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(71) Applicant: **General Electric Company**
Schenectady, New York 12345 (US)

(72) Inventors:
- **Ansari, Asif Iqbal**
  560066 Bangalore, Karnataka (IN)
- **John, Joshy**
  560066 Banagalore, Karnataka (IN)
- **Subramaniyan, Moorthi**
  560066 Bangalore, Karnataka (IN)
- **Valliappan, Lakshmanan**
  560066 Bangalore, Karnataka (IN)

(74) Representative: **Cleary, Fidelma**
GPO Europe
GE International Inc.
The Ark
201 Talgarth Road
Hammersmith
London W6 8BJ (GB)

(54) **Turbine vibration reduction system**

(57) A turbine vibration reduction system (10) includes a nozzle (14), a bucket (18) in operable communication with the nozzle (14), and a structure (16) having at least one opening (22) configured to inject fluid into flow traveling past the nozzle (14) and the bucket (18) to disrupt formation of a vortex.

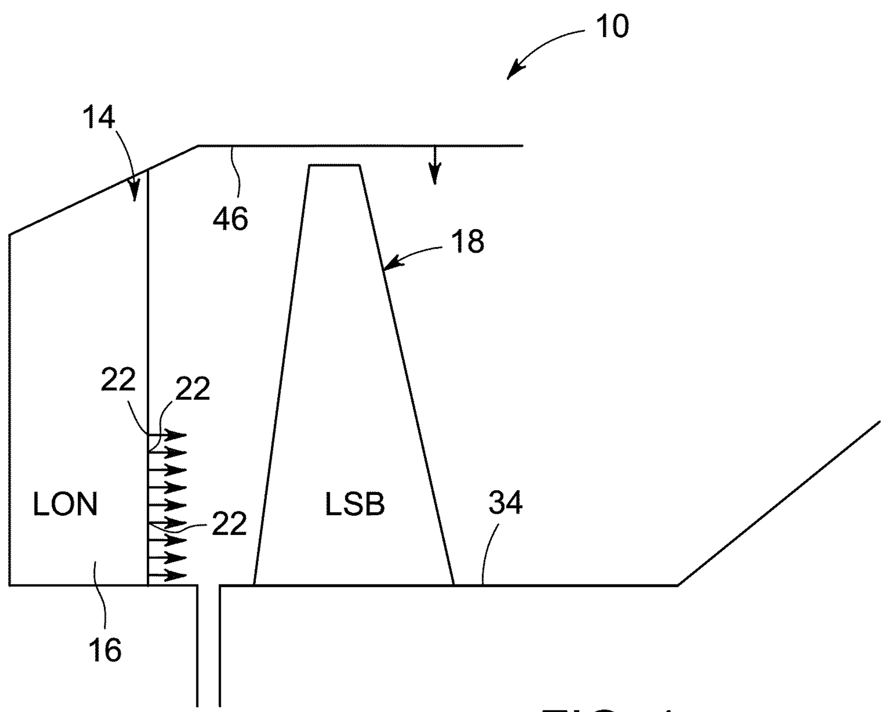

FIG. 1

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Description

[0001] The subject matter disclosed herein relates generally to turbines and more particularly to systems for reduction of vibration thereof.

[0002] According to one aspect of the invention, a turbine vibration reduction system includes a nozzle, a bucket in operable communication with the nozzle, and a structure having at least one opening configured to inject fluid into flow traveling past the nozzle and the bucket to disrupt formation of a vortex.

[0003] According to another aspect of the invention, a turbine vibration reduction system includes, a nozzle, a last stage bucket in operable communication with the nozzle and a casing surrounding the last stage bucket having an opening therein located downstream of the last stage bucket that is configured to inject fluid into flow having passed the last stage bucket to disrupt formation of a vortex in the fluid during operational conditions of the turbine conducive to vortex formation. These and other advantages and features will become more apparent from the following description taken in conjunction with the drawings.

[0004] The subject matter, which is regarded as the invention, is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 depicts a portion of a side view of an embodiment of a turbine vibration reduction system disclosed herein;

FIG. 2 depicts a view of a bucket from a computational fluid dynamic model showing a vortex;

FIG. 3 depicts a portion of a nozzle and bucket with a line depicting location of formation of a vortex;

FIG. 4 depicts a portion of a side view of an alternate embodiment of a turbine vibration reduction system disclosed herein; and

FIG. 5 depicts a portion of a side view of another alternate embodiment of a turbine vibration reduction system disclosed herein.

[0005] The detailed description explains embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

[0006] Referring to Figure 1 a turbine vibration reduction system is illustrated at 10. The system 10 includes, a nozzle 14, a bucket 18 in operable communication with the nozzle 14, and a structure 16 having at least one opening 22 configured to inject fluid into fluid flow traveling past the nozzle 14 and the bucket 18. This embodiment employs steam as the fluid.

