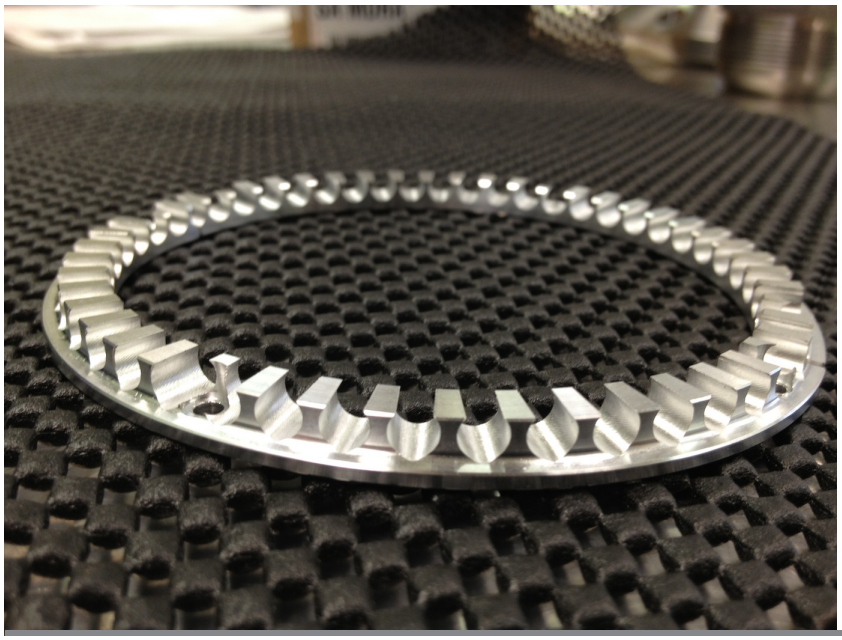


National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Mechanical and Fluid Systems

Reverse Vortex Ring (RVR)

For Dramatic Improvements in Turbomachinery Rotordynamic Stability

Innovators at the Marshall Space Flight Center (MSFC) have developed a mechanism for improving rotordynamic stability and response in turbomachinery. The Reverse Vortex Ring (RVR) invention was created specifically to solve instability problems with turbopumps on the Space Shuttle main engine, which has been a persistent problem for NASA engineers since the 1970s.

With the advent of rotating machinery, high-speed rotors have been of interest to engineers. Rotating machinery has been employed in a wide range of applications in the past century, ranging from steam turbines for electric power generation to the turbo pumps used in the Space Shuttle Main Engines. As these machines have become more commonplace, there has been an increased demand for lightweight, compact designs. The required power output of these units has also increased leading to ever high power to weight ratios. These leaner designs are the hallmark of the aerospace industry.

BENEFITS

- Improved system design: allows turbopumps and similar devices to be made smaller, lighter, faster and safer.
- Offers significant improvements over the state of the art: RVR creates a zero whirl frequency ratio, while commercially-available solutions, like swirl brakes, can only reduce the whirl frequency ratio by up to 30%.
- Enables more stable, and more effective turbomachinery: RVR eliminates destabilizing rotor dynamic forces in turbomachinery and can even create a negative whirl frequency ratio, thus, increasing stability and dramatically increasing the allowable speed.
- Features a small footprint: The invention takes up very little axial real estate, which is a precious commodity in turbomachinery: about 12% of the length of the seal.

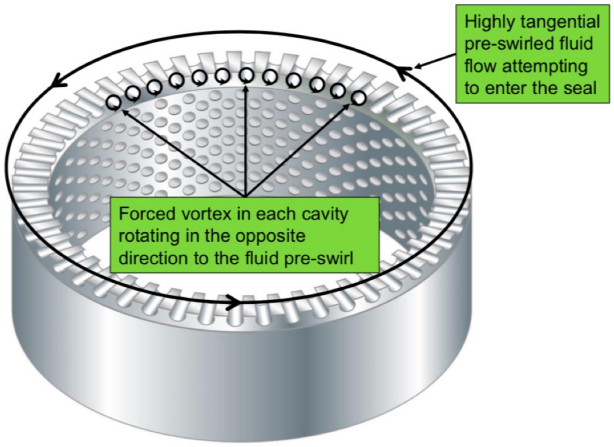
THE TECHNOLOGY

Vibration problems, which occur more frequently in high power to weight machines, often lead to costly down time, subsequent redesign, and, in some instances, catastrophic failure. A disproportionate number of vibration problems in rotating machinery can be attributed to highly pre-swirled fluid entering tight clearance locations such as seals and fluid bearings. The relationship between high fluid pre-swirl and undesirable vibration issues is clear. Machines with high levels of fluid pre-swirl are more susceptible to instabilities and vibration problems.

A top priority in rotor dynamic design, therefore, is to develop devices to minimize the level of fluid pre-swirl entering tight clearance locations. The RVR was designed to condition the flow prior to entering the seal (or axial flow fluid-film bearing) so that the flow through the annular clearance is at a minimum purely axial. While conventional swirl brakes have only been shown to reduce pre-swirl by up to 30%, the RVR can actually reverse the direction of the swirl, so that circumferential fluid velocity flows in a direction counter to shaft rotation. Thus, a classic detriment to rotating machinery has now become an asset to ameliorate vibration issues through the RVR.

The RVR is axially efficient, typically increasing the axial length of a smooth annular seal on the order of 10-12%.

The RVR has been extensively tested and is now in use at NASA.



The RVR is shown above attached to a damping seal. The RVR converts the destabilizing pre-swirled flow into a stabilizing flow in the opposite direction.

APPLICATIONS

The technology has several potential applications:

- Turbomachinery
- Super pressurized turbines
- Boiler feedwater pumps
- Turbopumps
- Labyrinth and annular seals
- Petroleum industry
- Power generation

PUBLICATIONS

Patent No: 10,753,226

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