Multi-physics analysis on 6-cell separated drift tube linac tank

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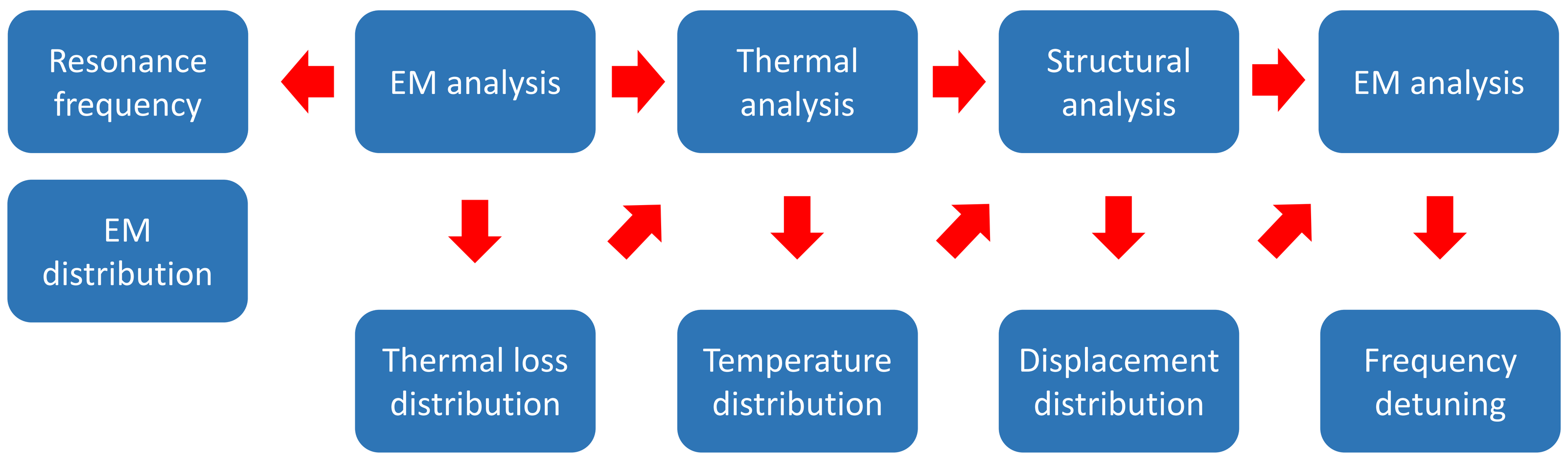
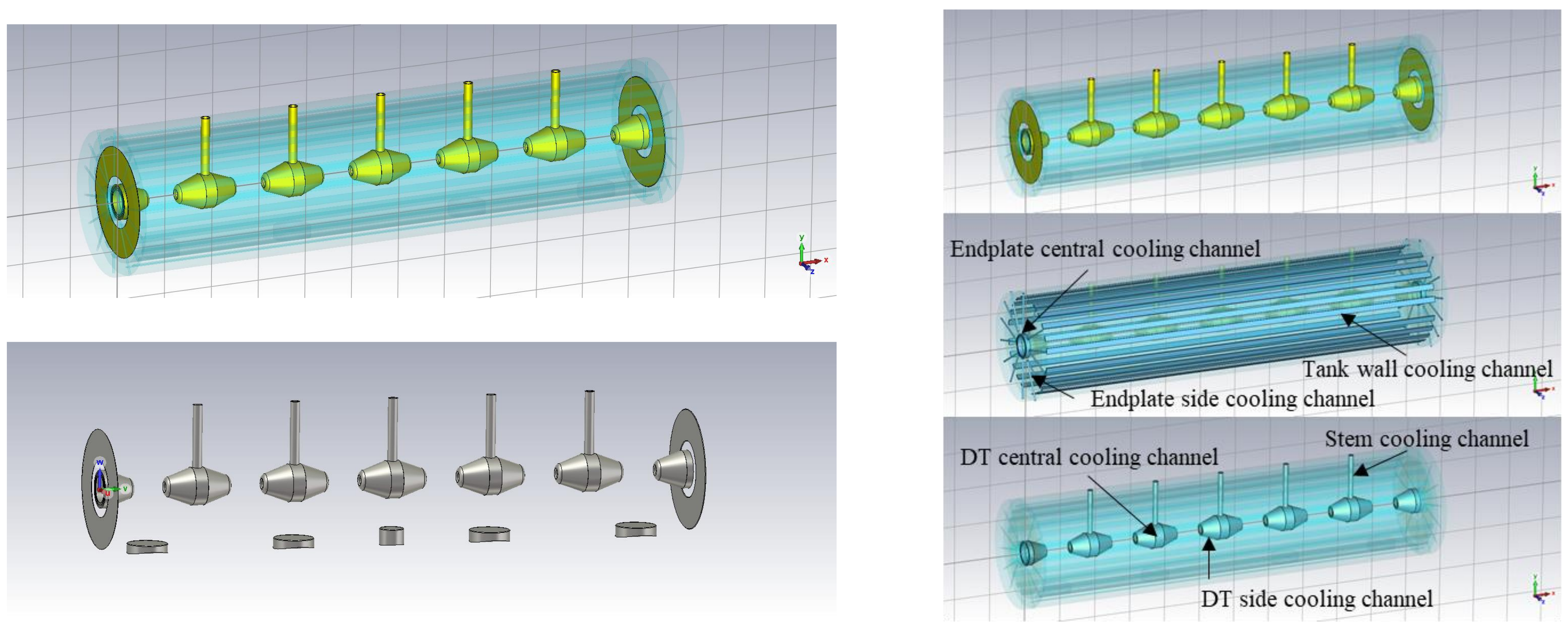
Introduction

