

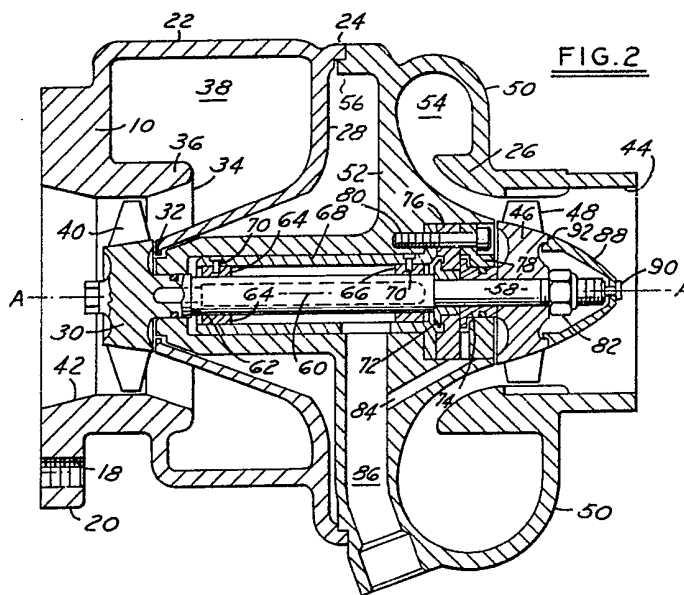
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(54) **Axial flow supercharger for internal combustion engines**

(57) An axial flow supercharger has an exhaust gas turbine (40) mounted on an axially-extending rotor shaft (60) that has a compressor rotor (46) mounted at the opposite end. An exhaust gas casing (10) carries the exhaust gas from the engine exhaust manifold and directs it through an

inlet orifice (34) toward the blades of the turbine rotor (40). The gas expands within the turbine which drives the shaft (60) in rotation. A compressor casing (26) carries ambient air to the compressor rotor (46) which increases its pressure and pumps the air to the engine inlet manifold. The turbine and rotor shaft may be made of silicon nitride or silicon carbide material.



