GAS filter improvement for post O4.

For respond to 40 kg payload increasing.

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VIS meeting 28 Aug. 2020

GAS filter modification plan for 40kg test mass

R. Takahashi
20 Nov 2019 rev.2

Modification of GAS Filter for 40kg TM

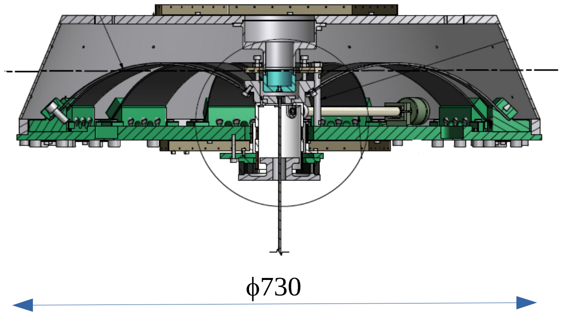
40kg TMのためのGAS Filterの改造

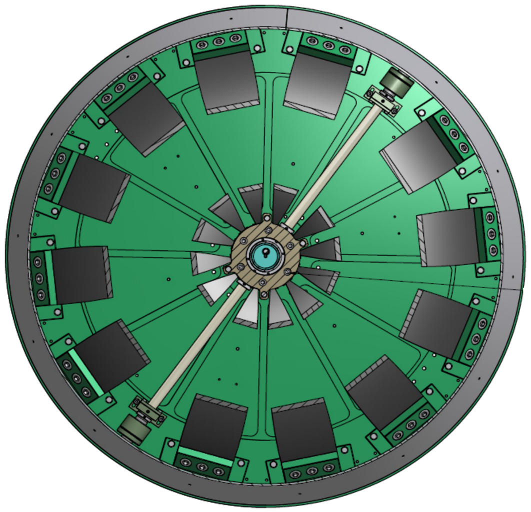
Test mass
- 23kg → 40kg

Blade in GAS filter
- Blade thickness: 2.4mm (from yield limit)
- Load capacity: 40kg/blade
- Maximum number of blade: 12

Body design
- Closed cup → Open frame
- Keep rigidity to avoid deformation
- Reduced body mass

Function
- Fishing rod with strong spring
- Magic wand (for SF)
- Connector anchor
- Moving mass and primary coil (for BF)





Mass Budget

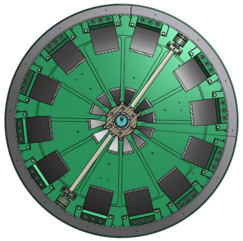
	Original body [kg]	New body [kg]	Reduction [kg]	Blade capacity [kg/blade]	Original #blade	New #blade	Load capacity [kg]	Total load [kg]
Top filter				115	6	6	690	566
Filter 1	100	90	−10.0	40	12	12	480	476
Filter 2	86	76	−10.0	40	10	10	400	400
Filter 3	83	73	−12.6	40	8	10	400	327
Bottom filter	105	87	−19.3	40	5	6	240	240
Payload	200	240	+40.0					

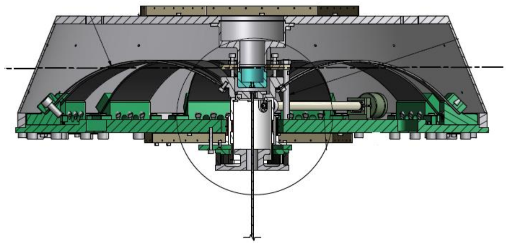
	Original body [kg]	Original base [kg]	Original cup [kg]	Blade block [kg]	Original #blade	All blade [kg]	base+cup+blade [kg]	Ballast [kg]
Top filter					6			
Filter 1	100	27.0	40.2	1.3	12	15.6	82.8	
Filter 2	86	27.0	40.2	1.3	10	13.0	80.2	0～+6
Filter 3	83	27.0	40.2	1.3	8	10.4	77.6	−3～+6
Bottom filter	105	40.5	38.3	1.3	5	6.5	85.3	−3～+5
Payload	200							

Instruction of Takahashi-san.

- Considering multiple models.