- Multi-physics analysis is conducted for the first tank of 200 MeV separated drift tube linac (SDTL) in KOMAC utilizing CST microwave studio.
- Tank wall and endplate are assumed as stainless steel, while stem, drift tubes, and slug tuners are assumed as copper.
- RF duty factor is assumed as 3%.
- Varying parameters, frequency detuning of the tank are discussed via electromagnetic, thermal, and structural analysis.



<Process of multi-physics analysis>

Tank modeling



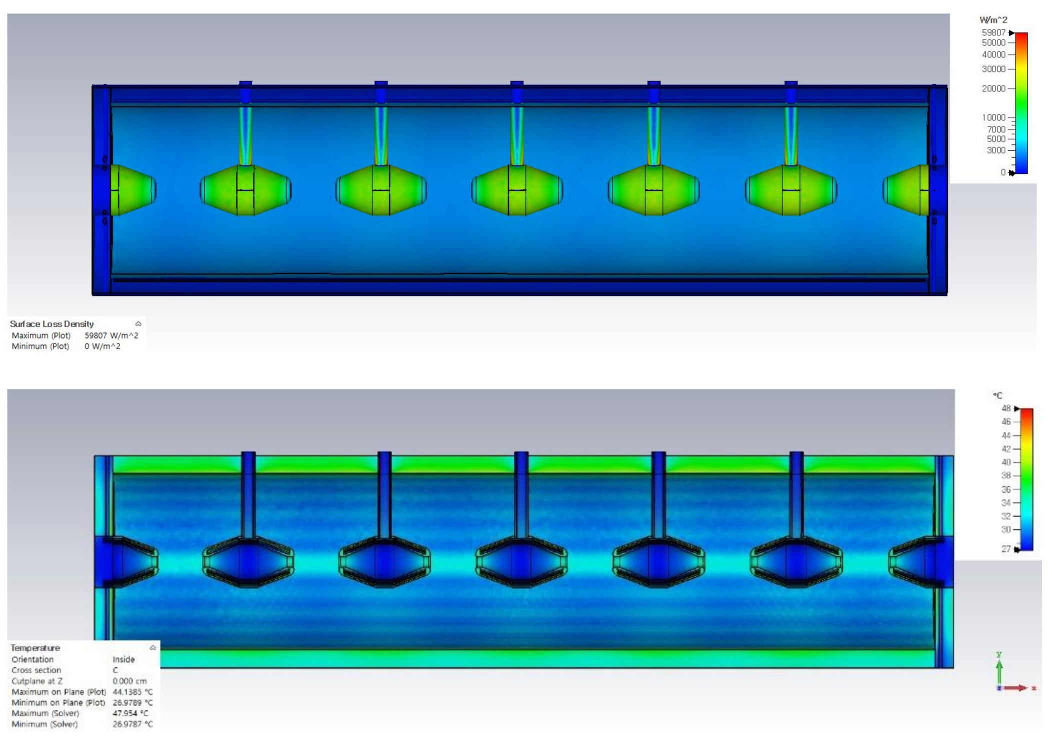
Components	Materials	Initial cooling channel HTC [W/m2K]	Minimum required HTC [W/m2K]
Tank wall	Stainless steel	10000	6000
Stem	Copper	8000	8000
DT	Copper	6000 (cen), 600 (side)	6000 (cen), 1000 (side)
Endplate	Stainless steel	8000	8000

