Rotor modeling at low temperature for NMR

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Introduction: Two laboratories of CEA, SBT and SCIB, are developing a novel technique of NMR taking advantage of low temperature. A cold (down to 10K) rotating (up to 30 kHz) rotor allows for quicker and more precise spectrum.

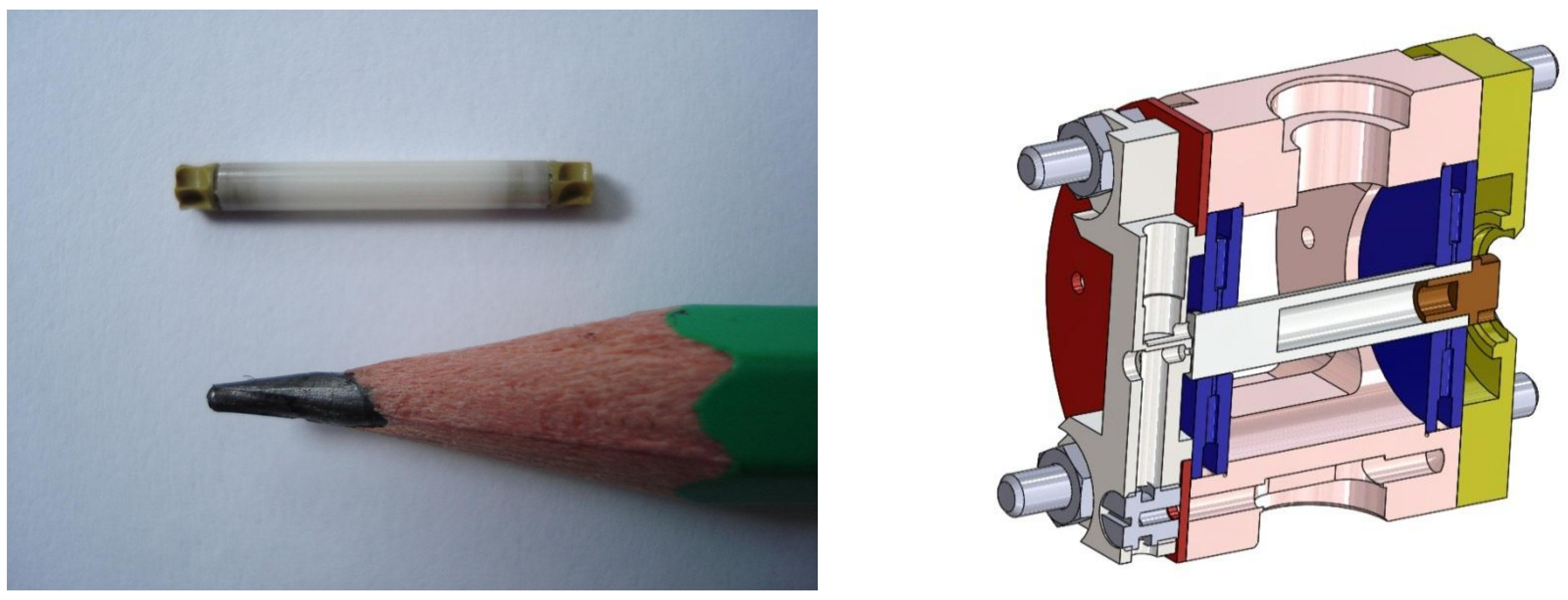

Figure 1. MNR rotor (left); a view of its chamber (right)

The rotor is maintained in its chamber by two aerostatic bearings (two Helium mass flow)

Computational Methods: two "Thin-Film Flow" interfaces have been used. The geometry is shown in **figure 2, left**.