GB 2 063 368 A

FIG.1

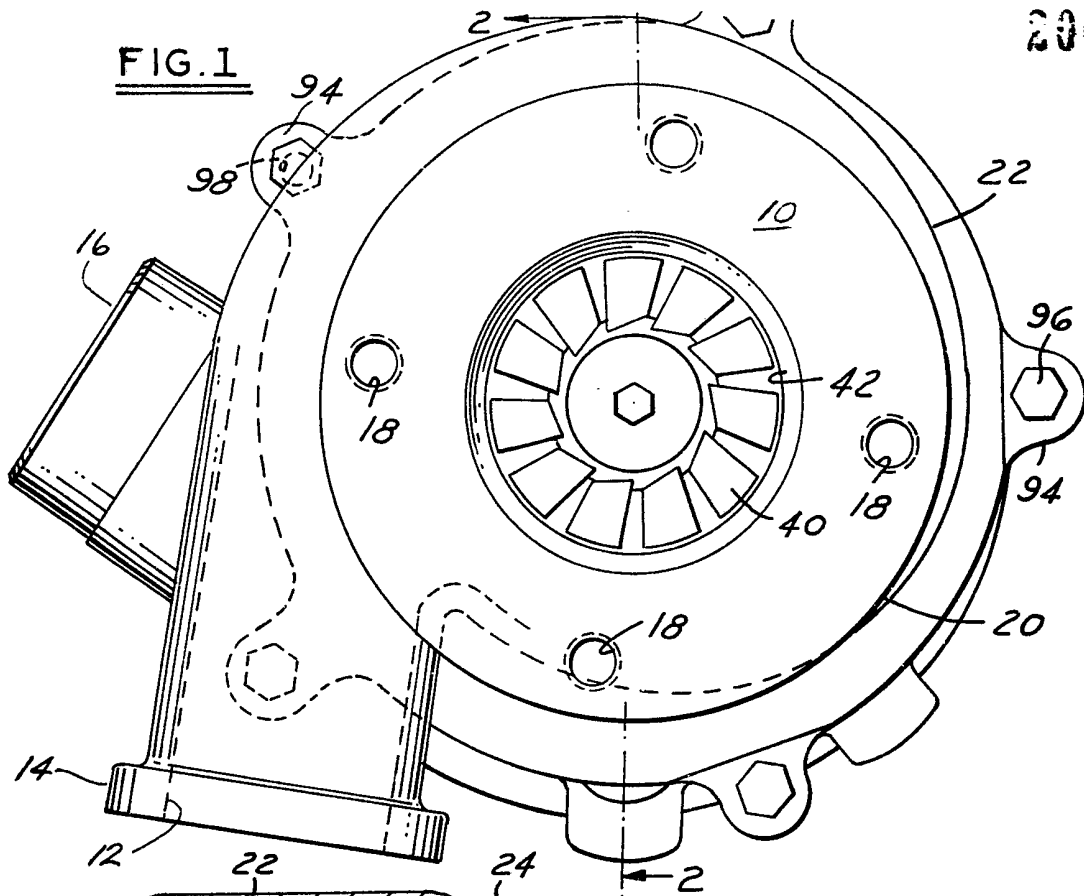
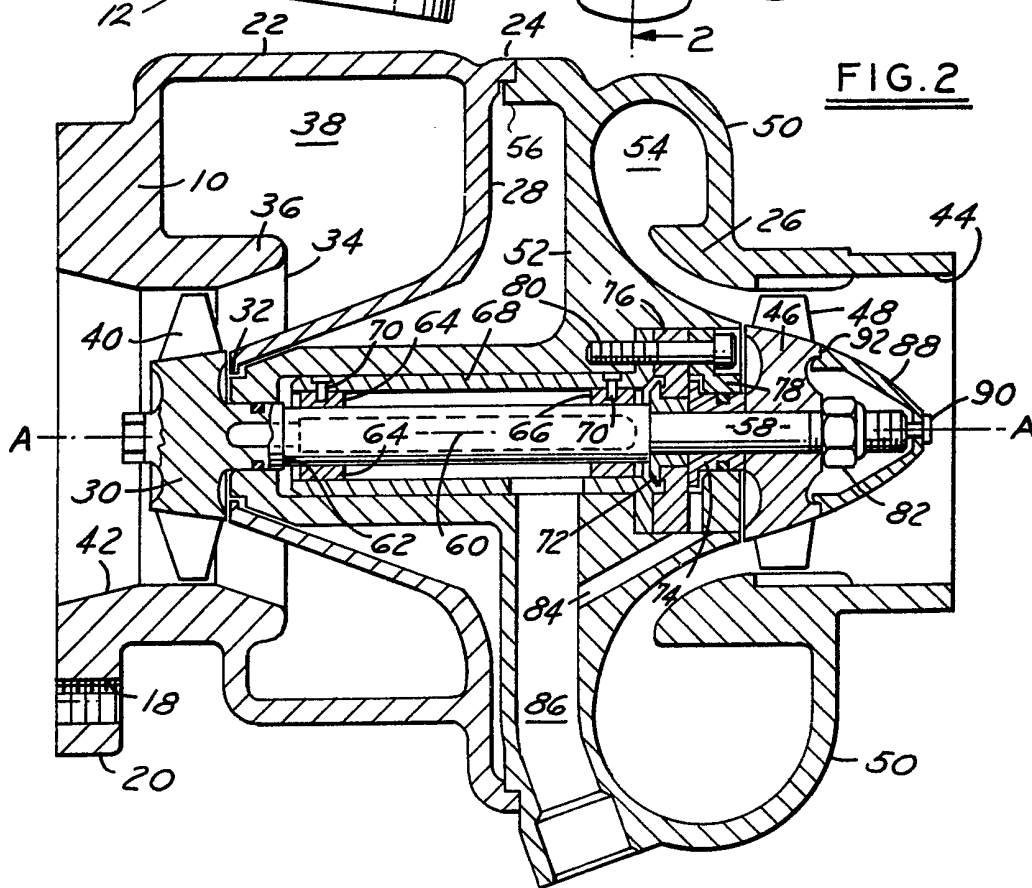


FIG.2



SPECIFICATION

Supercharger for internal combustion engines

The present invention relates to superchargers for use with a spark ignition gasoline engine.