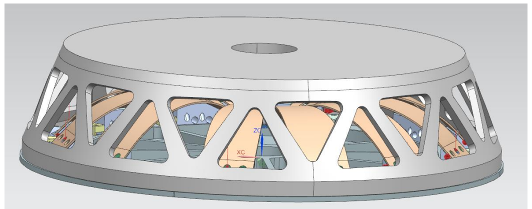
現KAGRAの場合
（完全クローズ）





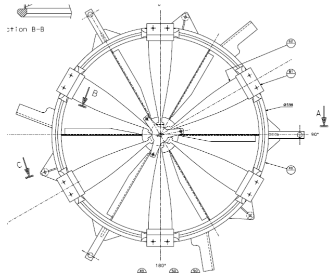
Current KAGRA
(Completely closed)

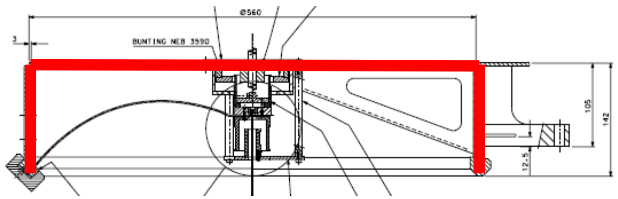
清水案の場合
（側面オープン）



Shimizu's proposal
(Side wall open)

TAMA-SASの場合
（下オープン）





TAMA SAS
(Open bottom)

Modify the Base Plate

On hold

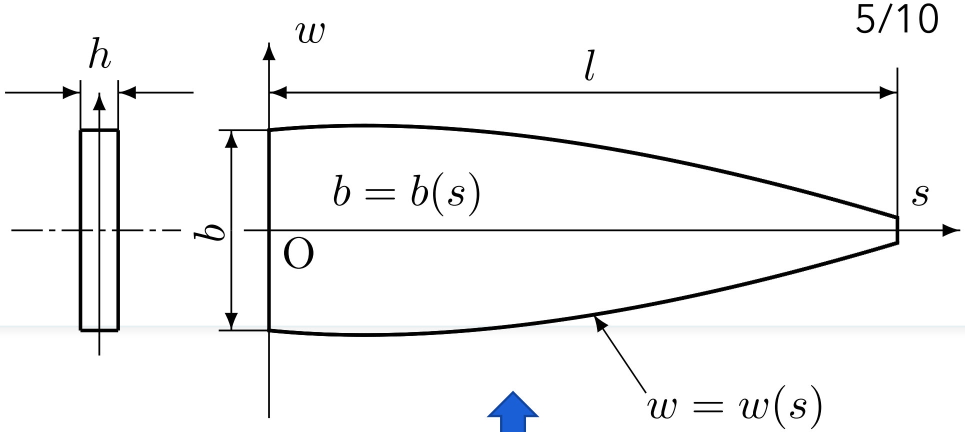
Ishizaki's response

Did not adopted

Rigidity is difficult to secure due to open cross-section structure

Current Structure Survey

- Blade (Yielding)



Young's Module : E Pa

Moment of Inertia of Area : $I = \dfrac{bh^3}{12}$ m^4

Critical Load : $P_{\mathrm{cr}} = \dfrac{\pi^2}{4}\dfrac{EI}{l^2}$ N ← Buckling Theory

Critical stress : $\sigma_{\mathrm{cr}} = \dfrac{P_{\mathrm{cr}}}{A} = \dfrac{\pi^2}{4}\dfrac{E}{\lambda^2}$ Pa

Cross sectional area : $A = bh$ m^2

Slenderness ratio : $\lambda = \dfrac{l}{k}$

Radius of gyration of area : $k = \sqrt{\dfrac{I}{A}}$ m

$$k = \sqrt{\frac{bh^3/12}{bh}} = \frac{h}{\sqrt{12}}, \qquad \therefore\ \lambda = \sqrt{12}\,\frac{l}{h}$$

$$P_{\mathrm{cr}} = \frac{\pi^2}{4}\frac{E}{\lambda^2}\overline{A}, \qquad \overline{A} = \frac{\int_0^l b(s)h\,ds}{l}.$$

Maraging steel : $E = 186$ GPa $\sigma_{\mathrm{Y}} = \sigma_{\mathrm{c}} = 24.9$ MPa

Numerical evaluation

	l mm	h mm	λ	σ_{cr} MPa	$\sigma_{\mathrm{cr}}/\sigma_{\mathrm{Y}}$
TF	606	5.0	419.8	2.60	0.104
SF	274	2.4	395.5	2.93	0.118
BF	274	2.4	395.5	2.93	0.118