<Tank modeling and cooling channels>

- Flow velocity of 2.5 m/s in the tank wall and stem.
- Minimum required HTCs are decided from frequency detuning analysis part.

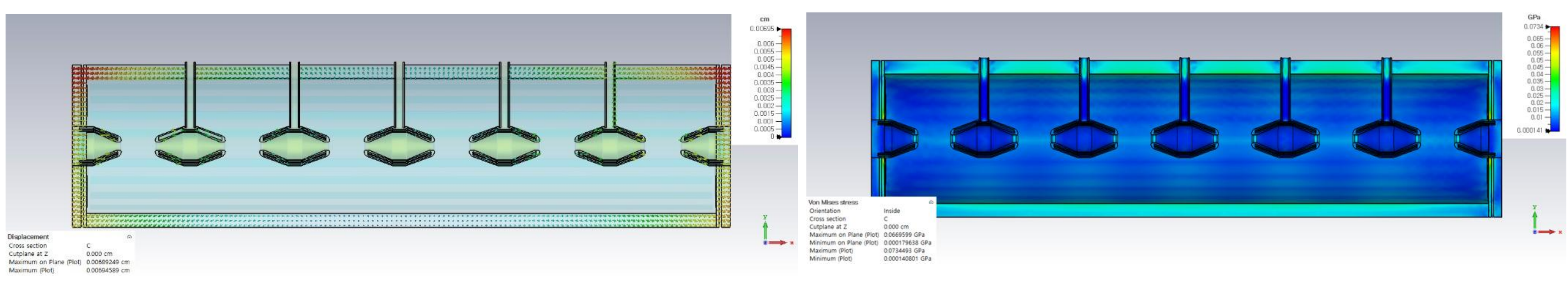
Multi-physics analysis

❖ Thermal and structural analysis



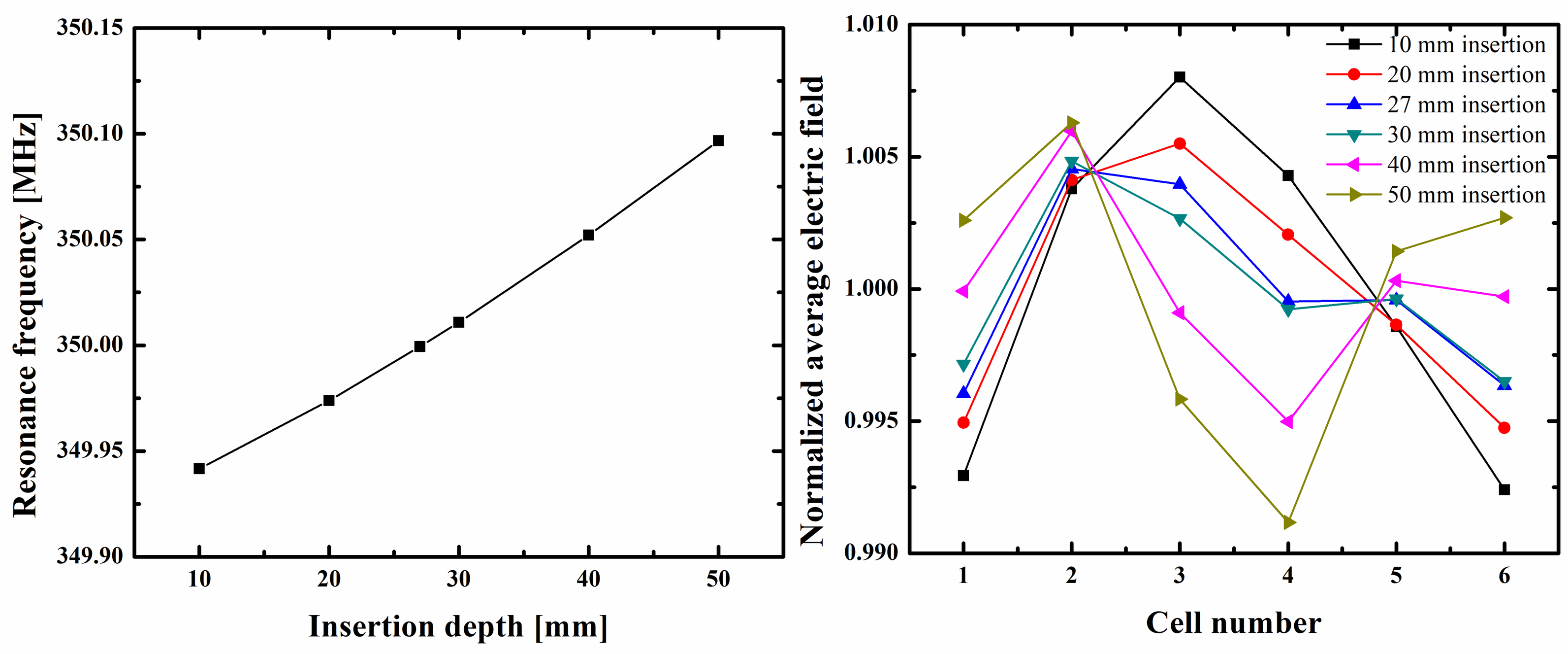
<Thermal loss distribution (up) and temperature distribution (down)>

- Between separated components, 50 um air gap is assumed. In addition, adiabatic boundary condition is assumed.
- Max temperature increase appears on the side of DT where heat transfer coefficient is relatively lower and tank wall point where magnetic field is maximum.
- Max von mises stress on DT and tank wall are kept less than yield strength of annealed copper and stainless steel.