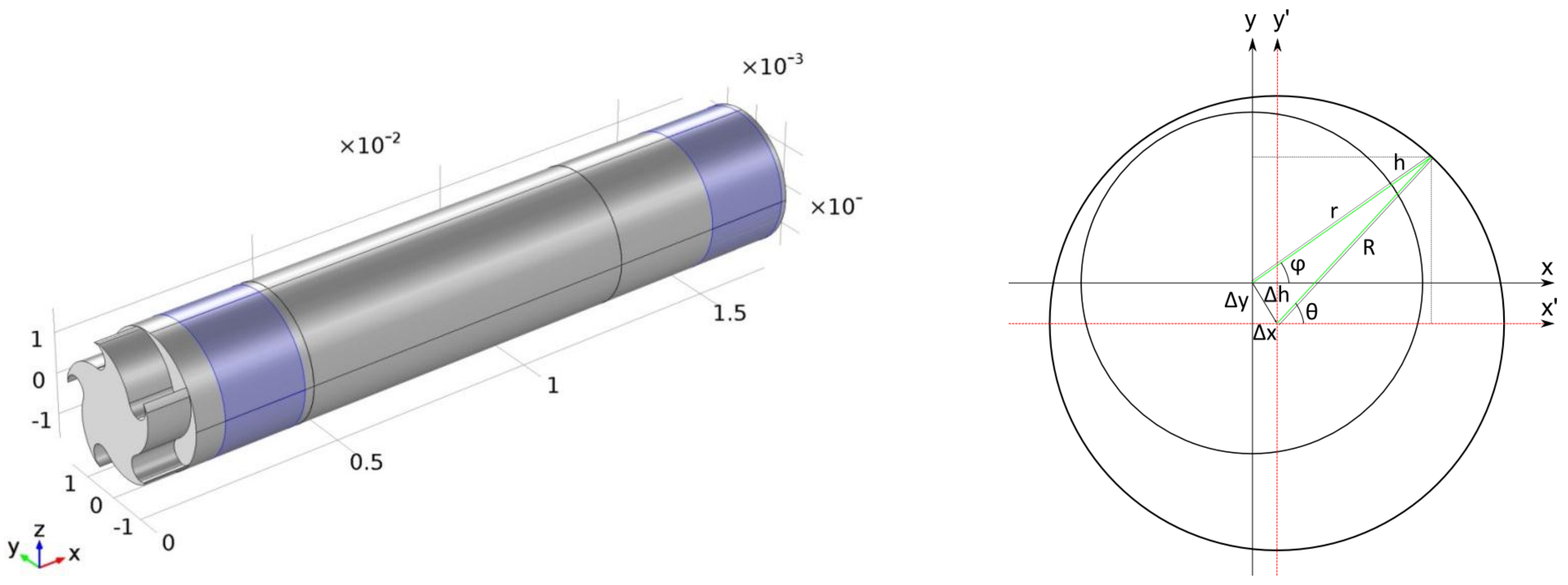

Figure 2. left : Modeled rotor. In blue, the aerostatic bearings. Right, the film thickness h and eccentricity

In addition, additional global equations has been use to calculate the film thickness (**figure 2, right, eq.1**) as

$$\begin{cases} \iint Fx_{fl\rightarrow p}\cdot dS = m\cdot \ddot{\Delta x} \\ \iint Fy_{fl\rightarrow p}\cdot dS = m\cdot \ddot{\Delta y} \end{cases}$$

Well as the interaction between the two bearings (**eq.2**).

$$\begin{cases} \frac{m}{2}\ddot{x}_b + \frac{m}{2}\ddot{x}_f + \iint F_b x_{fl\rightarrow p}\cdot dS + \iint F_f x_{fl\rightarrow p}\cdot dS = 0 \\ -\frac{I}{2\cdot L^2}\ddot{x}_b - -\frac{I}{2\cdot L^2}\ddot{x}_f - \iint F_b x_{fl\rightarrow p}\cdot dS + \iint F_f x_{fl\rightarrow p}\cdot dS = 0 \\ \frac{m}{2}\ddot{y}_b + \frac{m}{2}\ddot{y}_f + \iint F_b y_{fl\rightarrow p}\cdot dS + \iint F_f y_{fl\rightarrow p}\cdot dS = 0 \\ -\frac{I}{2\cdot L^2}\ddot{y}_b - -\frac{I}{2\cdot L^2}\ddot{y}_f - \iint F_b y_{fl\rightarrow p}\cdot dS + \iint F_f y_{fl\rightarrow p}\cdot dS = 0 \end{cases}$$

As the rotor is rotating, the resulting couette flow creates a parietal pressure and the precession of the rotor (**fig. 3**).

