United States Patent

Silvestri, Jr.

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[54] **LOW PRESSURE END DIFFUSER FOR AXIAL FLOW ELASTIC FLUID TURBINES**

[72] Inventor: **George J. Silvestri, Jr.**, Morton, Pa.

[73] Assignee: **Westinghouse Electric Corporation**, Pittsburgh, Pa.

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[52] **U.S. Cl.** **415/121**, 415/144, 415/168, 415/DIG. 1

[51] **Int. Cl.**.....**F01d 1/00**, F01d 25/32, F01b 25/00

[58] **Field of Search**.....415/DIG. 1, 168, 144, 145, 415/121 A

[56] **References Cited**

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Primary Examiner—Henry F. Raduazo

Attorney—A. T. Stratton, F. P. Lyle and F. Cristiano, Jr.

[57] **ABSTRACT**

An improved low pressure end diffuser for axial flow elastic fluid turbines, such as steam turbines, is disclosed. A housing is provided on the outer fairing member of the diffuser, which housing defines a vented chamber. The outer fairing member is provided with openings communicating between the chamber and the annular area within the turbine casing adjacent the leading edges of the last stage turbine blades. Injection slots are formed in the outer fairing member to communicate between the chamber and the exhaust outlet downstream of the trailing edges of the last stage turbine blades. The injection slots are formed in such a manner that the fluid will flow from the chamber along a major portion of the inner surface of the outer fairing member whereby fluid boundary layer on the fairing surface will be accelerated to prevent separation of the boundary layer from the surface thereby resulting in improved diffuser performance.