<Displacement distribution (up) and Von mises stress distribution (down)>

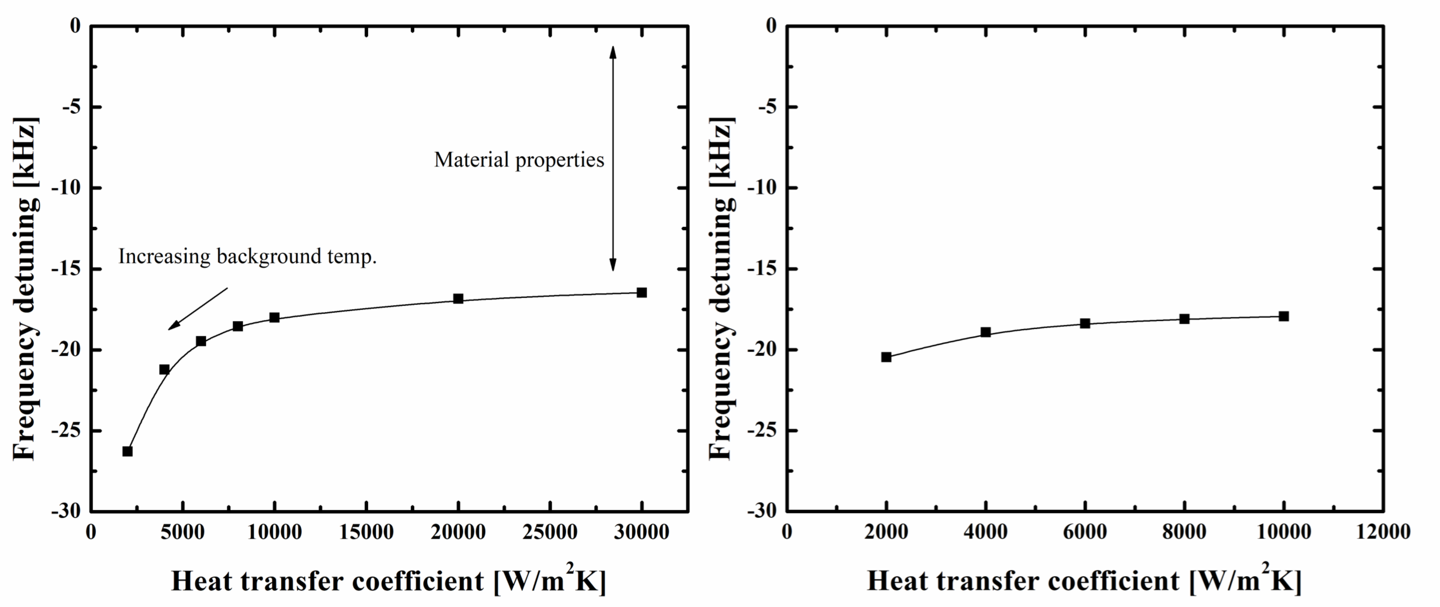
❖ Resonance frequency and field flatness