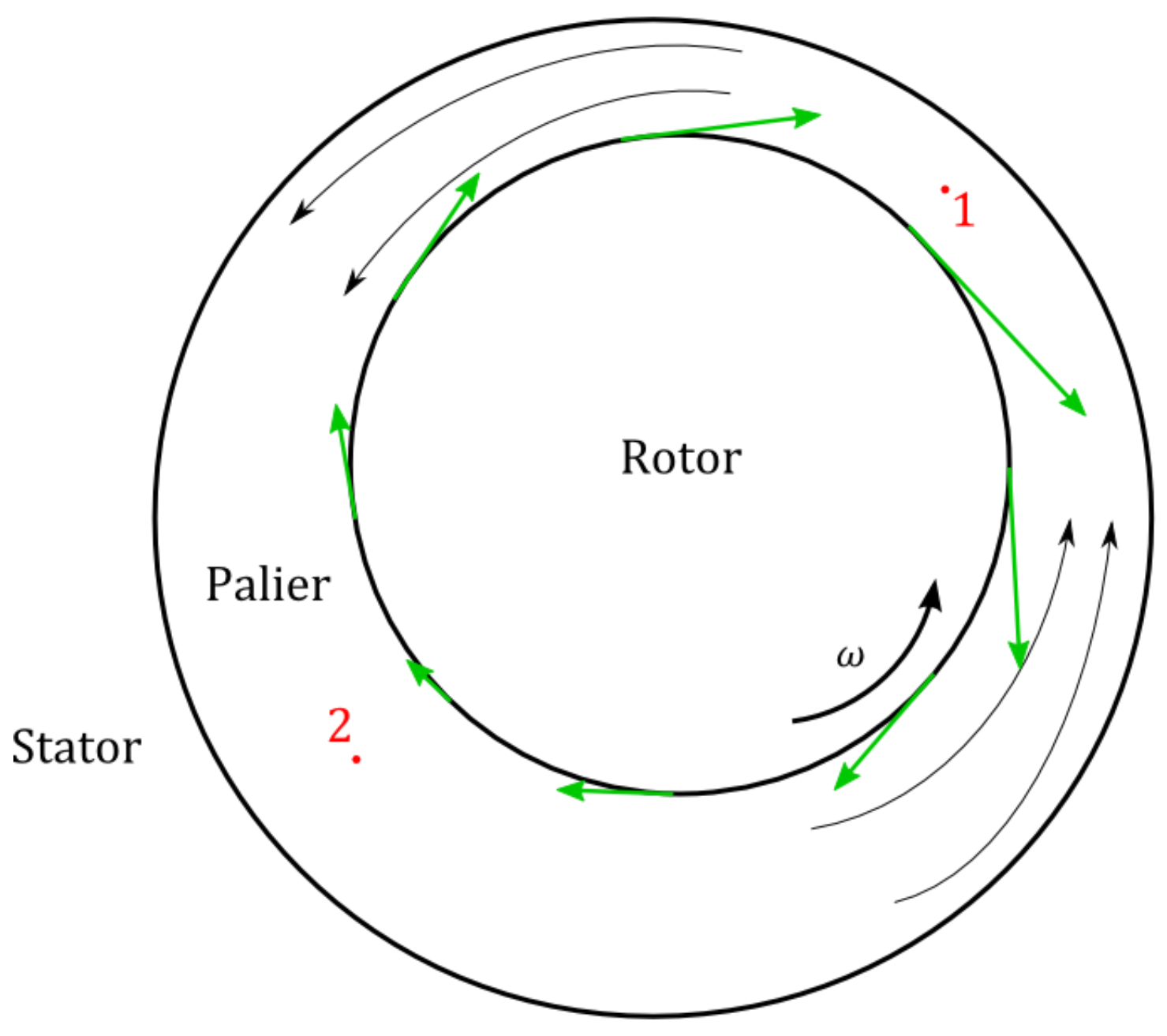

Figure 3. Couette flow and the parietal pressure (green)

Results: Both direct and cross bearings rigidities have been calculated as a function of the Helium mass flow. The results shows an optimum in the mass flow (**figure 4**).