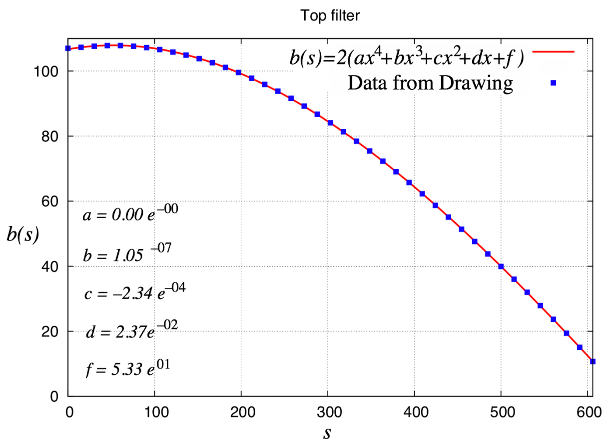
各 blade の `load` を計算した結果

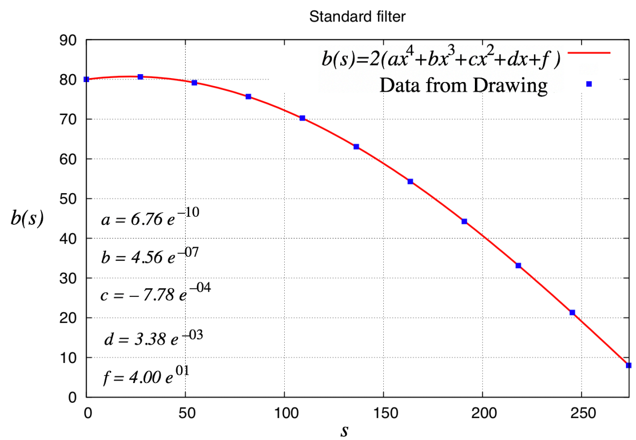
Top filter : 982.35 N = 100.24 kgw

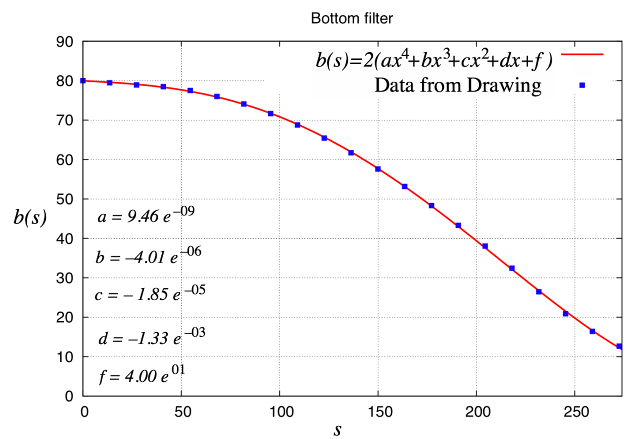
Standard filter : 398.26 N = 40.64 kgw

Bottom filter : 398.08 N = 40.62 kgw

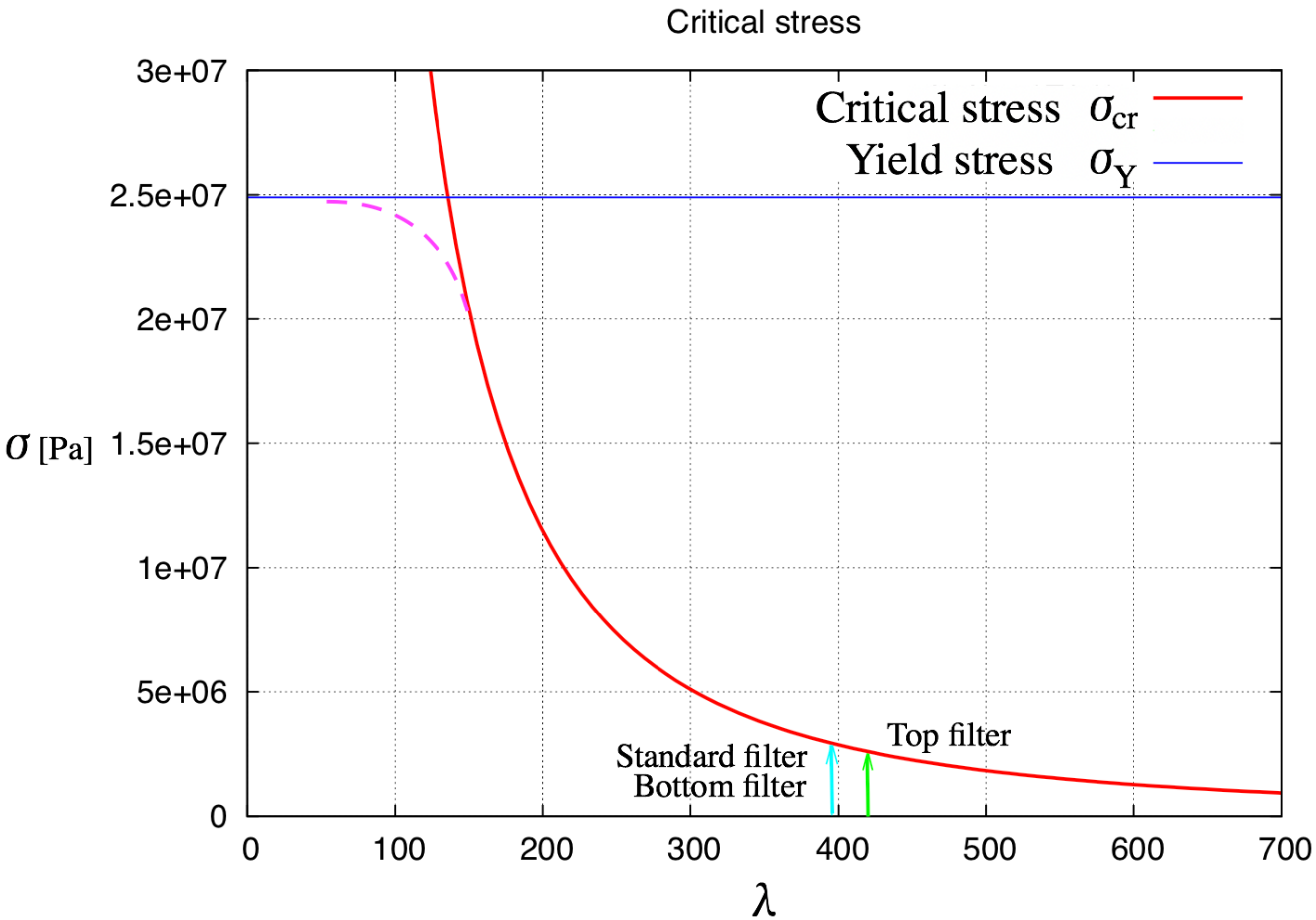
- Blade wedge curve fitting







Critical stress of the Blades

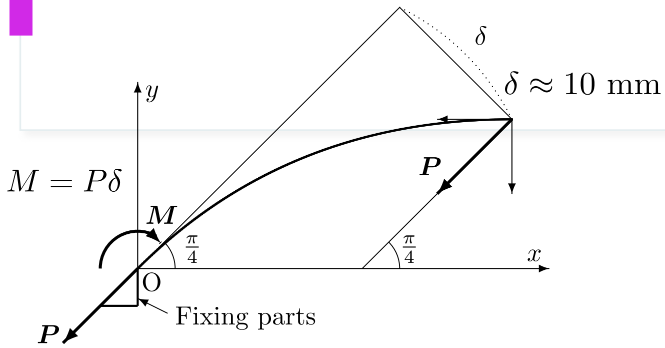


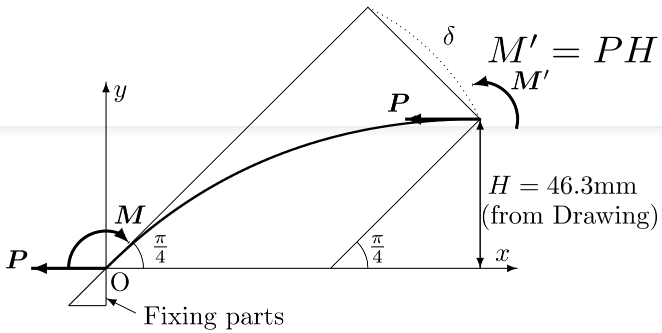
Current Structure Survey

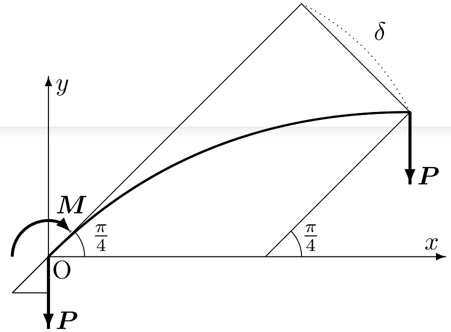
- Rigidity of Base Plate

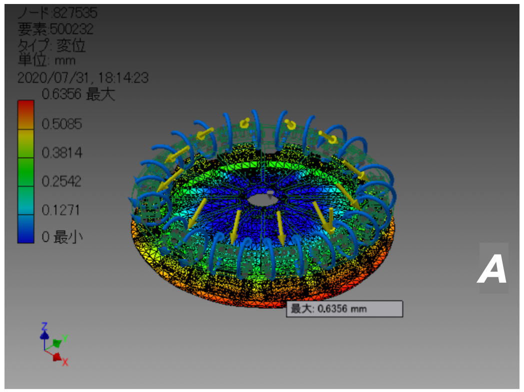
$$P = \sqrt{2} \cdot 398.26 = 563.22 \doteqdot 563 \text{ N},$$

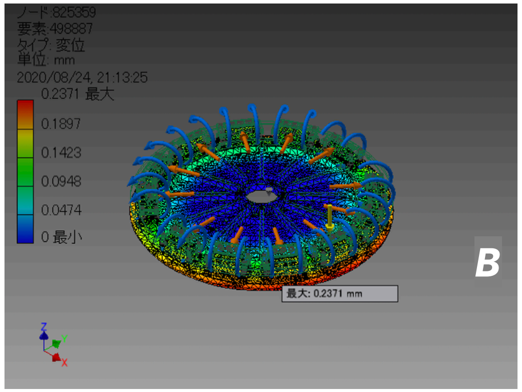
