Flexware®
Turbomachinery Engineers
A Veteran & Employee Owned Small Business

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Wearing In PEEK Seals

Due to the pressure rise across successive compression stages, seals are required at the impeller eye and rotor shaft to prevent gas backflow from the discharge to the inlet end of the compressor. The effectiveness of these seals therefore directly affects the compressor efficiency.

The simplest and most economical of all shaft seals is the straight labyrinth shown in Figures 1 & 2. This seal is commonly utilized between compression stages and consists of a series of thin strips or fins, which are normally part of a stationary assembly mounted in the diaphrams.

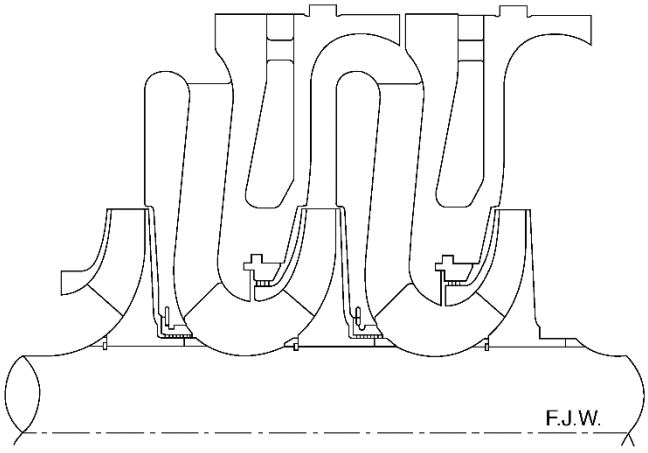


Figure 1. Seals are required at the impeller eye and rotor shaft to prevent gas backflow from the discharge to the inlet end of a compressor stage.

Calculations and field performance have demonstrated that wiped interstage seals can decrease unit efficiency by 7% or more. Operating modes that contribute to labyrinth damage include surging, passing through the critical speed and liquid ingestion.

Typically, over the years the labyrinth seal has been made from soft aluminum because in the event of a rub, it will deform and not cause excessive rotor vibration when this occurs. A hard rub can cause rotor whirl and the rotor can self-destruct from a rub on a material that will not deform. For example, because the aluminum seals did not last due to excessive corrosion, a user made labyrinth seals from cast iron. During an excursion through the critical, the rotor touched the labyrinths and initiated a rotor whirl condition so severe the bearing housings dropped off the compressor body.

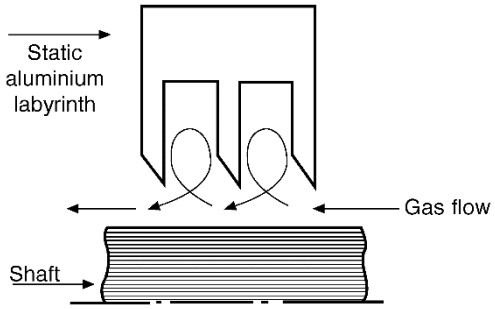
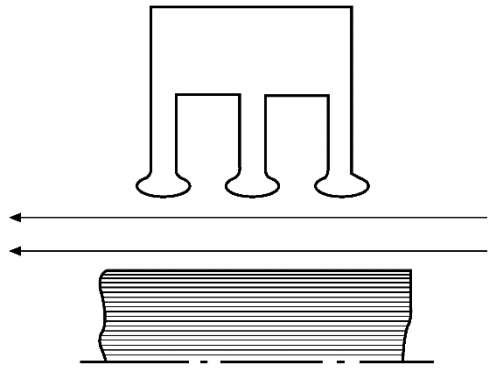


Figure 2. Aluminum labyrinth seal. New and clean. Tight clearance and turbulence creates resistance to leakage flow.

A labyrinth seal works by acting as a series of restrictions, like a series of orifices. Turbulence between the teeth cause resistance in addition to the restriction itself.



Firgue 3. Aluminum seals after a rub. The tips of the teeth mushroom, minimizing the turbulence between the teeth. This mushrooming along with the increased clearance means makes for a much larger flow through the seal and thus much lower efficiency for the compressor.

Following a rub, the tips of the aluminum labyrinths are mushroomed and limit the turbulence between the teeth. Leakage is then increased due to the increased leakage but also due to the reduced turbulence between the teeth.

