Reply to the comments of refree#1

The manuscript: Updating Thermal Head of Recoverable Autonomous Sonde (RECAS) for Better Drilling Performance in Qilin Subglacial Lake Exploration submitted by Li et al., reports on updates to an existing drilling instrument. The manuscript is well-written and generally easy to follow, also for a non-expert like me in this niche area. The English language is generally good, with only a few odd phrasings (that are still easy to understand).

The introduction is good and gives a nice overview of the field with adequate references for prior research. Obviously, this is an instrument paper with only a laboratory scale demonstration of the system, but the results presented are convincing. I have only some minor comments before I can recommend the manuscript is accepted.

Thanks for your fruitful comments. The manuscript has been carefully revised according to your suggestion.

Line 110: The manuscript would benefit from an improved description of the filters used to remove dust, i.e., what materials are used. Further is also not clear to me if the dust can risk clogging the filters or does the design make dust move into the internal cavity? The text states that dust is collected in this internal cavity. How big is this cavity and is there a risk of overfilling it during deep drilling? Please clarify this in the manuscript.

The filter is made of 400-mesh stainless steel wire screen, as described in Section 3.4.3 (near line 339).

In the design of the upgraded RCEAS thermal head, the dust was intended to be stored in the internal cavity, defined as the unused space within the outer tube that is not occupied by other components. The outer tube is a cylinder with an inner diameter of 160 mm and a length of 570 mm. Assuming that half of its internal volume is occupied by other components, the remaining cavity volume would theoretically be approximately 5727 cm^3. In polar ice sheets, the dust layer thickness is typically less than 20 mm. Given a borehole diameter of 220 mm, the volume of dust encountered would be about 757 cm^3. Therefore, filling the cavity to capacity would require the accumulation of seven ash layers—a condition that is rarely observed in polar ice sheets. Therefore, in our opinion, the overfilling of the internal cavity is almost impossible.

Nevertheless, a real risk of filter clogging exists. To reduce the likelihood of blockage, the contact area between the filter and water was enlarged through a double-layer design. As illustrated in Fig. S1, the two-layer stainless-steel wire screen provides approximately twice the contact area of a single layer. A total of five filters are employed.

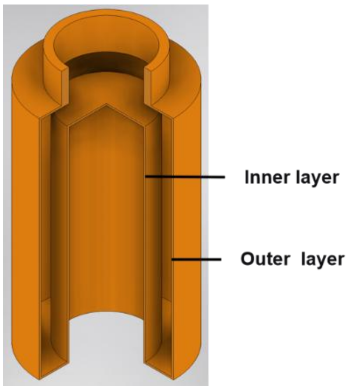

Figure S1 The structure of the filter

In the revised manuscript, the following sentences have been added to the section 3.4.3 to clarify the issue.

"*Nevertheless, a real risk of filter clogging does exist. To mitigate this, the contact area between the filter and the water was increased through a double-layer design. The two-layer screen provides approximately twice the contact area of a single layer.*"

"*In the future, other methods to prevent filter clogging, such as water flushing, should be explored*".

"*In the design of the upgraded RCEAS thermal head, dust is intended to accumulate in the internal cavity, defined as the void space within the outer tube after the installation of other components. The outer tube is cylindrical, with an inner diameter of 160 mm and a length of 570 mm. Assuming that half of this internal volume is occupied by other hardware, the theoretical cavity volume is approximately 5727 cm³. In polar ice sheets, dust-laden layers are typically less than 20 mm thick. With a borehole diameter of 220 mm, the corresponding dust volume would be less than 757 cm³. Consequently, overfilling the cavity would necessitate the accumulation of eight such layers, which is uncommon in polar ice sheets.*"

Line 113 (and also 409): "When drilling in dust-laden ice, the pump must be started". How will the operator of the system in field conditions in Antarctica know that a layer of dust has been reached? Please clarify in the manuscript.

The RECAS melt probe is equipped with built-in sensors that can measure the penetration rate in real time and transmit the data to the surface. When the operator observes a notable decrease in the rate, this indicates the likely presence of dust-loden or debris-rich ice, and the operator may then command the probe to activate the pump.

