July 21, 1953 J. A. N. GALLIOT 2,646,209

TURBINE DRIVEN MULTISTAGE COMPRESSOR

Filed May 18, 1949 2 Sheets-Sheet 1

Fig. 1.

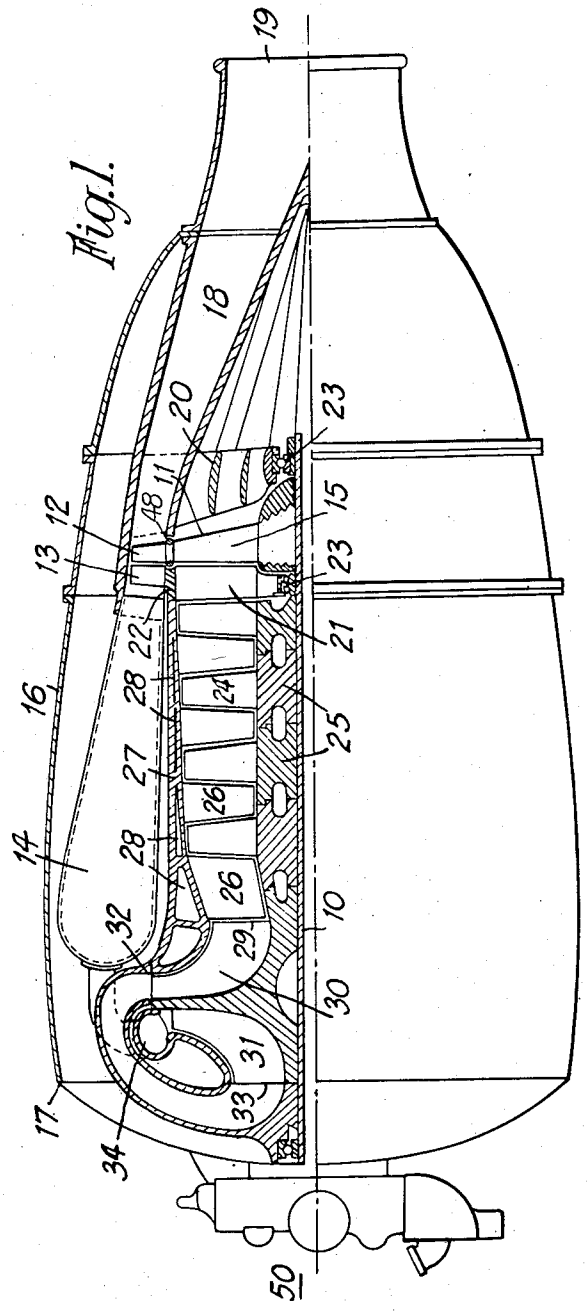


Fig. 4.

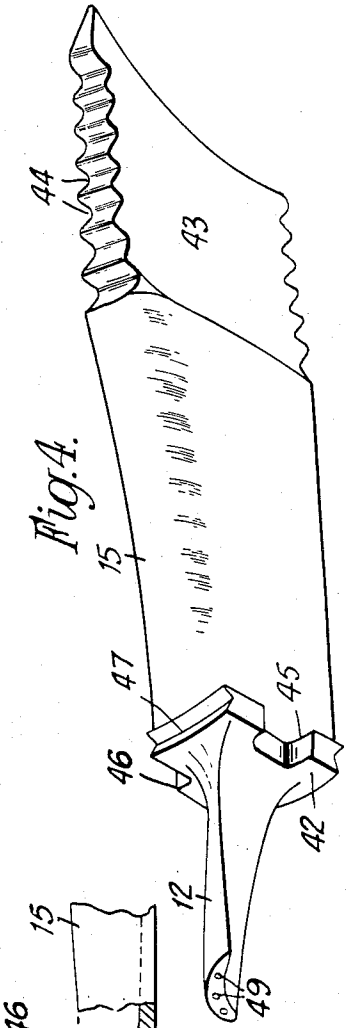
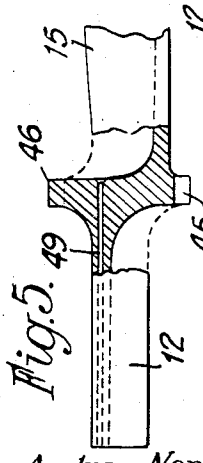


Fig. 5.



