation of the nozzle wheel 58 is transmitted to the hollow shaft 30a and to the mounting flange 62 by way of the blade ring 34 and the hub shaft 60. Similarly, the rotation of the Pelton turbine wheel 54 is transmitted to the mounting flange 56 by way of the main rotor 52.

[0033] FIG. 5 shows a gas turbine 10c in which, unlike the embodiment according to FIGS. 1 and 2, the second turbine stage 20d is designed as an axial stage and not as a radial stage. Reference numerals similar to those in the other figures identify similar components. In this embodiment an air sup-
ply channel 80 is provided which supplies heated air from a combustion chamber or a heat exchanger which impacts the first radial turbine stage 18. In the region downstream thereof, the turbine stage 18 includes a bend 82 in the channel in the axial direction, such that the gas flow leaves the turbine stage 18 at least largely without a radial velocity component and impacts the second axial turbine stage 20b. In this configuration the first turbine stage 18 includes Laval nozzle-like flow channels 42. Downstream of the axial turbine stage 20b is a gas outlet channel 84.

[0034] In one variation, the turbine stage 18 may be connected to the air supply channel 80, and in a second variation the turbine stage 18 is separate from the air supply channel 80, and thus, the air supply channel 80 forms the housing of the gas turbine.

1. A gas turbine comprising a first turbine wheel and a second turbine wheel rotating in the opposite direction which is impacted by the first turbine wheel, further comprising an inner shaft on the outside of which multiple first blade rows of a multi-stage axial compressor and the second turbine wheel are mounted, further comprising a hollow shaft on which the first turbine wheel and multiple second blade rows of the axial compressor are mounted, which are arranged alternatingly in the axial direction relative to the first blade rows.

2. The gas turbine according to claim 1, wherein the first turbine wheel comprises flow channels distributed over the circumference thereof, which include gas outlets of a laval cross-sectional shape.

3. The gas turbine according to claim 2, wherein the gas outlets include a substantially tangential flow direction component.

4. The gas turbine according to claim 3, wherein the gas outlets of the first turbine wheel are oriented at an angle of 10° to 30° relative to the tangential direction.

5. The gas turbine according to claim 1, wherein at least one rotating combustion chamber is mounted on the hollow shaft.

6. The gas turbine according to claim 1, wherein the flow channels exhibit a Laval nozzle-like cross-section in one transverse direction of the flow and no variation in cross-section in the other transverse direction of the flow.

7. The gas turbine according to claim 2, wherein the first turbine wheel comprises a disk to which shaped pieces distributed over the circumference thereof are molded or attached, between which the flow channels of Laval cross-sectional shape are formed.

8. The gas turbine according to claim 1, wherein the second turbine wheel in the direction of flow includes Pelton turbine blades.

9. The gas turbine according to claim 1, wherein the second turbine wheel is an axial turbine wheel.

10. The gas turbine according to claim 1, wherein the second turbine wheel is a radial turbine wheel.

11. The gas turbine according to claim 1, wherein each flow channel of Laval cross-sectional shape is associated with a co-rotating combustion chamber.

12. The gas turbine according to claim 1, wherein a radial compressor is mounted on the hollow shaft downstream of the axial compressor.

13. The gas turbine according to claim 1, wherein the rotor of the first generator is mounted on the inner rotor and the rotor of the second generator is mounted on the outside of the hollow shaft.

14. The gas turbine according to claim 1, wherein by controlling the two generators the rotational speed of the two turbine wheels can be set as desired, allowing the operational states of the two systems to be optimally set without adjusting systems.