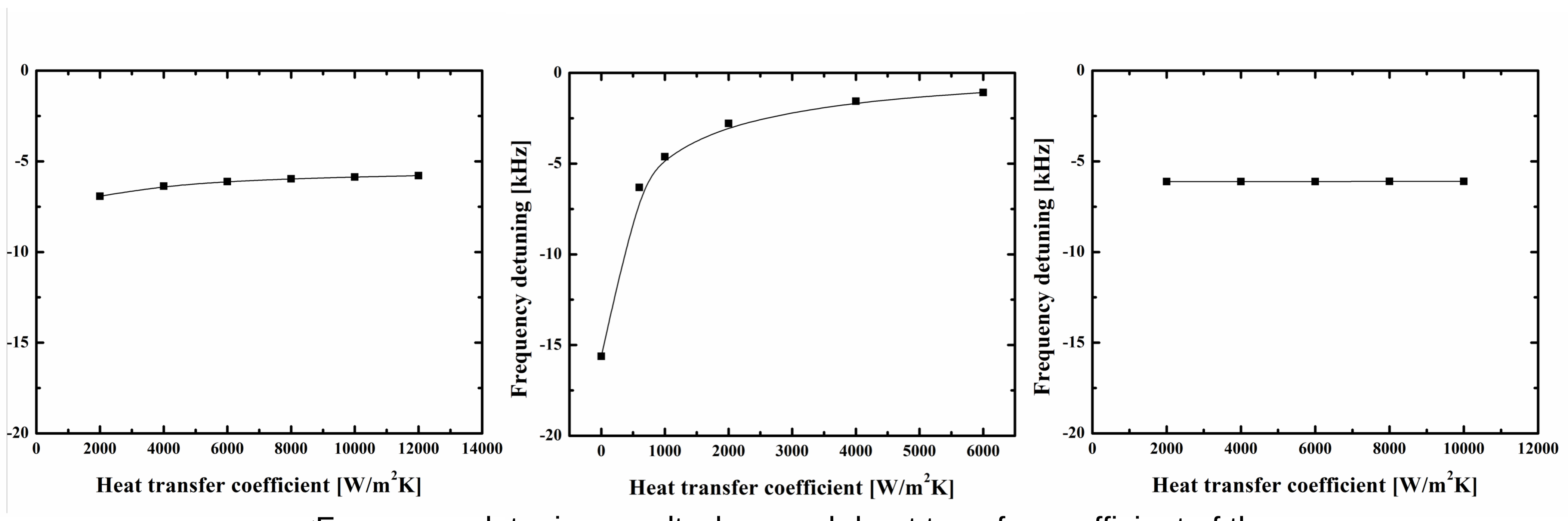
<Resonance frequency (left) and field flatness (right) according to insertion depth of movable tuner>

