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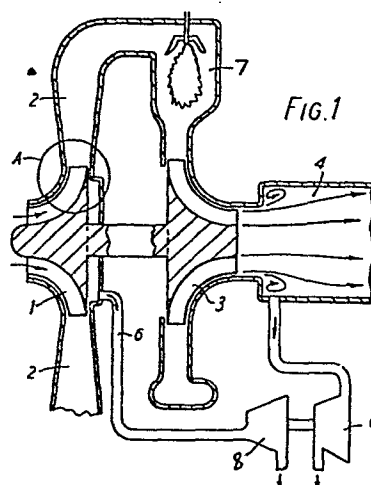
71 Applicant: **A/S Kongsberg Våpenfabrikk**
Kirkegardsveien
N-3600 Kongsberg(NO)

72 Inventor: **Mowill, Jan**
Rugdeveien 7
Oslo 3(NO)

74 Representative: **Jackson, David Spence et al,**
REDDIE & GROSE 16, Theobalds Road
London, WC1X 8PL(GB)

54 **Method of bleeding off working fluid in turbo-machines, and turbo-machines with bleed-off means.**

57 In a turbo-machine comprising a compressor (1) including a labyrinth seal (5) and a turbine (3) including an exhaust gas diffuser (4), air leaking through the labyrinth seal (5) of the compressor (1) is bled off and used as a driving medium for removing exhaust gas from boundary layers or vortex flows in the exhaust gas diffuser (4). Since the pressure of the exhaust gas to be removed from the exhaust gas diffuser (4) is below the ambient pressure, suction has to be established to remove the desired gas from the boundary layers or vortex flows. This suction is established by an ejector or a pump (9) which is driven by the energy of the compressed leakage air bled from the compressor (1). Such a pump (9) may be driven by a turbine (8) driven by the leakage air.



METHOD OF BLEEDING OFF WORKING FLUID IN TURBO-MACHINES,
AND TURBO-MACHINES WITH BLEED-OFF MEANS

The present invention relates to a method of improving the overall engine efficiency of a turbo-machine comprising an air compressor and a gas turbine including an exhaust gas diffuser, by bleeding off a part of the fluid working medium from boundary layers or vortex regions of the exhaust gas diffuser. The invention further relates to turbo-machinery for carrying out the method.

10 It is known, such as shown in US Patent No. 3856430 and French Patent No. 1199042, that the flow in diffusers can be stabilized and the pressure losses therein be reduced by selective bleedoff of parts of the working medium. When working medium such as air with low kinetic energy is bled from a vortex
15 flow in a diffuser, the vortex will be replenished by air of a higher energy level from the main-stream and thus be stabilized. A stepped diffuser (a diffuser in which the flow area abruptly increases to the desired value instead of increasing gradually such as in conical diffusers) with such a stabilized vortex flow
20 may function without detachment of the flow even at very high diffuser area ratios. A bleedoff of working medium may also be used for obtaining a given pressure recovery with a shorter diffuser length, whereby the diffuser will be lighter and probably also cheaper. A bleedoff of boundary layers has a beneficial
25 effect on most types of diffusers, but the effect is especially large in stepped diffusers as indicated above.

However, the utilization of these advantages has been very limited, because bleeding off a part of the working medium constitutes a loss which at least partly offsets the increase of
30 the efficiency due to stabilization of the flow. In addition pumps or other suction devices must be used when bleeding off working medium from exhaust gas diffusers, since the pressure in such diffusers is lower than the ambient pressure, requiring bleedoff of the working medium by suction, whereas working medium
35 may be removed from a high pressure region, e.g. from a compressor diffuser, simply by tapping.

Leakage of air through clearances such as labyrinth seals between rotating and static parts of a turbo-machine is unavoidable. At the exit of a centrifugal compressor 0,5% to 2% of the air will

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normally be bled from the engine cycle, and this represents a performance penalty.

The object of the present invention is to provide a simple method of effecting the bleedoff of working medium from exhaust gas diffusers in turbo-machinery in such a manner that the total efficiency can be improved to such an extent that a bleedoff of working medium constitutes a more attractive and interesting possibility.