- 5 Superchargers are compressors used with an internal combustion engine as a means for raising the output power of the engine by increasing the amount of air that is inducted into the engine. The power of the engine is directly limited by the amount of air that can be inducted during the intake stroke, therefore, by compressing the inlet air to a pressure higher than ambient conditions, a greater quantity of air is inducted and the power delivered by the engine is increased. By increasing the compression ratio of the engine in this way, a higher density and a higher temperature charge within the engine at ignition will result. These effects increase the tendency of the spark ignition to knock. For this reason the inlet air pressure is increased above ambient conditions approximately 6 to 8 psi. In compression ignition engines there is less tendency to knock as the pressure of the inlet air increases; therefore, the boost given is in the range between 15 and 30 psi. In spark ignition engines the tendency to knock is a direct consequence of premature ignition that results from the higher energy state of the inlet air-gas mixture. When superchargers that develop a boost of between 6 and 7 psi in the inlet air stream are used, the tendency to knock requires that the timing be adjusted to retard the spark.

- Rotary turbochargers are a type of supercharger which rely upon the power of the engine from which they are driven to produce the boost in inlet air pressure. They have associated with their operation a distinctive and familiar delay in the increase of engine output torque upon accelerating the vehicle, the delay being caused by the requirement for engine speed to increase sufficiently to produce the necessary increase in inlet air pressure. To overcome the delay time, various means have been sought to disassociate the rotational speed of the turbocharger from the increase in boost it produces. Compression wave turbochargers wherein a traveling pressure wave produced by the engine exhaust gas compresses the inlet air and pumps it to the inlet manifold is one solution to the engine power delay problem. However, turbochargers of this type typically produce a boost in inlet air pressure that greatly exceeds the limitation of a turbocharger for use with spark ignition engines.

- Boosting the pressure of the inlet air in internal combustion engines has conventionally been accomplished in the art by means of a turbine-driven centrifugal supercharger of the type wherein hot engine exhaust gas is passed through a single stage turbine fixed to one axial end of a driveshaft. A centrifugal compressor is mounted at the axially opposite end of driveshaft and receives cool ambient air at an inner inlet portion of a rotor. Rotation of the compressor pumps the air radially outwardly from the inlet through the operation of centrifugal force and into a volute section of the

- 65 supercharger casing that carries the compressed air to the inlet manifold of the engine. Centrifugal superchargers of the type heretofore known typically require that the casing comprise 3 or 4 segments each of which is mechanically joined to produce the casing assembly. The rotor of the compressor requires that the inner surface of one casing define, in the axial and radial sense, the space between the rotor blades in which the ambient air is compressed and pumped from the rotor centre outwardly into the volute. Similarly, at the turbine end, the supercharger compressor must provide an inner surface to contain and bound the exhaust gas so that it will flow into the turbine stage and from the turbine into the exhaust system of the vehicle. At least two casings are required on the centrifugal compressor side, one inner casing surface for confining the volume of air to be compressed and a second casing segment cooperating with the rotor-defining casing portion for directing the compressed air outwardly into the volute.

- It has also been recognised that a pressure exchange from the engine exhaust gas to ambient air is possible with an axial flow device provided the boost in inlet air pressure is fairly minimal. Spark ignition engines require a lesser boost than do compression ignition engines; therefore, axial flow compressors are capable of being driven directly by an axial flow turbine that receives energy from the engine exhaust gas and directly drives the compressor. In order for the energy exchange to be self-sustaining over the operating range of the engine it is crucial that the rotor have the lowest possible inertia.

- According to the present invention there is provided a supercharger for an internal combustion engine comprising:

- an exhaust gas casing having a high pressure exhaust gas passage for communication with the exhaust manifold of the engine, and a low pressure exhaust gas passage;

- a compressor casing having a low pressure air inlet passage, a high pressure air passage for communication with the intake manifold of the engine;

- a rotor that includes a shaft mounted for rotation about its longitudinal axis;

- an axial flow turbine rotor secured to said shaft positioned within the exhaust gas casing having turbine blades extending radially therefrom through which rotor the exhaust gas flows whereby the energy of the exhaust gas is converted to drive the rotor shaft in rotation; and an axial flow compressor rotor secured to said shaft, positioned within the compressor casing having compressor blades extending radially therefrom through which rotor the inlet air passes whereby the inlet air is increased in pressure and delivered to the engine.