8 Claims, 4 Drawing Figures

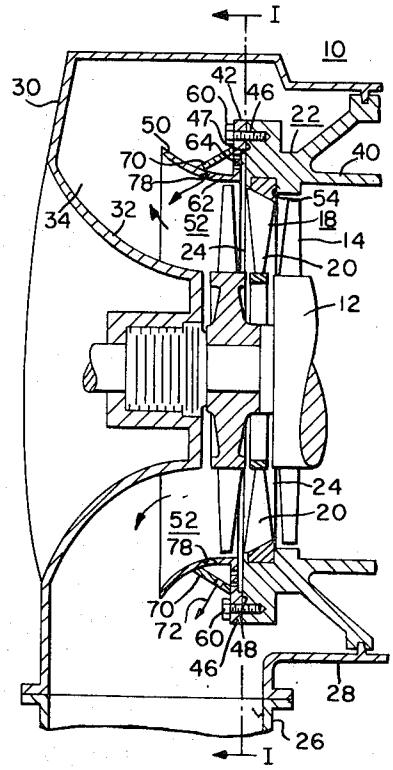


FIG. 1

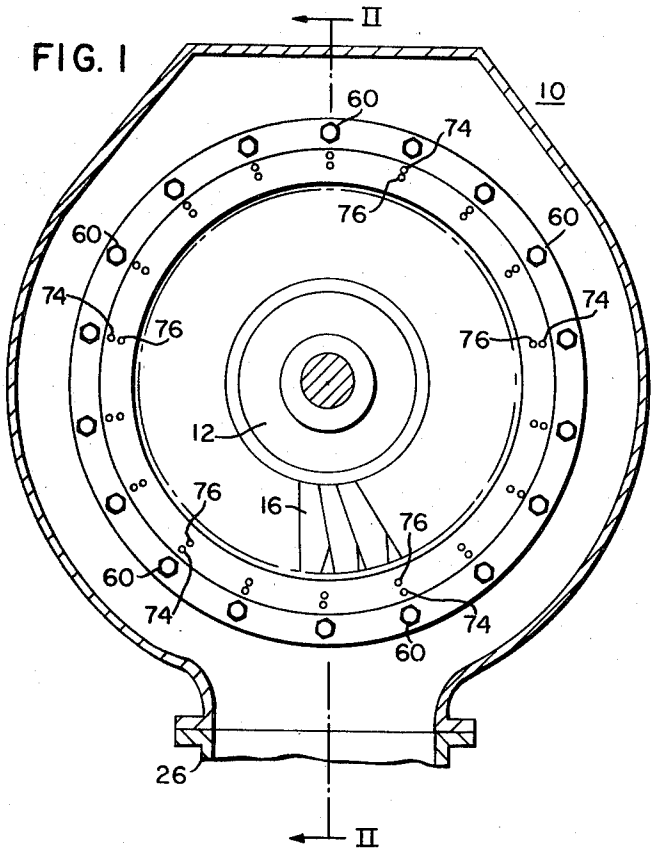
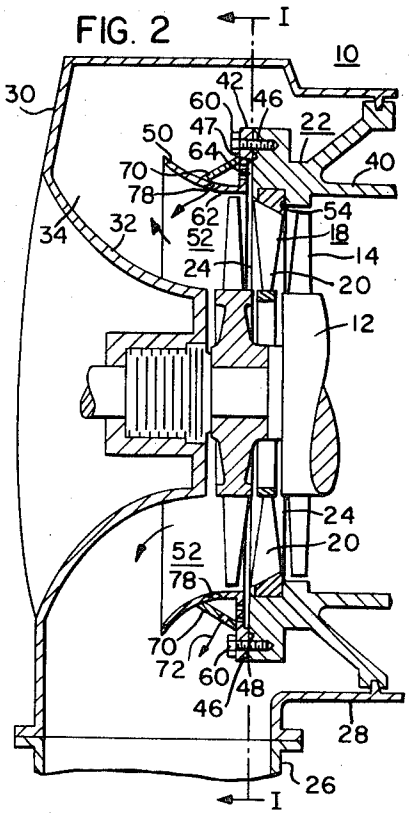


FIG. 2



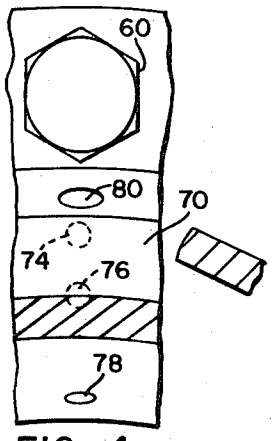


FIG. 4

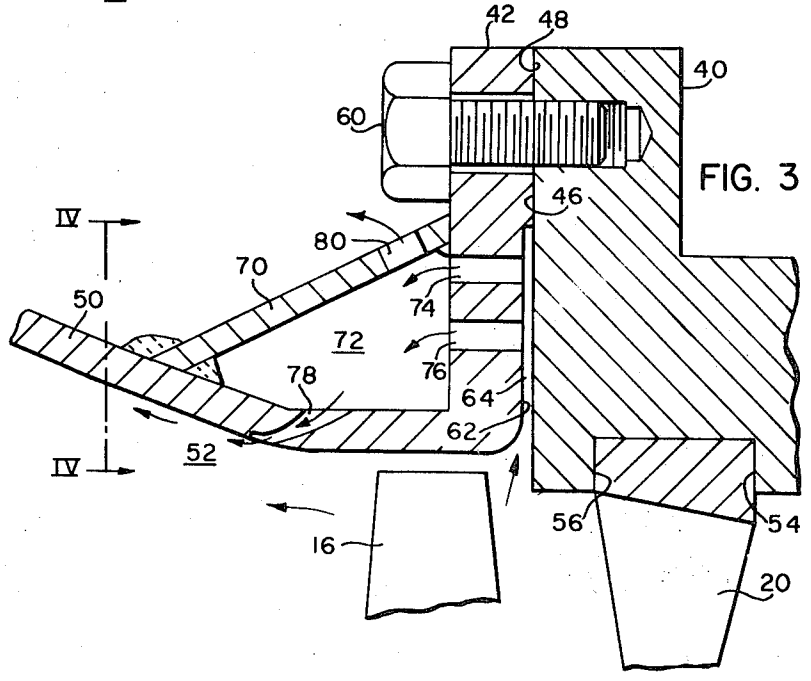


FIG. 3

LOW PRESSURE END DIFFUSER FOR AXIAL FLOW ELASTIC FLUID TURBINES

This invention relates to an improved low pressure end diffuser for axial flow elastic fluid turbines, such as steam turbines.