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Filed May 18, 1949 2 Sheets-Sheet 2

Fig.2.

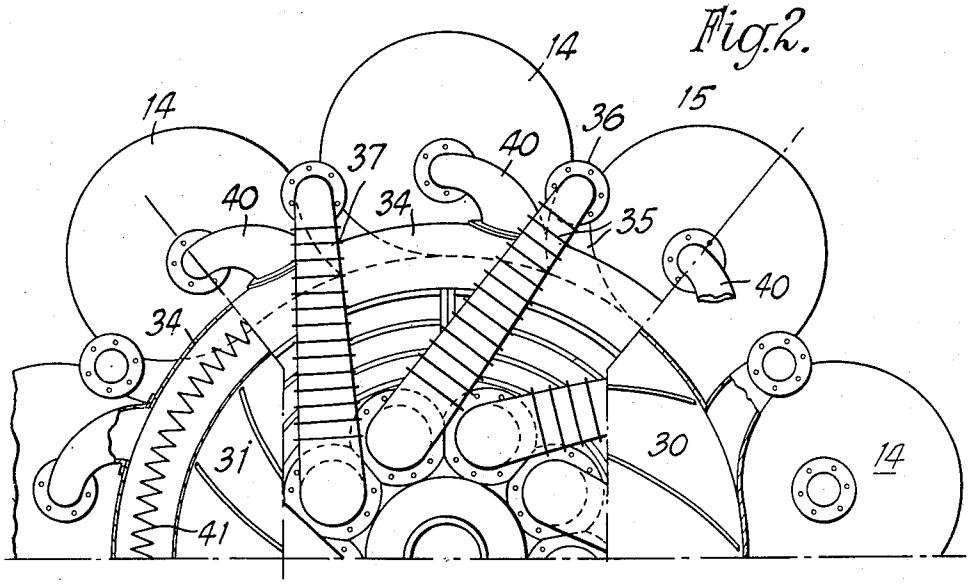
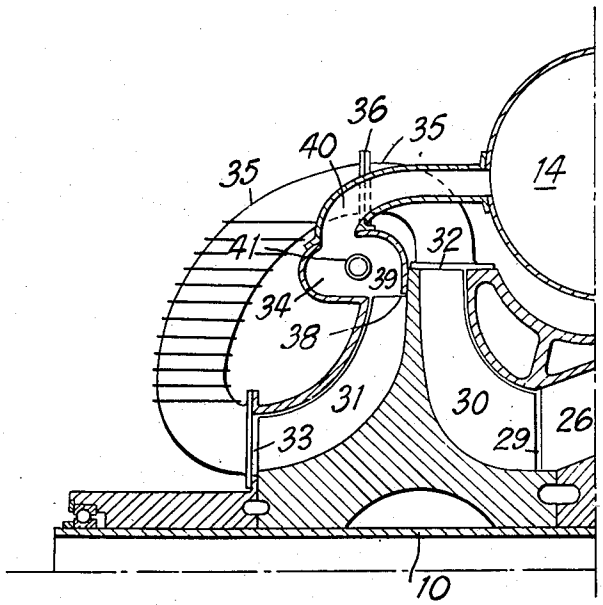


Fig.3.



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2,646,209

TURBINE DRIVEN MULTISTAGE COMPRESSOR

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In France May 21, 1948

6 Claims. (Cl. 230—116)

1

This invention relates to gas turbines such as employed for jet-propelled aircraft and like purposes.