$$M = 5.632 \text{ Nm} \qquad M' = 18.150 \text{ Nm}$$

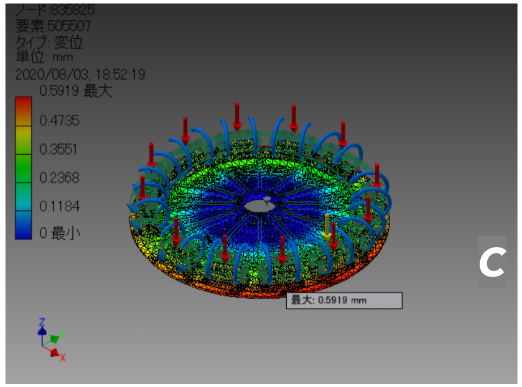












SF	F1	F2	F3
blades	12 sheets	10 sheets	8 sheets
displacement	0.636 mm	0.556 mm	0.478 mm

SF	F1	F2	F3
blades	12 sheets	10 sheets	8 sheets
displacement	0.237 mm	0.212 mm	0.188 mm

SF	F1	F2	F3
blades	12 sheets	10 sheets	8 sheets
displacement	0.592 mm	0.518 mm	0.445 mm

The improvement is evaluated using the current displacement value as an index.

Improvement Plan

- Base Plate Material

Carbon Fiber Reinforced Plastic : CFRP

炭素繊維強化プラスチック

Models	F1	F2	F3
	12 sheets	10 sheets	8 sheets
	displacement		
A	0.636 mm 0.235 mm	0.556 mm –	0.478 mm –
B	0.237 mm 0.090 mm	0.212 mm –	0.188 mm –
C	0.592 mm 0.219 mm	0.518 mm –	0.445 mm –

Materials	ρ kg m^{-3}	E GPa	σ MPa
MS1C	8.0×10^3	186	$\sigma_Y = 1890$
SUS304	8.0	197	$\sigma_Y = 520$
CFRP	1.94	588	$\sigma_B = 3820$

Out Gas

TML (Total Mass Loss：質量損失比 %) ＝ 0.31〜0.49 %

CVCM (Collected Volatile Condensable Materials：再凝縮物質量比 %) = 0.00〜0.01 %

summary

- The improvement of the GAS filter corresponding to the increase in payload mass of 40 kg was examined.
- Current blades are designed also to fit the Buckling theory.
- We evaluated the rigidity of the base plate and defined an index for estimating improvement.
- If the base plate is changed to CFRP, the rigidity and weight reducing will be significantly improved and the degree of freedom in designing other parts will be increased.

Buckling Phenomenon