As is well known in the art, low pressure ends of axial flow elastic fluid turbines are usually provided with a diffuser for directing fluid discharged from the last stage turbine blades along a smooth aerodynamic path to a discharge stack or to a condenser, in the case of a steam turbine. The diffuser is often formed from radially spaced inner and outer fairing members forming an annular shaped exhaust outlet for the discharged fluid. It has been found that the layer of fluid moving along the inner surface of the outer fairing member increases in thickness and eventually separates from the surface of the fairing member thereby reducing the efficiency of the diffuser in its ability to convert the kinetic energy of the moving fluid into pressure. Thus, the discharged fluid does not move smoothly into the exhaust section of the turbine with major consequences being a decrease in the overall turbine efficiency.

Various arrangements have been used in order to hold a layer of fluid, commonly known as boundary layer, on a surface defining the flow path for the moving fluid. For example, it is common to subject the surface to suction which tends to hold the boundary layer onto the surface. Also, so-called flow splitters are used which are in the form of thin rings fixed to the surface and arranged so that the flowstream is broken up to reduce the tendency of the boundary layers from separating from the surface. In the low pressure end diffusers of axial flow turbines, however, there is no readily available suction source while the use of flow splitters would require expensive manufacturing steps in fixing the splitters to the surfaces of the fairing members. Thus, the problem of boundary layer flow separation persists in the low pressure end diffusers of turbines.

I overcome the boundary layer flow separation problem mentioned above by providing an improved low pressure end diffuser which uses the fluid injection principle for accelerating the boundary layer along the surface of the outer fairing member of the diffuser, whereby the diffuser boundary layer is accelerated and thereby prevented from separating from the surface of the outer fairing member. By keeping the boundary layer moving along the surface of the outer fairing member, the diffuser performance is improved as is the overall turbine performance. In addition, in the case of steam turbines, I use as the injection fluid steam which is ordinarily discharged from the turbine prior to reaching the last stage turbine blades. The steam used as the injection stream is that which would ordinarily be dissipated from a moisture removal device located at inlet to the last rotating blade upstream of the last turbine stage. Such a moisture removing device is disclosed in U.S. Pat. No. 3,058,720 to J. J. Hart et al., assigned to the assignee of the present application. The structure for achieving the results noted hereinabove preferably comprises: a housing means fixed to the outer surface of the outer fairing member which together with an inner fairing member forms the diffuser, with the housing means being arranged to define a vented chamber having at least a portion thereof disposed downstream of the trailing edges of the last stage turbine blades; means defining at least one opening between the chamber and the annular space adjacent the leading edges of the last stage turbine blades; and the outer fairing member having injection slots communicating between the chamber and the inner surface of the outer fairing member, the slots discharging at a point downstream of the trailing edges of the last stage turbine blades and arranged such that fluid will flow from the chamber along a major portion of the inner surface of the outer fairing members. The structure just recited diverts a small portion of pressurized fluid from a position just upstream of the leading edges of the last rotating blade or any location upstream of the last stage turbine blades onto the outer surface of the diffuser to thereby accelerate the diffuser boundary layer to prevent separation of the boundary layer and thus improve the diffuser performance.

Other details and advantages of this invention will become apparent as the following description of a present preferred embodiment thereof proceeds.

In the accompanying drawings I have shown a present preferred embodiment of this invention in which:

FIG. 1 is a transverse section of a low pressure portion of a steam turbine embodying the present invention, the section being taken along the line I—I of FIG. 2;

FIG. 2 is an axial section of the downstream portion of the turbine taken on the line II—II of FIG. 1;

FIG. 3 is an enlarged axial section of a portion of the diffuser section and the last stages of turbine blades and last stage diaphragm blades of the turbine of FIGS. 1 and 2 showing details of construction; and

FIG. 4 is a view taken along the line IV—IV of FIG. 3.

The following description will be made with reference to a steam turbine. The present invention is, however, useable with gas turbines also. Thus, reference to the steam turbine is for sake of illustration only and it should be understood that the improved diffuser of this invention is not to be construed as limited to use only in a steam turbine.