The invention relates more particularly to gas turbines as described in my pending patent application Serial No. 730,446, filed February 24, 1947, Patent No. 2,600,235, issued June 10, 1952.

The main objects of the present invention are to provide means for obtaining higher power output from the turbine and to reduce the weight of the rotating parts.

More specifically, the invention has for object to lighten the turbine rotor by making it of a light alloy having a specific weight or density of about 4 or less, the use of such material being made possible by intensive cooling of the turbine blades and connected parts.

Another object is to provide for higher compression of the air delivered to the combustion chambers, by arranging for multi-stage compression preferably with inter-stage cooling and with final heating of the compressed air supplied to the combustion chambers.

Other objects and advantages of the invention will hereinafter appear from the following description, given with reference to the accompanying drawings, in which:

Fig. 1 is a diagrammatic view of the turbine, one half being in longitudinal section and the other half in elevation.

Fig. 2 is an enlarged end view from the left of Fig. 1, with parts broken away on the right to show the interior of one compressor and its outlet connections, and on the left to show the interior of the other compressor and its connections.

Fig. 3 is a similarly enlarged view showing a half-section of the centrifugal compressors at one end of the turbine.

Fig. 4 is a perspective view of one of the turbine blades with the associated vane element of a primary compressor.

Fig. 5 is a sectional detail of the turbine blade and wheel spoke.

Referring to Fig. 1, the turbine shaft 10 is fitted at one end with a driving wheel 11 having external blades 12 against which hot gases are directed by guide vanes 13, the gases being delivered from combustion chambers 14 spaced around the shaft and extending approximately parallel to its axis. The central portion of the turbine wheel 11 is apertured by providing it with spokes or webs which are shaped as helicoidal vanes 15 to constitute a primary element of an axial-flow compressor; air is admitted to the

2

turbine wheel from the interior of an outer casing 16, the open end 17 of which faces the direction of flight of the aircraft driven by the turbine. Within the casing, the cold incoming air passes between and along the outside of the combustion chambers 14 to the rear end of the casing, where it is deflected inwardly to pass between a plurality of ducts 18 conveying the exhaust gases from the turbine to the jet outlet 19. The air passages are preferably of oval or streamlined section to allow the deflected air to flow freely between the ducts 18 and substantially in a radial direction, after which the air travels forwards through a fixed grid 20 including annular guide vanes to the rotating vanes 15. After passing through the latter, the air encounters another set of guide vanes 21 formed by radial arms supporting the turbine stator 22, these vanes or arms and the fixed grid 20 carrying bearings 23 for the shaft 10.

Beyond the guide vanes 21 there is arranged a multi-stage axial-flow compressor composed of alternate rotor blades 24 secured to rings 25 fixed on the shaft 10 and stationary blades 26 fixed inside an induction tube 27, the outer wall of which is insulated against the heat of the combustion chambers 14 by inserts 28 of suitable material. The tube 27 tapers in diameter, the compressor blades 24, 26 being of gradually decreasing height until near the forward end of the tube, where the last set of stationary blades 26 are shaped to give a sharper taper whereby the partly compressed air is led into the eye or intake 29 of a centrifugal compressor 30 secured upon the shaft; this compressor 30 has its runner made integral with that of another centrifugal compressor 31, the two runners being placed back to back, as shown.

From the compressor 30, the air is delivered at 32 into a suitably designed manifold or branched connection leading to the eye or intake 33 of the other compressor 31, which finally delivers the compressed air to the combustion chambers 14 through another manifold 34, the several branches of these two manifolds being designed to avoid interference.

As seen more clearly in Figs. 2 and 3, the branches 35 of the first manifold or connection extend more or less tangentially from the casing of the main compressor 30 and are then curved over forwardly and inwardly towards the intake 33 of the other compressor, where the gases enter with a tangentially velocity component; these relatively long branches 35 may be made in two lengths connected by flanged joints

36 to facilitate manufacture and erection, and the exposed lengths leading to the intake 33 are preferably ribbed externally or provided with gills 37 or the like (as shown in Fig. 2, in one instance) for cooling purposes.