- Movable tuner can be utilized to compensate frequency detuning instead of adjusting coolant temperature.
- For the reference condition, insertion depth of the movable tuner is 27 mm and insertion depth of 4 fixed tuners are adjusted to achieve resonance frequency of 350 MHz and flat average electric field distribution under 0.5% variation.
- It is found that movable tuner sensitivity is 3.9 kHz/mm. Compensation range of the movable tuner reaches ±60 kHz in the insertion depth range between 10 mm and 40 mm and field flatness remains within 1%.

❖ Frequency detuning analysis



<Frequency detuning result when each heat transfer coefficient of the cooling channel is varied, left : tank wall, right : endplate>

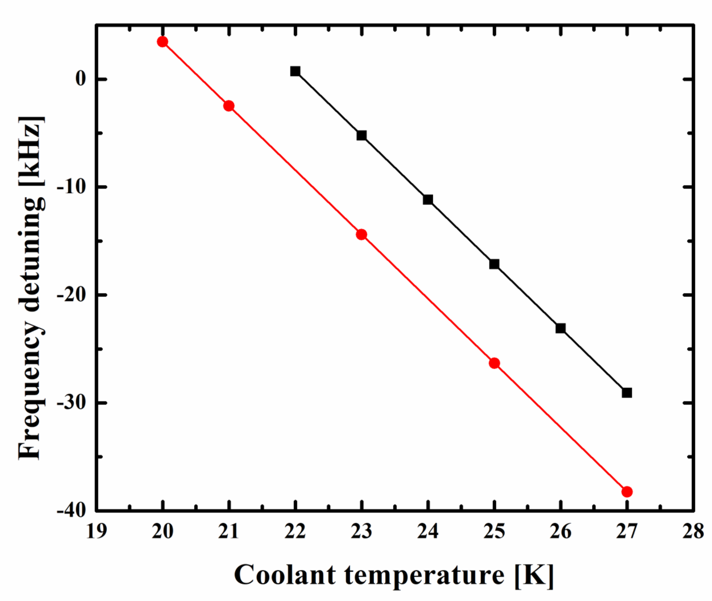


<Frequency detuning result when each heat transfer coefficient of the cooling channel is varied, left : DT central, mid : DT side, right : stem>

- When heat transfer coefficient increases, frequency detuning values tend to converge as temperature distribution is decided on conduction properties of the materials.
- When heat transfer coefficient decreases, absolute value of frequency detuning increases as temperature difference at the interface between cooling channels increases.
- It is found that heat transfer coefficients of tank wall and DT side cooling channel have relatively large effect on frequency detuning.
- To avoid sharp increase of absolute value of frequency detuning, minimum required heat transfer coefficient exists. (especially for tank wall and DT)
- It is shown that coolant temperature should be lowered 5-7 degree Celsius to compensate frequency detuning under current condition.

Component	Frequency detuning [minimum required, kHz]	Frequency detuning [initial, kHz]
1st DT + stem	-4.0	-5.5
2nd DT + stem	-4.1	-5.7
3rd DT + stem	-4.3	-5.8
4th DT + stem	-4.4	-6
5th DT + stem	-4.5	-6.1
Wall + endplate + half DT	-7.9	-9.2
Sum	-29.1	-38.3
Total	-29.1	-38.2

<Frequency detuning result when initial HTC and minimum required HTC are set respectively>



<Frequency detuning result when coolant temperature is varied, red : initial heat transfer coefficient, black : minimum required heat transfer coefficient for each component>

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