[0007] Referring to Figures 2 and 3, in embodiments disclosed herein the injection of steam disrupts flow separation near the buckets 18. This flow separation has been modeled with computational fluid dynamics and is shown herein as a vortex 30 that initiates near a hub 34 and grows radially outwardly along a line 38 shown in Figure 3. This flow separation tends to form during full-speed no-load operation and particularly in combination with high condenser pressure. The flow separation imparts an unsteady aerodynamic force, or random vibration (non-synchronous vibration) on the bucket, commonly a L-0 (or last stage) bucket. Embodiments disclosed herein disclose systems to inject steam that disrupt formation of the vortex 30 (and flow separation) thereby reducing vibration. Embodiments of the system disclosed herein are further configured to inject steam specifically during operational conditions of the turbine that are conducive to formation of the vortex.

[0008] Referring again to Figure 1, the at least one opening 22, through which steam is injected in this embodiment, is a plurality of openings 22 formed in a plurality of the nozzles 14. The nozzles 14 define the structure 16 in this embodiment. The openings 22 may be on the trailing edge of the nozzles 14 and oriented to align steam ejected therefrom in alignment with fluid flowing there past. The openings 22 may be holes with diameters in the range of 0.1 to 0.2 inches. It may be preferable to position the openings 22 toward the inner radial portion of the nozzles 14, for example on a half of each nozzle 14 that is nearer to the hub 34 than a casing 46, and to have the openings 22 equally spaced. Mass flow rates of about 10.0 pounds per second at pressures of about 1.5 pounds per square inch from the openings 22 in the nozzle 14 have been found sufficient to disrupt flow separation.

[0009] Referring to Figure 4 an alternate embodiment of a turbine vibration reduction system disclose herein is illustrated a 110. The system 110 differs from the system 10 in the location of at least one opening 122 through which steam is injected. In this embodiment in a hub 134 defines the structure 16 and the at least one opening(s) 122 are located in the hub 134 between a nozzle 114 and the bucket 18. The opening(s) 122 can have different configurations, for example, an axisymmetric slot (as illustrated in the Figure) or a plurality of holes formed in the hub 134. Both slots of about 0.15 inches or 200-240 holes with diameters of about 0.15 inches have been found to work well. Orienting the opening(s) 122 at an angle of 25-45 degrees relative to an axis of the hub 134 preferentially aligns the steam being injected to disrupt formation of the vortex 30. Mass flow rates of about 3.0 pounds per second at pressures of about 1.0 pounds per square inch from the opening(s) 122 in the hub 134 are adequate to disrupt flow separation.

[0010] Referring to Figure 5 another alternate embodiment of a turbine vibration reduction system disclosed herein is illustrated at 210. The system 210 differs from the systems 10 and 110 in the location of at least one opening 222 through which steam can be injected. In this embodiment a casing 224 defines the structure 16 and the at least one opening 222 is located in the casing 224 downstream (as defined by flow through the turbine vibration reduction system 210) of the bucket 18. In this embodiment the opening(s) 222 is positioned about 2.0 inches downstream of the bucket 18. The opening(s) 222 can be an axisymmetrical slot with a width of about 0.5 inches formed circumferentially in the casing 224 or a plurality of separate holes (about 200-240) distributed circumferentially about the casing 224 having diameters of about 0.5 inches. Orienting the opening(s) 222 at an angle of about 45 degrees relative to an axis of the hub 134 toward the bucket 18 preferentially aligns the steam being injected to disrupt formation of the vortex 30. Mass flow rates of about 10.0 pounds per second at pressures of about 1.5 pounds per square inch from the opening(s) 222 in the casing 224 are adequate to disrupt flow separation

[0011] It should be noted that although the embodiments illustrated in the Figures herein each have only one of the separate opening(s) 22, 122 and 222, alternate embodiments are contemplated that have a combination of one or more of the separate opening(s) 22, 122 and 222 within a single turbine vibration reduction system.

[0012] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

Claims

1. A turbine vibration reduction system (10), comprising:

   a nozzle (14);
   a bucket (18) in operable communication with the nozzle (14); and
   a structure (16) near the bucket (18) having at least one opening (22) configured to inject fluid into flow traveling past the nozzle (14) and the bucket (18) to disrupt formation of a vortex (30).

2. The turbine vibration reduction system of claim 1, wherein the at least one opening (22) is on a portion of the structure (16) between the nozzle (14) and the bucket (18).

3. The turbine vibration reduction system of claim 1 or 2, wherein the bucket (18) is a last stage bucket.

4. The turbine vibration reduction system of any of claims 1 to 3, wherein the structure (16) is the nozzle (14).

5. The turbine vibration reduction system of claim 4, wherein the at least one opening (22) is at a trailing edge of the nozzle (14).

