About Open Rotor Machines

The PROTEUSS project is motivated by the open rotor aero engine. All modern aero engines have some air that passes around the outside of the engine. That's called bypass air; some air passes through the core of the engine. Most of the propulsion from the engine comes from the bypass air with an open rotor engine. The bypass air is pushed backwards by two different sets of blades, rotating in the opposite directions to each other and not surrounded by a duct as most existing aero-engines have.

One of the advantages of having two different sets of blades rotating in opposite directions is that you can throw the air behind the engine without any swirl left in that air. Swirl left in the air is not helpful for propelling the craft forward. If you only use a single set of blades, you tend to have a little bit of swirl left in the air behind the engine, so the open rotor engine is one way to achieve a higher propulsion efficiency. The PROTEUSS project is setting out to solve one of the very detailed technical challenges that exist in implementing an open rotor engine.

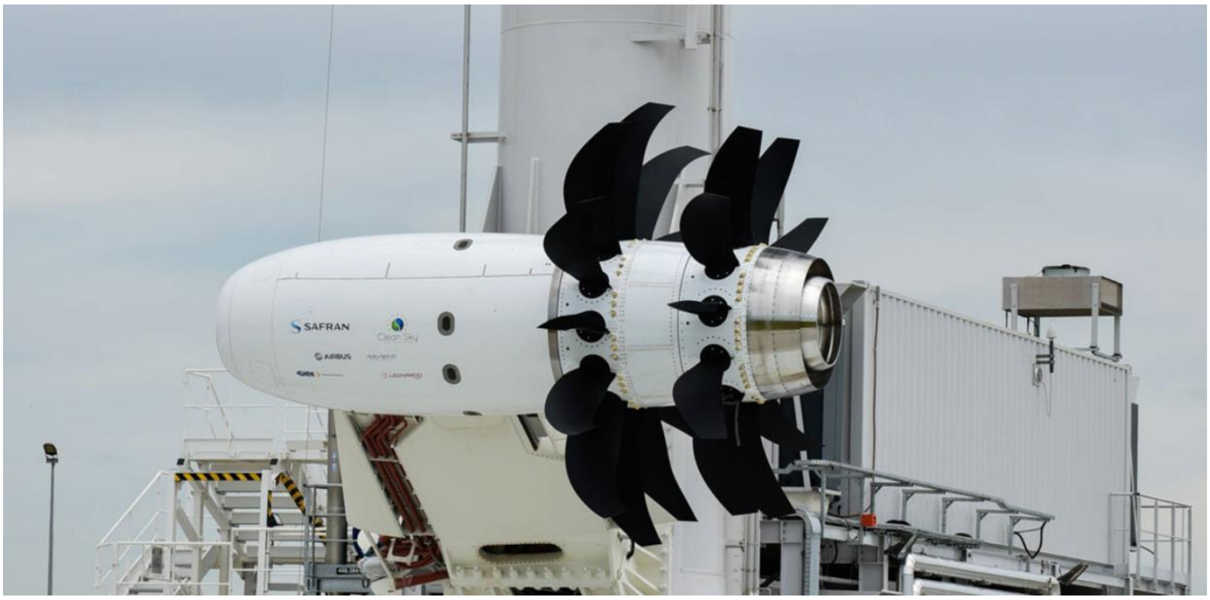

Figure 1: Reference https://www.ainonline.com/aviation-news/air-transport/2017-10-04/safran-inaugurates-open-rotor-test-program

About Controlling the Pitch of the Rotor Blades

For best efficiency, an open rotor engine will have the ability to control the pitch of the blades on at least one of the rotors or, optimally, both. “Pitch” is the angle of the blades relative to the hub onto which those blades are mounted. There are two stages of blades on an open rotor engine. Each stage has a hub with a number of blades sticking out of it, likely around seven to ten blades.

The angle of the blade relative to the hub is called the pitch angle. For good efficiency, we want to be able to change the pitch of the blades. If the engine was always operating in a single operating condition, it would not be necessary to change the pitch. You would leave the pitch fixed all the time. However, a real the engine goes through a number of different duty conditions. For example, take off conditions are very different from cruise conditions, which in turn are very different from landing ones. As such, it is important to be able to change the pitch of the blades in order to get best efficiency from the engine. There are many different ways of changing the pitch and controlling the pitch, but one of those ways is to control the oil pressure that occurs inside the rotating part. The PROTEUSS project is all about using oil pressure to control the pitch of the blades using oil transfer bearings on the rotors of the open rotor engine.

About the Challenges for an Oil Transfer Bearing

The oil transfer bearing (OTB) presents a very particular set of challenges. An oil transfer bearing is a way to communicate pressure in an oil supply from the stationary part of an engine into the rotating part of the engine. In other areas of engineering, this might be called a rotating union. There are other contexts in engineering where oil is transferred from a stationary part into a rotating part and most often, those applications are involved, transmitting hydraulic power from the stationary frame into the rotating frame in our context.

For an OTB, it is not really power that we want to transmit. We are expecting quite small flow rates of oil. It's really pressure that we are expecting to transmit from the stationary frame into the rotating frame. It's controlling the pressure that enables us to control the pitch of the blades on the rotating parts of the open rotor engine.

The main requirement, and biggest challenge, for an OTB is reliability. We absolutely must not cause the engine to go into an unsafe condition. If, for any reason, there was to be a failure of some sort it must be a safe failure. It does not matter too much if the efficiency of the engine drops for one part of one flight - but the engine must still be safe to operate at all times. As such, the OTB must continue to be able to communicate oil pressure from the stationary part of the engine onto the rotating part.

We'd like the OTB not to leak at all, but we know it will have some leakage. All efforts to transmit oil from a stationary part onto a rotating part will have some leakage rate associated with them. That leakage rate will have an associated power loss and, of course, we don't like power loss for a number of different reasons. Firstly, it’s inefficient and secondly, it causes heating in the oil. The oil then needs to be removed to cool it back down again So we don't like the fact that any oil could leak from the OTB. Realistically we know some oil will leak but a first requirement on the OTB is that the leakage should be very small.

A further requirement is that there should not be a significant pressure drop across the OTB when we have relatively small flow rates of oil between the stationary part and the rotating part (the OTB has to fit inside a space envelope). That flow is quite small under normal conditions. The OTB also has to be able to work even though the rotor will vibrate. We know that you can never make a mechanically perfect rotor. The rotor will move from side to side for a combination of reasons; some of those reasons have to do with unbalance on the rotor and other ones might have to do with geometric errors in the rotor and in the bearings. Differential thermal expansion can also account for some vibrations. Whatever the reasons, there will be some vibration and the oil transfer bearing must continue to work even though the rotor centreline is moving.