- By using an axial flow compressor driven by an axial flow turbine, each of which has radially extending blades that are short relative to similar devices and a compact rotor to which the blades are attached, the rotor and blades being capable

of being formed from a low density ceramic material, the polar moment of inertia of the rotor about the axis of rotation can be reduced as compared with existing devices.

5 A preferred supercharger according to this invention includes a turbine casing that forms a duct defining a volute through which exhaust gas from the engine is directed and carried to a one stage turbine and a central gas exhaust duct that
10 returns the gas to the engine exhaust system. At the axially opposite end of the supercharger, an air inlet and volute casing furnishes an air inlet duct through which ambient air enters a compressor and through which compressed air is directed to
15 the intake side of the engine. The volute at the exhaust end of the compressor, into and around which the compressed gas flows, is connected to the inlet manifold of the engine. The turbine casing and air casing further provide a central
20 passage into which the driveshaft of the supercharger is mounted on bearings. At one end of the driveshaft, the turbine rotor is electron beam welded to the shaft and, at the axially opposite end, the air compressor rotor is
25 mechanically mounted on the shaft for rotation with the shaft. The turbine and compressor rotors have blades mounted thereon extending radially outwardly therefrom but there are no stator blades used in combination with the compressor
30 and turbine rotor blades. The shaft is provided with thrust bearings at each end. The casings furnish an oil inlet and return duct through which lubricant is carried to the bearings and returned therefrom.
35 At the air compressor side of the driveshaft, an external screw thread is provided and a nut, when drawn up on the thread, positions the rotors and bearings on the shaft at a fixed position. A plurality of mounting flanges arranged around the
40 circumference of the turbine and air compressor casings, mount and locate one casing on the other in fixed position.

A preferred embodiment of the invention will now be described, by way of example only, with reference to the drawings, in which:—

Figure 1 is an end view of a turbocharger made according to this invention showing the exhaust gas casing, the exhaust gas inlet and the compressed air outlet ducts; and

50 Figure 2 is a cross-section of the supercharger taken at plane 2—2 of Figure 1.

Referring first to Figure 1, an engine exhaust gas casing 10 is shown having a high-pressure engine exhaust gas inlet duct 12 formed integrally therewith and providing a mounting flange 14
55 which can be mechanically attached to the engine exhaust manifold (not shown). The gas inlet duct 12 provides a volute passage through which the exhaust gas enters the turbine portion of the supercharger, eccentrically of its axis, thereby
60 causing the exhaust gas to travel a tangential path from the outer periphery of the gas casing circumferentially around the casing perimeter and radially toward the central axis of the
65 supercharger.

Similarly, the compressed air outlet 16 is a volute directed eccentrically of the central axis of the supercharger. The compressed air is made to pass through the compressor rotor
70 circumferentially around the volute casing and radially outwardly around the tangential path which direct the compressed air to the engine inlet manifold.

With reference to Figure 2 the exhaust gas casing 10 is mounted on the vehicle structure so that mechanical attachments may engage internal screw threads 18 formed on the casing 10. The
75 tapped threads are arranged around the circumference in the form of an attachment circle on an exterior flanged portion 20. The gas casing 10 has an axially extending outer wall 22 that extends away from the mounting flange 20 and toward a guide surface 24 that mates with the
80 compressor casing 26. The inner wall 28 of the exhaust gas casing 10 extends radially inwardly from the guide 24 axially toward the turbine rotor 30 and terminates in a flange portion 32 that forms a seal with an adjacent portion of the compressor casing 26.
85

An inlet orifice 34 is defined between the surfaces of the inner wall 28 and an extension 36 of the mounting flange 20. The orifice 34 performs the function of an inlet nozzle and directs the engine exhaust gas from the annular cavity 38,
90 which is defined by the walls of the gas casing, through the turbine rotor blades 40. The annular cavity 38 communicates with the exhaust gas inlet duct 12 and provides a space within which swirl or turbulence of the entering exhaust gas is increased before it is directed through the inlet
95 orifice 34 to the turbine rotor blades 40. At the exit side of the turbine rotor, a low pressure exhaust gas exit duct 42 carries the expanded gas to the vehicle exhaust system (not shown) to which it is mounted by the bolted attachments 18.
100