6. The turbine vibration reduction system of claim 4, wherein the at least one opening (22) is located on an inner radial half of the nozzle (14).

7. The turbine vibration reduction system of any of claims 4 to 6, wherein the at least one opening (22) is a hole with diameter about 0.15 inches.

8. The turbine vibration reduction system of any of claims 4 to 7, wherein the at least one opening (22) is a plurality of openings (22) that are equally spaced on the nozzle (14).

9. The turbine vibration reduction system of claim 8 wherein the plurality of openings (22) are oriented to inject steam in alignment with the flow.

10. The turbine vibration reduction system of any of claims 4 to 9, wherein the at least one opening (22) is configured to inject about 10 pounds per second of steam at about 1.0 pounds per square inch.

11. The turbine vibration reduction system of any of claims 1 to 3, wherein the structure (16) is one of a hub (134) or a casing (224).

12. The turbine vibration reduction system of claim 11, wherein the at least one opening is a plurality of openings or holes distributed circumferentially around the hub (134) or the casing (224).

13. The turbine vibration reduction system of claim 11 or 12, wherein the structure (10) is a hub (134) and the at least one opening (22) is angled to inject steam at an angle of about 25-45 degrees relative to an axis of the hub (234).

14. The turbine vibration reduction system of claim 11 or 12, wherein the structure is a casing (224) and wherein the at least one opening (222) is located in a portion of the casing (224) that is downstream of the bucket (18).