The final compressor 31, being supplied with air already compressed in the previous stages and preferably cooled as stated before transfer to this final stage, can be made of smaller capacity and of a diameter considerably less than the main compressor; the manifold 34, into which the finally compressed air is delivered, can therefore be of smaller diameter at the jointing surfaces 38 than the first manifold 32: see Fig. 3. This second manifold intake 34 is conveniently made of toroidal annular shape, as seen more clearly in Fig. 2 with alternate inlets 39 and delivery branches 40 respectively, arranged obliquely to its cross-section, as seen in Fig. 3; thus the compressed air passing through it travels for a short distance circumferentially from each inlet 39 to the next delivery branch 40, and with a helicoidal swirling motion inside the manifold. The delivery branches or connectors 40 of this second manifold will extend more or less tangentially and in the same direction around the axis of the shaft 10 as the branches 35 from the main compressor 30, but in a different plane, so that as they curve over rearwardly of the aircraft to connect with the respective combustion chambers 14, they can be located alternately between the respective forwardly curving branches 35 of the first manifold, the two sets of branches 35, 40 thus crossing without interference. The air may be caused to slow down inside the second manifold by increasing the cross-sectional area of the latter relative to the area of the inlets 39, thereby converting part of its kinetic energy into pressure.

Within the second manifold 34, and extending either continuously or at intervals around its circumference, suitable heating means are provided, for example in the form of an electrical resistor such as a coiled wire 41, as shown on the left of Fig. 2; this resistor coil may be raised to red heat by passage of a current supplied by a generator (not shown) driven by the turbine.

Assuming that the atmospheric air entering by ram effect into the open end 17 of the casing, and preheatd slightly by the combustion chambers 14 along which it flows and by the exhaust ducts 18 between which it passes inwardly to the open center of the turbine wheel 11, is compressed by the primary element or vanes 15 and the axial-flow compressor 24, 26, to a pressure of 1½ atmospheres before entry to the main compressor 30, the latter can be designed to raise the compression to about 3½ atmospheres, instead of the more usual pressure of about 4 atmospheres required for feeding the combustion chambers 14; the main compressor can thus be made of smaller size than if it had to produce the final pressure. The air delivered by this main compressor 30 is then conveyed through the connected manifold 32 and its branches 35 to the eye or intake of the other compressor 31 mounted in front of the former; this other compressor 31, being supplied with air at a pressure of 3½ atmospheres, can be made of still smaller diameter, while serving to compress the air to a final pressure of about 5 atmospheres for feeding the combustion chambers 14. This air is conveyed through the second manifold 34, wherein it is allowed to slow down slightly so as to convert part of its kinetic energy into pressure, and is also heated by the electrical resistor coil 41 before delivery from the branches 40 leading into the respective combustion chambers, these branches 40 being heat insulated to retain the heat of the air; as the heating is applied to pure air, there is no danger of ignition within the manifold 34 or its branches 40.

The increase of pressure of the compressed air reduces the overall size or bulk of the combustion chambers and turbine, and also leads to fuel economy sufficient to offset the small amount of energy consumed in heating the air within the second manifold 34, which is kept as hot as possible by external lagging (not shown). Fuel is supplied to the combustion chambers 14 through injectors of known kind (not shown), the supply of fuel being effected by the auxiliary mechanism 50 indicated in Fig. 1.

The number of branches of both manifolds 32, 34 will be made equal to the number of combustion chambers 14 to be supplied, for example nine, so that the branches of each manifold can be inter-spaced between those of the other, the delivery branches 40 of the second manifold crossing the first manifold at the points between its branches 35. The air from the main compressor 30 has its temperature lowered by the inter-stage cooling effected by the ribbed or gilled branches 35 of the first manifold which is kept as cool as possible; these branches are preferably cooled by the air entering the casing 16, this air being thus slightly pre-heated so as to reduce the risk of icing up the primary compressor.