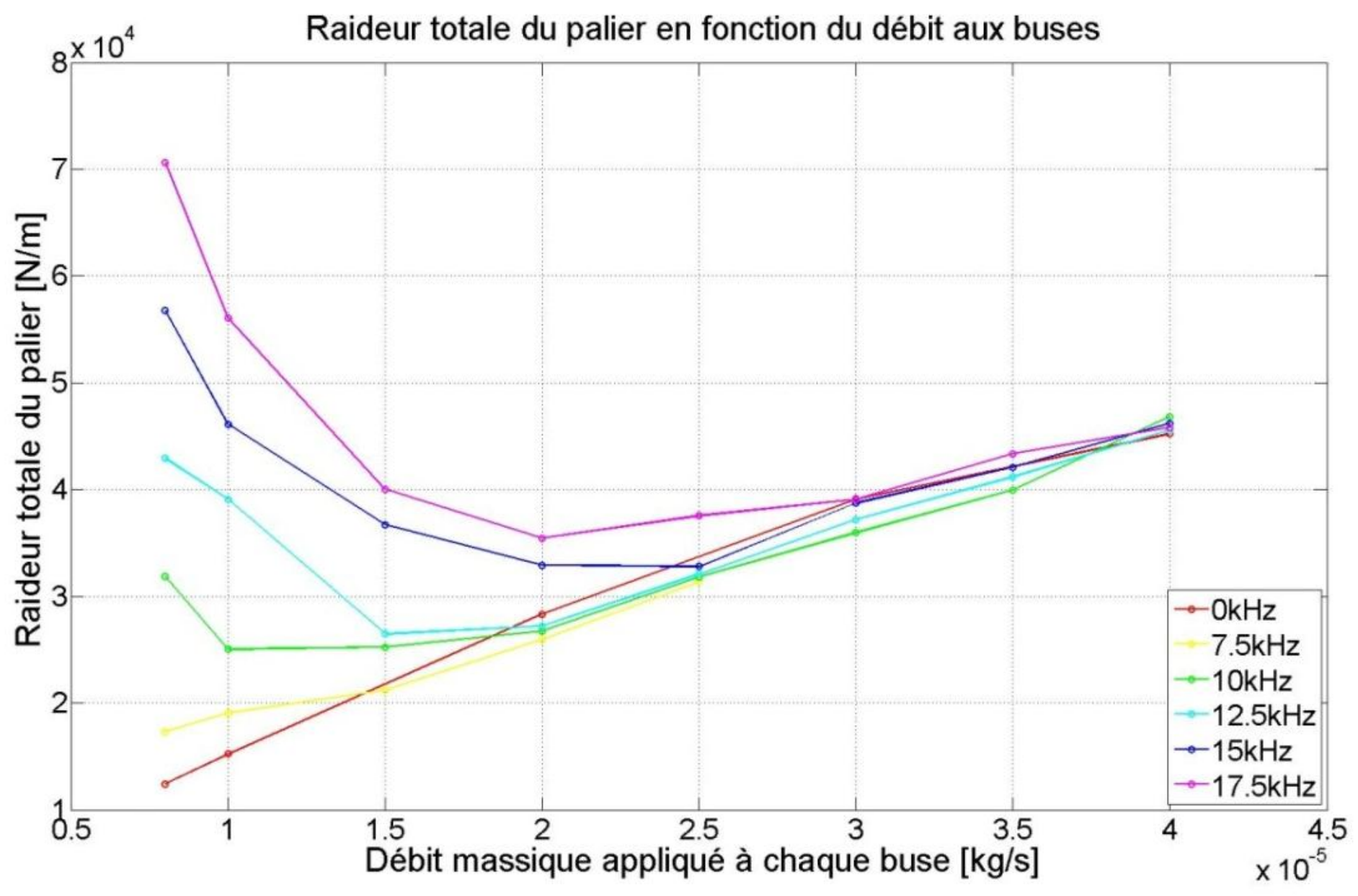

Figure 4. Bearings rigidity as a function of the Helium mass flow for different rotation frequencies

The precession radius as a function of the mass flow has also been calculated. It shows a mass flow optimum.