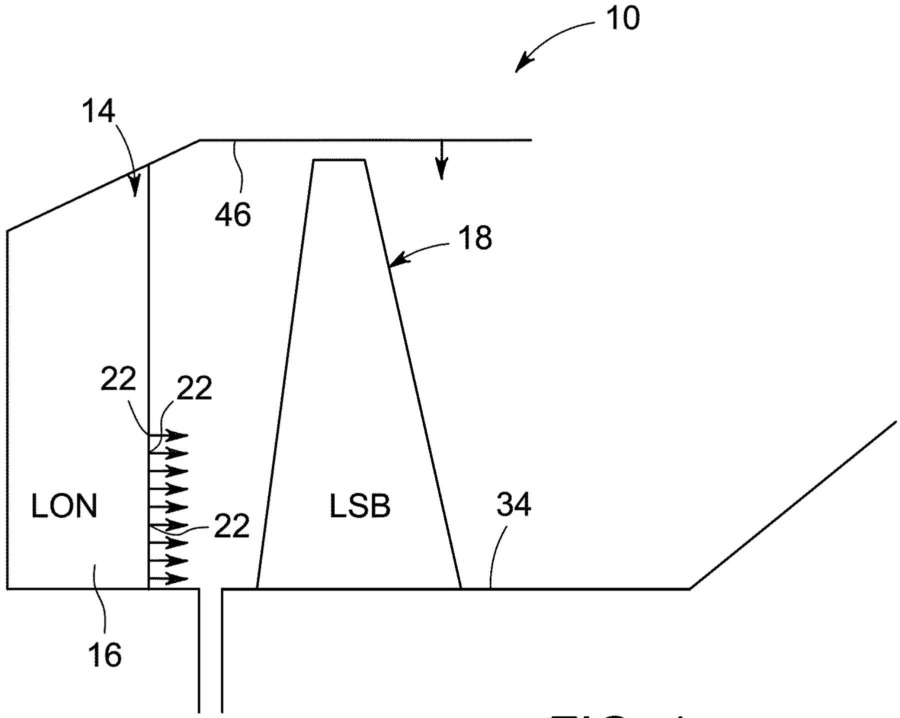

FIG. 1

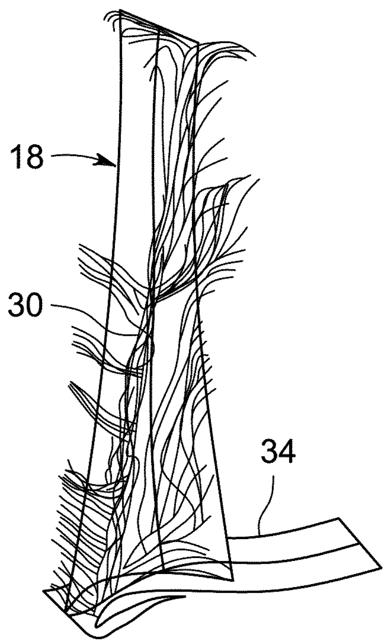

FIG. 2

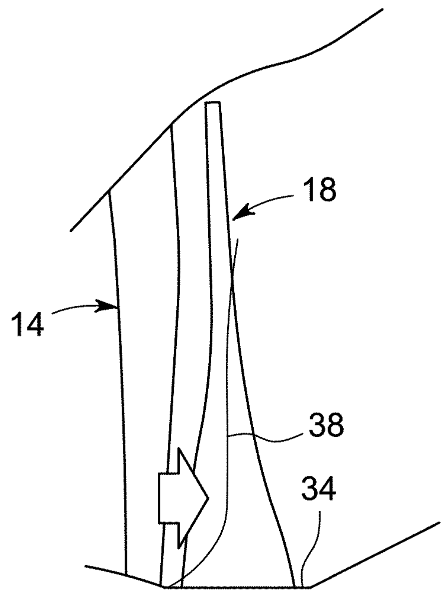

FIG. 3

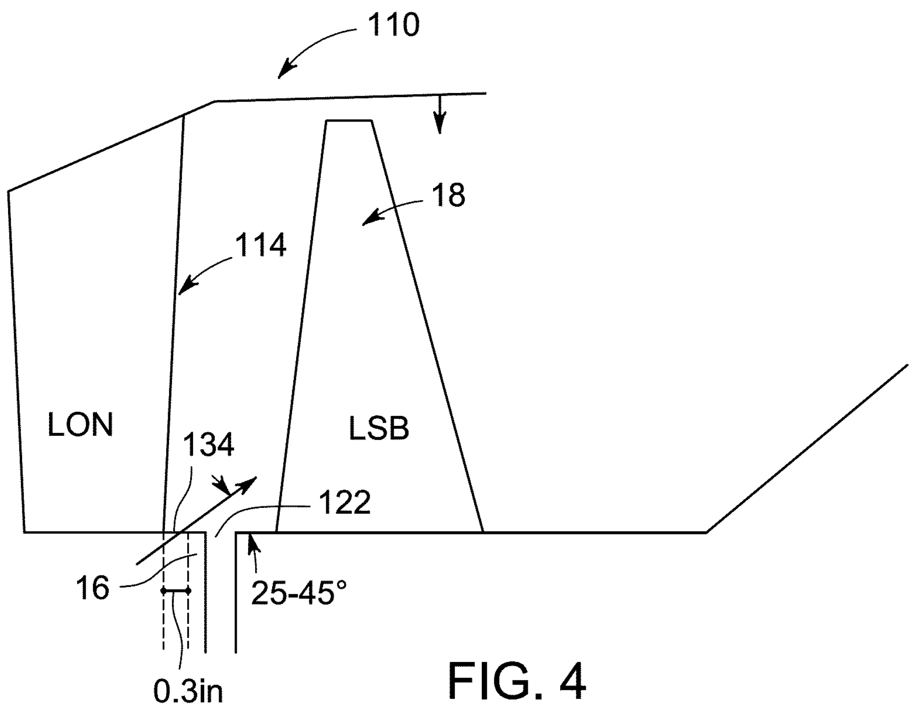
110
18
114
LON
LSB
134
122
16
25-45°
0.3in

FIG. 4

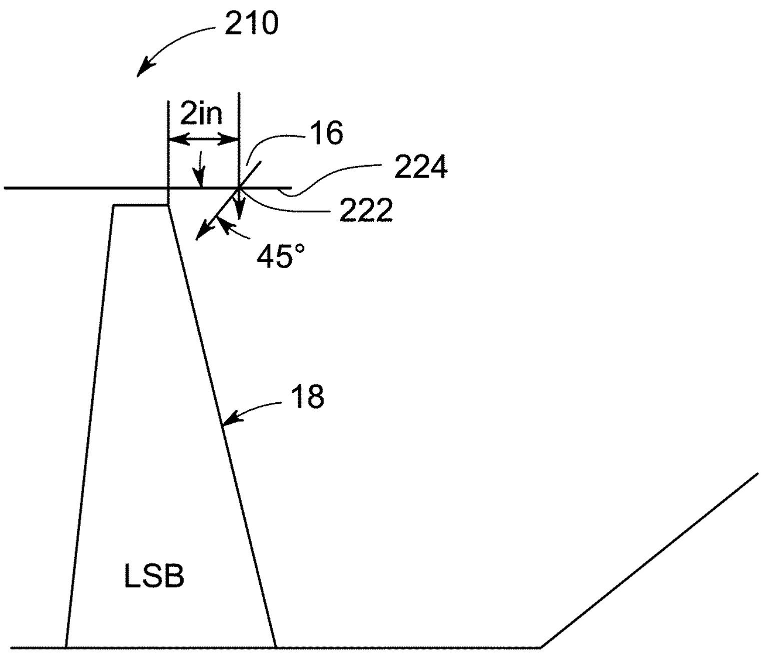
210
2in
16
224
222
45°
18
LSB

FIG. 5