The invention is based upon the recognition that the unavoidable leakage of compressed air through a labyrinth seal in the compressor may be combined with the bleeding of fluid working medium from boundary layers or vortex regions of the exhaust gas diffuser in an advantageous manner to give a substantially improved total efficiency. Thus, the leakage air may be used directly to provide a removal of working medium from the low pressure region of the exhaust gas diffuser. This means that a working medium escaping from a high pressure region and normally constituting a loss, may be utilized to provide energy for drawing off a working medium which it is advantageous to remove from a low pressure region. The predicted improvement in exhaust diffuser performance is large enough to make up for the lost air and additionally to provide a net improvement in power output and thermal efficiency.

Thus, the invention resides in bleeding off leakage air leaking through a labyrinth seal of the compressor and using the energy of said leakage air to draw off by suction said part of the working medium from said exhaust gas diffuser.

Turbo-machinery with which the invention may be carried out, comprises a compressor assembly including a labyrinth seal, and a turbine assembly including an exhaust gas diffuser. Such machinery, which may e.g. be a turbo-charger or a turboshaft engine, is characterized in that it comprises an energy conversion means which is operated by compressed air leaking through said labyrinth seal and supplies energy for removing working medium by suction from a boundary layer or vortex flow in said exhaust gas diffuser, said energy conversion means comprising a first conduit connected at one end to the low pressure side of said labyrinth seal of said compressor assembly to receive air leaking through said seal and connected at the other end to a pump means, a second conduit

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connected at one end to the suction inlet of said pump means and connected at the other end to said boundary layer or vortex flow of said exhaust gas diffuser.

As indicated above, a bleedoff is especially effective in stepped diffusers, since the bleeding may be effected from a single area close to the step in the flow path, and the present invention is therefore especially useful in connection with such diffusers. According to available data a stepped diffuser with bleedoff may provide a pressure recovery of about 90% compared with about 60% for an ordinary linear conical diffuser. A pressure recovery or efficiency of above 60% may also be obtained with conical diffusers without bleedoff if consisting of a series of coaxially placed diffusers. However, this involves a far more expensive and mechanically complicated design which is seldom used. In order to obtain a pressure recovery of about 90% it may be necessary to bleed off approximately 1-3% of the working medium, but it may also be possible to manage with smaller amounts. The aerodynamic gains may provide a total improvement of the efficiency in the order of 10%. In the case of a gas turbine this may result in a corresponding reduction of the fuel consumption. The use of stepped diffusers is believed also to provide substantial practical advantages with respect to manufacturing costs. In connection with the high exhaust gas velocities used or planned in modern radial turbines a good exhaust gas diffuser will be of especial significance to the total thermal efficiency. The importance of the invention is believed to be especially great for medium and small turbo-machinery such as turbo-chargers and gas turbines for use in propelling machinery in e.g. automobiles, since the boundary layers in such small machines occupy a comparatively large part of the flow passages, thereby resulting in a rather large reduction of the efficiency. The internal utilization of the energy in the compressed leakage air according to the invention will therefore provide an especially large increase of the efficiency in small machinery, so that the disadvantage of a low efficiency inherent in such small turbo-machinery may be reduced.

The invention will now be described in more detail, solely by way of example, with reference to the accompanying

drawings, in which:-

Fig. 1 is a diagrammatic axial sectional view of a gas turbine engine having a stepped diffuser in which a bleedoff of working medium according to the invention is obtained by means of leakage air from the compressor assembly of the engine, and

Fig. 2 is a sectional view on a larger scale of the part in the circle A in Fig. 1 illustrating a labyrinth seal between the compressor wheel and housing.

In Fig. 1 there is shown a compressor 1 which through a compressor diffuser 2 supplies compressed air to a combustion chamber 7. The gases from the combustion chamber are passed to a turbine 3 having a stepped exhaust gas diffuser 4. The turbine 3 drives the compressor 1. Of course, the turbine 3 generates substantially more energy than required for driving the compressor 1 and also supplies energy for operating a further load, e.g. an electric power generator which is not shown. Compressed air leaking through a conventional labyrinth seal 5 of the compressor 1 is bled off through a conduit 6 which leads to an air turbine 8 operating a pump or compressor 9 for removing working medium by suction from the vortex flow in the stepped exhaust gas diffuser 4.