Of course, the size of the restriction (radial clearance) is directly related to the amount of leakage through the seal. Increasing the clearance of the seal will increase the flow, thus reducing the efficiency of the compressor.

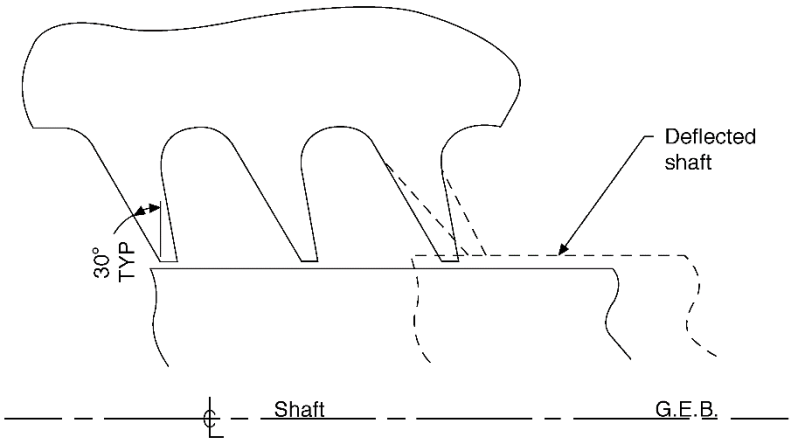


Figure 4. Rub tolerant seal made from PEEK (or Torlon).

Rub tolerant seals are thermo plastic seals designed to flex when touched by the rotor, thus reduced clearances are possible. PEEK and Torlon are the most common and have been used for over 30 years but are not all that common in new machinery due to the expense and difficulty of machining. However, they are excellent for replacement parts as they can be designed to fit the existing cavity. No changes to anything else is typically needed.

For a very brief rub, the PEEK material will act as a bearing and deflect. For a sustained rub, the PEEK material will locally overheat and soften and deform or even melt opening up the clearances to an amount that can be sustained. PEEK is not a good conductor of heat, thus the heat generated by a rub is local and does not affect the bulk of the material, just very locally at the rub point. For these reasons the rub tolerant seals are far superior to the aluminum seals and can be assembled with very tight clearances

It is important that the PEEK seal is well supported especially in the radial position by the stationary metal component so the seal can take some abuse from the rotating element and "wear in" as necessary.

A simple test can be conducted by using a piece of scrap PEEK Labyrinth and briefly holding the tip of the teeth against a rotating element (smooth drill shank, smooth object in a lathe, etc.) and observing the behavior of the material at the tooth tips.

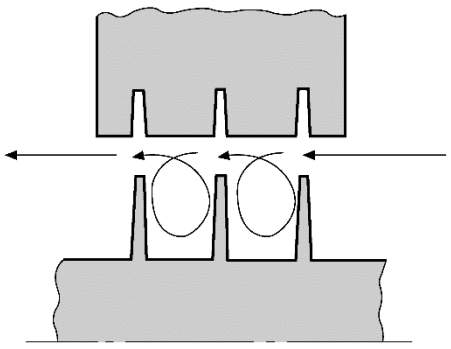


Figure 5. Abradable seal. Note the labyrinth teeth are on the rotating member and the abradable material is the stationary piece.

Typically, today OEMs use abradable seals to obtain tight operating clearances and improved efficiency.