Referring to the drawings, there is shown a portion of a multi-stage axial flow steam turbine **10** including a rotor **12** having a plurality of turbine blades **14** and **16** mounted thereon in any suitable manner. Interposed between the turbine blade rows **14** and **16** is a stationary diaphragm structure **18** having an annular row of nozzle blades **20**. Tubular wall structure of shell structure generally designated **22**, is disposed in encompassing relationship with the rotor **12**, turbine blades **14** and **16**, and diaphragm **18**, and the shell structure **22**, jointly with rotor **12** define an annular flow passage **24** for the motive steam. As well known in the art, motive steam is supplied to the passage **24** in any suitable manner from any suitable source (not shown) and during flow past the blades, the steam is expanded to impart rotational energy to the rotor **12**.

The steam turbine **10**, in the illustration shown, is of a low pressure type exhausting to any suitable condenser **26** and having an outer shell structure **28** disposed in encompassing relation with the shell structure **22**. The outer shell structure is further provided with an annular exhaust hood **30** having a centrally disposed fairing member **32** hereinafter called the inner

fairing member 32. Inner fairing member 32 is of generally hyperboloidal shape, the upstream end of which substantially coincides with the circumference of rotor 12. Exhaust hood 30 further defines an annular exhaust passageway 34 for directing the stream exhausted from the passage 24 to the condenser 26 in an aerodynamically efficient manner, as well known in the art.

Shell structure 22 is formed with a pair of annular shell portions 40 and 42. Each of the shell portions 40 and 42 is provided with planar end faces 46 and 48. The upstream shell 40 is shown in fragmentary form. However, it may continue upstream with relation to steam flow therethrough to any desired length, thereby to accommodate an additional plurality of cooperating turbine blades and nozzle blades (not shown), as well known in the art.

The downstream shell portion 42 is provided with a fairing member or diffuser 50 of hollow hyperboloidal shape cooperating with inner fairing member 32 to form a smoothly faired exhaust outlet 52 of annular shape for flow passage 24. Fairing member or diffuser 50 will be referred to hereinafter as the outer fairing member 50. The upstream shell portion 42 encompasses the diaphragm 18 and is provided with a pair of radially inwardly extending flanges 54 and 56 for retaining the diaphragm 18 the annular groove formed between the flanges.

The annular shell portions 40 and 42 are maintained in axial alignment with each other by an annular array of bolts 60 extending through the abutting portions of end faces 46 and 48. End face 48 is provided with an undercut section 62 which, when end faces 46 and 48 are in abutting relationship, is spaced from the opposing portion of end face 46 to define an annular passageway 64 disposed in a transverse plane adjacent the leading edges of the last stage turbine blades 16. The function of annular passageway 64 is to direct steam into a chamber for discharge onto the inner surface of outer fairing member 50, as will be more fully described hereinafter.

An annular frusto-conical shaped housing member 70 is fixed to the upper surface of outer fairing member 50 and the outer surface of end face 48 to define an annular chamber 72. The chamber 72 is arranged with a major portion thereof located downstream of the trailing edges of the last stage turbine blades 16. Arrays of arcuately spaced upper and lower openings 74 and 76 are provided through end face 48 to provide communication between annular passageway 64 and chamber 72. Thus, steam will flow from passageway 64 into chamber 72. A series of arcuately shaped injection slots 78 are provided in an arcuately spaced array through outer fairing member 50. The injection slots 78 are disposed downstream of the trailing edges of the last stage turbine blades 16, with each slot 78 having a smoothly curved profile whereby the outlet of each of the inner surface of outer fairing member 50 is generally tangential to that surface. In other words, the injection slots 78 are shaped such that steam being discharged therefrom smoothly exits onto the inner surface of outer fairing member 50. Housing member 70 is provided with a series of arcuately spaced vent openings 80 through which moisture will be drained as it accumulates in chamber 72.