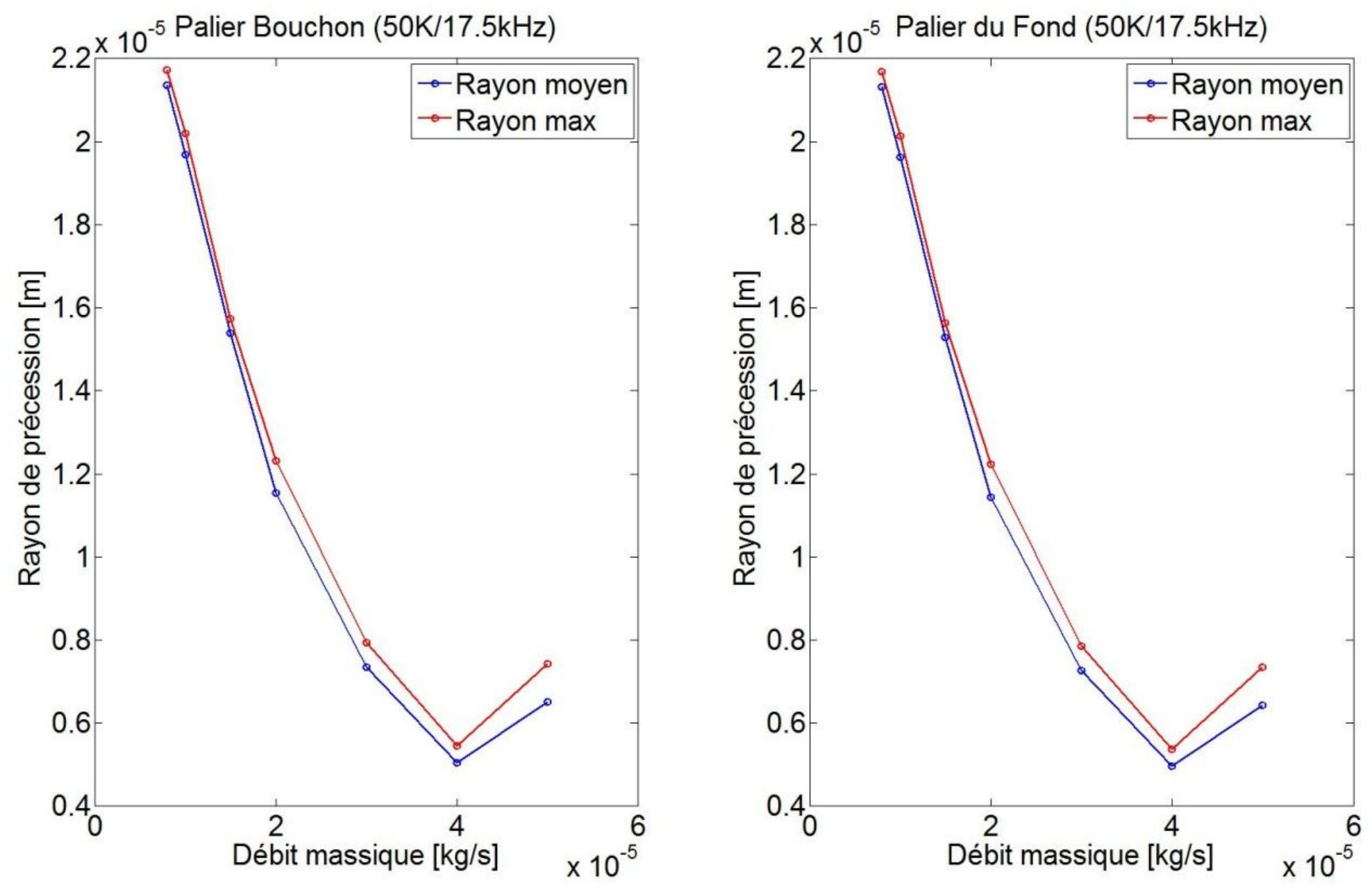

Figure 5. Precession radius as a function of rotor rotation frequency at different mass flow

Further developments:

* Viscous dissipation heating: taking into account the temperature variation

* Rotor rotation : study of the fluid/structure interaction of the rotation creation by an additional helium flow.

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