Ambient air enters the compressor casing 26 through a low-pressure inlet duct 44 which carries the air and directs it through a one stage axial compressor whose rotor is indicated at 46 and
110 whose radially extending rotor blades are shown at 48. Between the outer wall 50 and the inner wall 52 of the compressor casing 26 an annular cavity 54 receives the air after it passes through the compressor rotor. Cavity 54 is a conduit by which the air is pumped in a tangential direction
115 outwardly through the air exhaust duct 16. In this way the air is carried axially through the compressor rotor and then is made to swirl tangentially thereby producing a preferred amount of turbulence in the air that is delivered to the engine inlet manifold. The inner wall 52 of the casing 26 extends radially inwardly from the guide
120 lip 56 that mates with the guide surface 24 and extends longitudinally along the axis A—A to a point at which it terminates in a complementary surface to the lip portion 32 of the gas casing wall 28.
125

A driveshaft 58 having a central axial bore 60 is joined to the turbine rotor at a weld seam 62,
130 which is formed by inertia or electron beam

welding procedures. The drive shaft 58 is journaled by way of bearings 64 and 66 that are of bronze or brass and which are secured on the inner surface of a sleeve by the floating pins 70.

- 5 Thrust bearings 72, 74 are mounted on the outer surface of the driveshaft 58. The thrust bearing 72 abuts the shoulder of the driveshaft 58 at one axial end and is in abutting engagement with the thrust bearings 74 at its opposite axial
10 end. A retainer ring 76 is interposed between the flanges of the thrust bearings, and the mounting block 78 provides a recess into which is fitted the heat of an attachment bolt 80 that extends through the mounting block 78, the ring 76 and an
15 annular flange of the sleeve 68, thereby fixing these in position on the compressor casing.

- An external screw thread is formed on the axial end of the driveshaft 58 and is engaged by the nut 82, which, upon being drawn up causes the
20 compressor rotor 46, the thrust bearings 72 and 74 and the driveshaft 58 to be held in a fixed position. The compressor rotor 46 is fixed on the outer surface of the driveshaft 58 by the preload developed when the nut 86 is tightened so that
25 relative rotary motion between the shaft and the rotor is prevented.

- The compressor casing 26 can be made of an aluminium casting, but at the turbine end of the supercharger higher temperature materials are
30 required; the exhaust gas casing 10 would preferably be made from cast nodular iron. The turbine rotor 30, turbine blades 40 and driveshaft 58 are preferably formed from stainless steel in order to have sufficient strength at the higher
35 temperatures than the exhaust gases present. Alternatively, the turbine components 30, 40 and the driveshaft 58 may be formed from a low density ceramic material such as silicon nitride or silicon carbide.

- 40 Either of the casings 10 or 26 can provide lubricating ducts whereby lubricating oil is delivered to the bearings 64, 66, 72, 74 and is returned to the oil sump by oil exit passages 84, 86.

- 45 Within the air inlet duct 44 and aligned with the central longitudinal axis A—A, a nose cone 88 is mounted on the axial extremity of the driveshaft 58 by way of the attachment 90. The nose cone functions to provide an inner surface within the
50 duct 44 along which the incoming ambient air is directed through the compressor rotor. The nose cone 88 rotates with the driveshaft 58 and the compressor rotor 46 with which it is joined at the mounting surface 92.

- 55 Assembly of the supercharger begins by aligning the exhaust gas casing 10 and the compressor casing 26 on the guide surfaces 24, 56; aligning the mounting flanges 94 and drawing up the attachment bolts 96 on the tapped screw
60 threads 98 formed in either of the casing flanges. Next, the weld seam 62 is produced thereby joining the driveshaft 58 to the turbine rotor 30. A subassembly comprising the thrust bearings 72, 74, the mounting block 78, the ring 76 and the
65 sleeve 68 is arranged and fitted on the outer

surface of the driveshaft 58. The mounting bolt 80 engages the tapped threads formed in the compressor casing 26 and the subassembly that includes the turbine rotor and the driveshaft is
70 inserted through the bore of the thrust bearing. The compressor rotor is then fitted over the driveshaft and the mounting nut 82 is brought up securely on the external threads at the end of the driveshaft. Finally, the nose cone 88 is secured on
75 the end of the driveshaft 58.