In operation, as steam flows through passage 24 and past nozzle blades 20, moisture laden steam is thrown radially into passageway 64 where it will flow into chamber 72 through openings 74 and 76. While in chamber 72, the moisture in the stream will collect on the walls of chamber 72 and will flow out vent openings 80 into the space between inner and outer shells 22 and 28, respectively, and thence exhaust passageway 34 to the condenser 26. The steam will then flow out of injection slots 78 onto the inner surface of the outer fairing member 50 to accelerate the boundary layer of steam on the surface. The pressure of the steam discharged through the injection slots 78 would, at maximum turbine load, be 2 or 3 psig above the pressure of the steam at the exit of the last stage turbine blades. This pressure differential would be sufficient to provide the needed acceleration to the steam boundary layer on the inner surface of the outer fairing member 50 to prevent separation of the boundary layer from the surface. The slots 78 provide a converging cross section to efficiently handle the steam passing therethrough.

It will now be understood how the present invention provides an improved low pressure end diffuser for an elastic fluid turbine, such improved diffuser being more efficient than those heretofore used in turbines since it prevents separation of the boundary layer from its surface. The present invention provides an improved diffuser for a steam turbine without need of using any of the useful motive steam since it makes use of moisture laden steam which would ordinarily be discharged to the condenser anyway. Thus, my improved diffuser also allows for the removal of moisture at the last stage of the turbine and thereby minimizing erosion of the last stage turbine blades.

While I have shown and described a present preferred embodiment of this invention, it is to be distinctly understood that the invention is not limited thereto, but may be otherwise variously embodied within the scope of the following claims.

I claim:

1. In the low pressure end of an axial flow elastic fluid turbine including a diffuser spaced with respect to the last stage turbine blades to provide an annular shaped exhaust outlet, with the diffuser being formed by a fairing structure, the improvement in the diffuser comprising:

a housing fixed to the outer surface of the fairing structure to define a chamber having at least a portion thereof disposed downstream of the trailing edges of the last stage turbine blades,

means defining at least one opening between said chamber and a location upstream of the last stage turbine blades,

said fairing structure having injection slots communcating between said chamber and said exhaust outlet downstream of the trailing edges of the last stage turbine blades and positioned such that fluid will flow from said chamber downstream along at least a major portion of the inner surface of said outer fairing structure, and

said housing having additional means for venting heavily ladened moisture fluid from said chamber.

2. The improvement as set forth in claim 1, wherein said housing is a continuous annular member fixed to the outer surface of said fairing structure to define a single chamber.

3. The improvement as set forth in claim 1, wherein each of said injection slots is shaped to have a discharge opening generally tangential to the inner surface of said fairing structure.

4. The improvement as set forth in claim 1, wherein said fairing structure has arcuately spaced openings communicating between said chamber and an annular space, adjacent the leading edges of the last stage turbine blades.

5. An axial flow elastic fluid turbine having

a tubular shell structure defining an axially extending elastic fluid passage,

a rotor centrally disposed in said passage and having at least one annular row of turbine blades,

means for directing fluid flow onto said turbine blades,

said tubular shell structure including outer and inner shells,

said outer shell including an annular exhaust hood structure having a centrally disposed fairing member,

said inner shell including a centrally disposed fairing member spaced from and cooperating with the fairing member of said outer shell to define an annular shaped exhaust outlet for passage of fluid flow from the last stage turbine blades,

a housing fixed to the outer surface of the inner shell fairing member to define a chamber having at least a portion thereof disposed downstream of the trailing edges of the last stage turbine blades,

means defining at least one opening between said chamber and a location upstream of the last stage turbine blades,

said inner shell fairing member having injection slots communicating between said chamber and said exhaust outlet downstream of the trailing edges of the last stage turbine blades and positioned such that fluid will flow from said chamber in a downstream direction along at least a major portion of the inner surface of said inner shell fairing member, and

said housing having vent opening means formed therethrough for discharging heavily ladened moisture fluid from said chamber.

6. The turbine as set forth in claim 5 wherein each of said injection slots is shaped to have a discharge opening generally tangential to the inner surface of said inner shell fairing member.

7. The turbine as set forth in claim 5 wherein said housing means is a continuous annular member fixed to the outer surface of said inner shell fairing member to define a single chamber.

8. The turbine as set forth in claim 5 wherein said inner shell is arranged to define an annular passageway disposed in a plane generally transverse to the axis of said rotor and adjacent the leading edges of the last stage turbine blades; and wherein said opening communicates between said passageway and said chamber.

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