It will be understood that the above-mentioned values of the compression in the various stages are given merely by way of example and that the proportional values of the three stages of compression may also be varied.

The turbine rotor, comprising the driving wheel 11, the rotating blades 24 of the axial-flow compressor, and the main and final compressors 30, 31, are made of a light alloy having a specific weight preferably lower than 4, as compared with the specific weight of about 8 in the case of austenitic steel and alloy steels with a high nickel-content, as hitherto employed, which steels are comparatively poor conductors of heat. Among the light alloys to be used, there may be mentioned "Hiduminium," of a specific weight of 2.85, capable of withstanding a temperature of 400° C., and possessing excellent thermal conductivity, the particular alloy preferred being that known as "RR–57," an alloy of outstanding merit for use at temperatures in the range 275°–400° C., and having the following chemical composition:

Copper	5.75–6.25%
Silicon	0.2% max.
Iron	0.3% max.
Manganese	0.2–0.3%
Titanium	0.1–0.15%
Aluminum	Remainder

with an ultimate tension stress of 27 tons per square inch (see "Hinduminium" booklet published by High Duty Alloys, Slough, Bucks, England, 1947, pages 26–27). As the temperature of the turbine blades is currently of the order of 550° C., it is possible to construct the bladed rotors from such light alloys provided they are subjected to a cooling action during operation, corresponding to that difference of 150° C.; this may be done by blowing air upon

the turbine wheel or otherwise forcibly cooling the rim, blades and central portion or spokes.

In the present case, the incoming air entering through the turbine wheel 11, after preliminary heating inside the casing 16, by contact with the combustion chambers 14 and exhaust ducts 18, will have a temperature lower than 200° C., so that it is capable of effectively cooling the wheel by means of the vane-forming spokes or webs 15. Moreover, this air is subject to centrifugal force inside the wheel 11, causing it to press against the interior of the rim connecting the vanes 15 to the external turbine blades 12; by forming air passages within these blades to admit the air from the interior of the wheel, the air can be made to flow outwardly through the blades in sufficient quantity to maintain their temperature at or below the safe working figure of 400° C.

Fig. 4 illustrates one of the turbine wheel spokes comprising the turbine blade 12, the primary compressor vane 15, a connecting segment 42 of the wheel rim, and a root element 43 of wedge shape having teeth 44 whereby the several spokes are rigidly clamped together at the wheel hub in the assembled position, as seen in Fig. 1. The rim segments are formed with alternate mortises and tenons 45, 46, which interengage with those of the adjacent segments, and are grooved at 47 to receive clamping rings 48 or the like. A number of holes 49 are drilled longitudinally through the turbine blade 12, so as to pass through the rim segment 42, as shown more clearly in Fig. 5, thus allowing the cool air from the interior to discharge through the blade 12, after which it mixes with the turbine exhaust gases.

The lowering of the temperature of the rotor in this way not only makes it feasible to employ light alloys which could not otherwise withstand the heat of the gases from the combustion chambers 14, but also secures other accessory advantages.

For example, the construction of the turbine rotors from light alloys, owing to the reduction of weight which it involves, allows of improving greatly the accuracy of aim when firing guns mounted upon single-seater aircraft. Upon the latter, which are generally unstable at high speeds, the gyroscopic effect due to the turbine rotors produces undesired oscillations, a circumstance which renders it difficult to maintain direction of flight within a few seconds of angle for firing the gun during the fugitive moments when the target comes into the line of fire. The gyroscopic effect is in practice greatly reduced owing to the reduction of mass of the rotors constructed in conformity with the invention.