The following sentences are added to the revised manuscript.

"*In field applications, the RECAS probe is equipped with built-in sensors that measure the penetration rate in real time and transmit the data to the surface. When the operator observes a significant decrease in the penetration rate, it can be inferred that dust-laden or debris-rich ice is present. In this case, the operator can send a command to the RECAS melt probe to start the pump*".

Equation 7: Shouldn't the x have a double dot $\ddot{x}$ above to indicate second time derivative or a d2/dt2?

In the revised manuscript, the equation has been rewritten as follows to indicate the second time derivative of x.

$$m\frac{d^2x}{dt^2}=F_g+F_z \tag{7}$$

Equation 9: (similar to previous comment) Using a dot above z to indicate a unit vector is a little unusual notation as this is standard physics notation for a time derivative. I suggest using a hat $\hat{z} instead.

We acknowledge that it was an error to denote the unit vector in the z-direction as $\dot{\boldsymbol{z}}$, since this notation does not represent the time derivative of z. In the revised manuscript, we have replaced it with $\hat{\boldsymbol{z}}$. Additionally, the symbols I and S have now been clearly defined.

Line 152 and 187: I believe it is only necessary to mention "COMSOL Multiphysics 6.1" once.

In the revised manuscript, the phrase "COMSOL Multiphysics 6.1" has been deleted from line 152.

Page 16. There are several expressions on this page, e.g. equations 17 and 19 for lambda, but it is not obvious where these expressions originate. I suggest adding a reference or two.

The method for calculating the hydraulic friction coefficient λ is widely used in engineering and is readily available in textbooks. Accordingly, we have added the following fluid mechanics reference to the revised manuscript.

Reference

Zhang, Y. (Eds.): Fluid mechanics, (second edition), Higher Education Press, Beijing, China, 273-275 pp., ISBN 9787040072723, 1999. (Text in Chinese)

Line 305: There's only a very short sentence on the supply voltage here, but I did not see a description of any electronic subsystems. I would assume that the unit contains a number of these. If so, it would be appropriate to have a description of these (or reference to previous papers with a description of these).

The updated RECAS thermal head employs a heating control system similar to the previous one, as described in Yu et al. (2021). The voltage of the lower thermal head is regulated by a self-developed 800 VAC solid-state power regulator. It uses the cycle power regulation method, which controls the conduction of 50 sinusoidal half-cycles per second (at 50 Hz) with a 2% resolution, thereby adjusting the effective power applied to the cartridge heaters in the thermal head. Since the thermal head has good heat dissipation and high temperature tolerance, its power control is simply open-loop or proportional regulation, without the complex fuzzy PID closed-loop algorithm. During downward drilling, the lower thermal head can be set to full power or reduced power as required to satisfy different penetration rate needs.

In the revised manuscript, the following sentences have been added.

"*Similar to the previous design, the updated RECAS thermal head uses a self-developed 800 VAC solid-state regulator. This regulator employs cycle power regulation, controlling the conduction of 50 sinusoidal half-cycles per second to adjust the effective power, thus enabling full-power or reduced-power operation to match different penetration rate requirements (Yu et al., 2021)*"

Reference

Yu, H., Zhu, T., Jiang, X., Tang, Y., Li, X., Li, C., Huang, S., Shi, J., Sun, Y., Talalay, P., Fan, X., Li, X., Li, Y. and Peng, S.: Recoverable Autonomous Sonde for subglacial lakes exploration: heating control system design, Ann. Glaciol., 62, 280-292, https://doi.org/10.1017/aog.2021.5, 2021.

Line 359: The increase in rate of penetration is given as "approximately 21.8%. Based on the good, but somewhat "noisy" results in figures 12, 13, and 14 (which are all based on only a single experiment) the quoted increase seems to contain a bit too many digits. I believe it would be fairer to state 22 % or even round to 20 %.

In the revised manuscript, all percentages that describe the increase in penetration rate have been rounded to integers, with no digits retained after the decimal point. As examples, the values 21.8%, 33.3%, 41.1%, and 253.4% were rounded to 22%, 33%, 41%, and 253%, respectively.