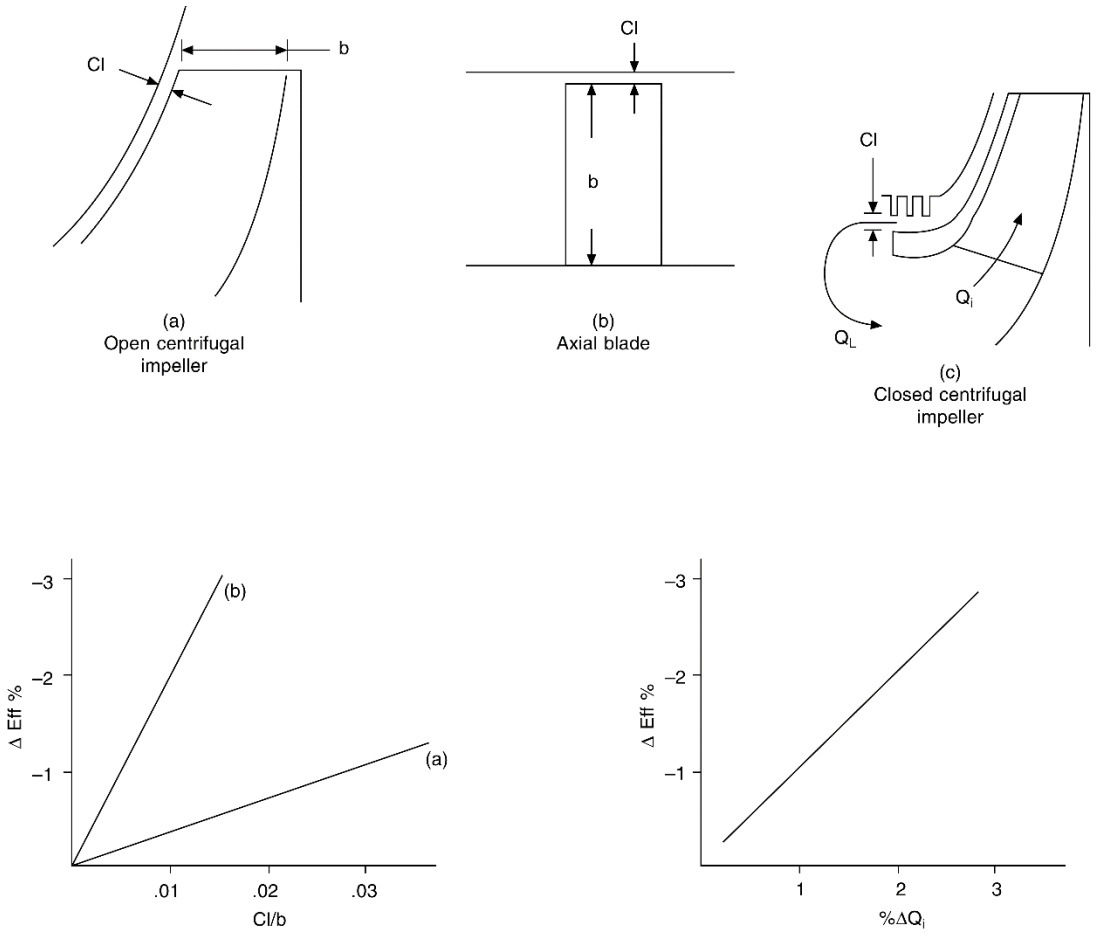


Figure 6. Effect of efficiency vs. clearance for various designs. (a) For an open centrifugal impeller, the efficiency loss is only one-third of a point for each percent of tip clearance ratio at the impeller outer diameter. (b) For an axial compressor blade the efficiency loss is about two percentage points for each percent of tip clearance ratio. This is also true for the throat region of an open centrifugal impeller. (c) For a closed centrifugal impeller, the efficiency loss is about one percentage point for each percent increase in Q_i (as a result of Q_L increasing and inlet flow to the compressor constant).

Compressor efficiency among many other things is directly dependent on the impeller eye clearance, Cl. So, every bit of reduction in clearance helps. But we don't want to go too tight with aluminum seals as they might rub and mushroom, thus eliminating the effect of the reduced clearances.

With the PEEK seals we can reduce the clearances to a bare minimum. The limiting factor is the ability to assemble the machine and maintain concentricity. A few mils above the bearing clearances is usually sufficient.

Ted Gresh
30-Jul-19

Ref: "Compressor Performance: Aerodynamics for the User" Third Edition, M. T. Gresh, 2018

Bio:

M. Theodore Gresh is president of Flexware, Inc., Grapeville, PA, United States. He has been involved in the design of high-efficiency centrifugal compressor staging, field testing of compressors, gas turbines and steam turbines, troubleshooting various field problems, including performance problems, rotor dynamic issues, impeller failures and seal problems for over 45 years. Mr. Gresh is author of "Compressor Performance: Aerodynamics for the User" now in it's third edition, a reference book for compressor design and maintenance trusted by rotating equipment engineers worldwide for over 25 years.