- In operation engine exhaust gas enters the supercharger through the exhaust gas inlet duct 12 and enters the annular cavity 38. The exhaust gas is directed through the inlet orifice 34,
80 through the turbine rotor blades 40, which are driven in a known manner by exchanging the energy of the exhaust gas and producing thereby rotary motion of the turbine rotor and driveshaft. The driveshaft causes the turbine rotor 46 to
85 rotate about the axis A—A thereby causing an inflow of ambient air through the inlet duct 44 to the compressor blades 48 and into the annular compressor cavity 54. The compressed air is then caused to rotate within the cavity 54 and
90 tangentially to exit the compressor.

- By using an axial flow compressor rather than a radial compressor, a bulky inner hub, characteristic of radial compressors is eliminated, enabling the supercharger to boost the pressure of
95 the inlet air a sufficient amount for use with a spark ignition engine that is of lighter weight and a lesser polar moment of inertia than similar devices heretofore known.

- The preferred supercharger of the invention described above is manufactured with casings that comprise two parts only. This advantage can be accomplished because of the axial flow nature of the turbine and compressor, the elimination of the need for stator blades in either the turbine or
100 compressor and by the reduction of the number of surfaces that provide radial and tip clearances that must be held within close tolerances as in conventional superchargers.

- The rotor shaft of the preferred supercharger can be easily inserted within the space provided in the turbine and compressor casings as distinguished from superchargers wherein the rotors must be encapsulated and separated from one another by inner surfaces formed in the
105 castings.

- Still another advantage of the embodiment of the invention described above is that the supercharger is extremely responsive to the requirements of the vehicle operator, a condition that is realised through the use of compact and light weight turbine and compressor rotors, which can be formed of low density material, preferably silicon nitride ceramic based material.

CLAIMS

- 125 1. A supercharger for an internal combustion engine comprising:
an exhaust gas casing having a higher pressure exhaust gas passage for communication with the exhaust manifold of the engine, and a low

- pressure exhaust gas passage;
a compressor casing having a low pressure air inlet passage, a high pressure air passage for communication with the intake manifold of the engine;
- 5 a rotor that includes a shaft mounted for rotation about its longitudinal axis;
an axial flow turbine rotor secured to said shaft positioned within the exhaust gas casing having
- 10 turbine blades extending radially therefrom through which rotor the exhaust gas flows whereby the energy of the exhaust gas is converted to drive the rotor shaft in rotation; and
an axial flow compressor rotor secured to said
- 15 shaft, positioned within the compressor casing having which rotor the inlet air passes whereby the inlet air is increased in pressure and delivered to the engine.
- 20 2. A supercharger according to Claim 1 wherein the compressor casing includes a volute located within the high pressure air passage for increasing the turbulence in the exit air that is delivered to the engine.
- 25 3. A supercharger according to Claim 1 or Claim 2 wherein the exhaust gas casing includes a volute located within the high pressure passage wherein turbulence of the exhaust gas is reduced before passing through the turbine rotor.
- 30 4. A supercharger according to any one of Claims 1 to 3 wherein the exhaust gas casing defines a turbine inlet nozzle within the high pressure gas passage adjacent the turbine rotor for directing exhaust gas toward the turbine blades.
- 35 5. A supercharger according to any one of Claims 1 to 4 wherein the turbine rotor and turbine blades are formed from a ceramic material.
- 40 6. A supercharger according to any one of Claims 1 to 5 wherein the turbine rotor and compressor rotor are secured to axially opposite ends of the shaft, the exhaust gas casing and the compressor casing are in mutually abutting engagement and disposed adjacent the turbine rotor and the compressor rotor, respectively, and the shaft is positioned within an annular, axially-extending space formed in the casings.
- 45 7. A supercharger for an internal combustion engine substantially as hereinbefore described and as illustrated in the drawings.