Instead of a turbine and pump combination there may be provided an ejector operated by the leakage air to produce the suction required to remove working medium from the diffuser 4. The use of an ejector provides the best results when the air from the compressor 1 and the working medium from the diffuser 4 have approximately the same density. However, by using other solutions than an ejector a better efficiency is usually obtained, but ejectors may still be preferable in connection with small machines, since they have various other advantages such as low costs.

The bleedoff of air from the compressor 1 may also be combined with a cooling of hot parts of the machinery, said air being used for cooling prior to utilizing the energy in the air in connection with a bleedoff from the exhaust gas diffuser. During cooling heat energy is supplied to the air, which heat will counteract the flow friction losses which usually are larger when the air is used for cooling purposes.

Fig. 2 shows schematically on a larger scale the labyrinth seal through which the compressed air flows before it reaches the

conduit 6. Leakage of higher than atmospheric pressure air through clearances between rotating and static parts of a turbo-machine is unavoidable. At the exit of a centrifugal compressor 0,5% to 2% of the air has normally to be bled from the engine cycle and this represents a performance penalty. For compressors with pressure ratios above 7:1 this air is too hot to be used as bearing seal air. The present invention uses this "lost" air to control the boundary layer in the turbine exhaust diffuser.

As shown in Fig. 2 air from the exit portion of a compressor 1 leaks through labyrinth seals generally indicated at 5. At the outer portion of the seals 5 this normally wasted leaking air is bled off through the conduit 6 and fed to an ejector inlet line (not shown) or to the inlet of an air turbine as shown at 8 in Fig.1. Thus, the invention can use the compressor leakage air either as primary air in a jetpump or ejector or to drive a compressor 9 which thus pumps the subatmospheric air out from the exhaust gas diffuser 4. The predicted improvement in exhaust diffuser performance is large enough to provide a net improvement in power output and thermal efficiency in addition to make up for the lost air.

According to the preceding description the working medium is air and combustion gases respectively, since the invention is illustrated in connection with turbo-chargers and turboshaft engines. However, a corresponding effect may be obtained in connection with other fluids. The use of other working mediums, especially vapour and other gases, is therefore within the scope of the invention.

CLAIMS

1. A method of improving the overall engine efficiency of a turbo-machine comprising an air compressor (1) and a gas turbine (3) including an exhaust gas diffuser (4), by bleeding off a part of the fluid working medium from boundary layers or vortex regions of the exhaust gas diffuser (4), characterized by bleeding off leakage air leaking through a labyrinth seal (5) of the compressor (1) and using the energy of said leakage air to draw off by suction said part of the working medium from said exhaust gas diffuser (4).

2. A method according to claim 1, characterized by feeding said leakage air to a jet ejector and bleeding off said working fluid from said exhaust gas diffuser (4) by connecting the suction inlet of said ejector to said diffuser (4).

3. A method according to claim 1, characterized by feeding said leakage air to an auxiliary gas turbine (8) to drive said auxiliary turbine (8), driving an auxiliary pump (9) by said auxiliary turbine (8), and connecting the suction inlet of said auxiliary pump (9) to said diffuser (4).

4. A turbo-machine such as a turbo-charger or a gas turbine engine having a compressor assembly (1) including a labyrinth seal (5), and a turbine assembly (3) including an exhaust gas diffuser (4), characterized by an energy conversion means which is operated by compressed air leaking through said labyrinth seal (5) and supplies energy for removing working medium by suction from a boundary layer or vortex flow in said exhaust gas diffuser (4), said energy conversion means comprising a first conduit (6) connected at one end to the low pressure side of said labyrinth seal (5) of said compressor assembly (1) to receive air leaking through said seal (5), and connected at the other end to a pump means (8,9), a second conduit connected at one end to the suction inlet of said pump means (8,9) and connected at the other end to said boundary layer or vortex flow of said exhaust gas diffuser (4).

5. A turbo-machine according to claim 4, wherein said pump means comprises an auxiliary gas turbine (8) and pump (9) assembly, said auxiliary turbine (8) and pump (9) being operably connected so that said turbine (8) drives said pump (9), and said other end of said first conduit (6) is connected to the inlet of said auxiliary turbine (8) to drive said turbine (9).

6. A turbo-machine improvement according to claim 4, wherein said pump means comprises a jet ejector.