The invention can be applied for example to the rotors of gas turbines such as described in my pending patent application Serial No. 730,446, in United States Patent No. 2,600,235, in which turbines the greater part or the whole of the cold air admitted for compression to feed the combustion chamber or chambers is caused to pass through the rotor with a view to increasing the cooling of the latter. It is however to be understood that the invention is not limited to that type of gas-turbine rotor.

What I claim is:

1. In a gas turbine including a rotary shaft and a bladed wheel secured thereon, a multistage air-compressor comprising as primary compression stage a plurality of helicoidal vanes forming spokes of said wheel, with stationary guide vanes co-operating with said spoke-forming vanes, and a plurality of axial-compressor rotors in series with said primary stage, and as intermediate and final compression stages two centrifugal compressors mounted on said shaft and operating in series, a tubular casing around said shaft conveying air from said primary compression stage to said intermediate compression stage, and a plurality of tubular connectors in parallel conveying air between said intermediate and final compression stages.

2. In a gas turbine including a rotary shaft and a bladed wheel secured thereon, a multistage air-compressor comprising as primary compression stage a plurality of helicoidal vanes forming spokes of said wheel, with stationary guide vanes co-operating with said spoke-forming vanes, and a plurality of axial-compressor rotors in series with said primary stage, and as intermediate and final compression stages two centrifugal compressors mounted on said shaft and operating in series, a tubular casing around said shaft conveying air from said primary compression stage to said intermediate compression stage, and a plurality of tubular connectors in parallel conveying air between said intermediate and final compression stages, and means for guiding said air into external contact with said connectors before being admitted to said primary compression stage.

3. In a gas turbine including a rotary shaft and a bladed wheel secured thereon, a multistage air-compressor comprising as primary compression stage a plurality of helicoidal vanes forming spokes of said wheel, with stationary guide vanes co-pending with said spokes-forming vanes, and a plurality of axial-compressor rotors in series with said primary stage, and as intermediate and final compression stages two centrifugal compressors mounted on said shaft and operating in series, a tubular casing around said shaft conveying air from said primary compression stage to said intermediate compression stage, and a plurality of tubular connectors in parallel conveying air between said intermediate and final compression stages, external cooling gills upon said connectors, means for guiding air into contact with said gills before admission to said primary compression stage, a manifold receiving air from said final compression stage, and a plurality of branches being equal in number to said connectors and also from said manifold conveying the finally compressed air, said branches being interspaced angularly between said connectors.

4. In a gas turbine including a rotary shaft and a bladed wheel secured thereon, a multistage air-compressor comprising as primary compression stage a plurality of helicoidal vanes forming spokes of said wheel, with stationary guide vanes co-operating with said spoke-forming vanes, and as intermediate and final compression stages two centrifugal compressors mounted on said shaft and operating in series, a tubular casing around said shaft conveying air from said primary compression stage to said intermediate compression stage, and a plurality of tubular connectors in parallel conveying air between said intermediate and final compression stages, external cooling gills upon said connectors, means for guiding air into contact with said gills before admission to said primary compression stage, a manifold receiving air from said final compression stage, and a plurality of branches from said manifold conveying the

finally compressed air, said connectors being curved over the exterior of said manifold, and said branches being equal in number to said connectors and also being interspaced angularly between said connectors.

5. In a gas turbine including a rotary shaft, a bladed wheel secured thereon, and a multi-stage air-compressor as specified in claim 1, a turbine wheel made of a light aluminum alloy of high thermal conductivity, said wheel having its blades integral with its spoke-forming vanes, and said vanes being exposed to the air traversing said primary compression stage.

6. In a gas turbine including a rotary shaft, a bladed wheel secured thereon, and a multi-stage air-compressor as specified in claim 1, a turbine wheel made of Hiduminium alloy having a specific weight lower than 4 and a safe working temperature limit of about 400° C., said wheel having its blades integral with its spokes-forming vanes, and said vanes being exposed to the air traversing said primary compression stage.

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