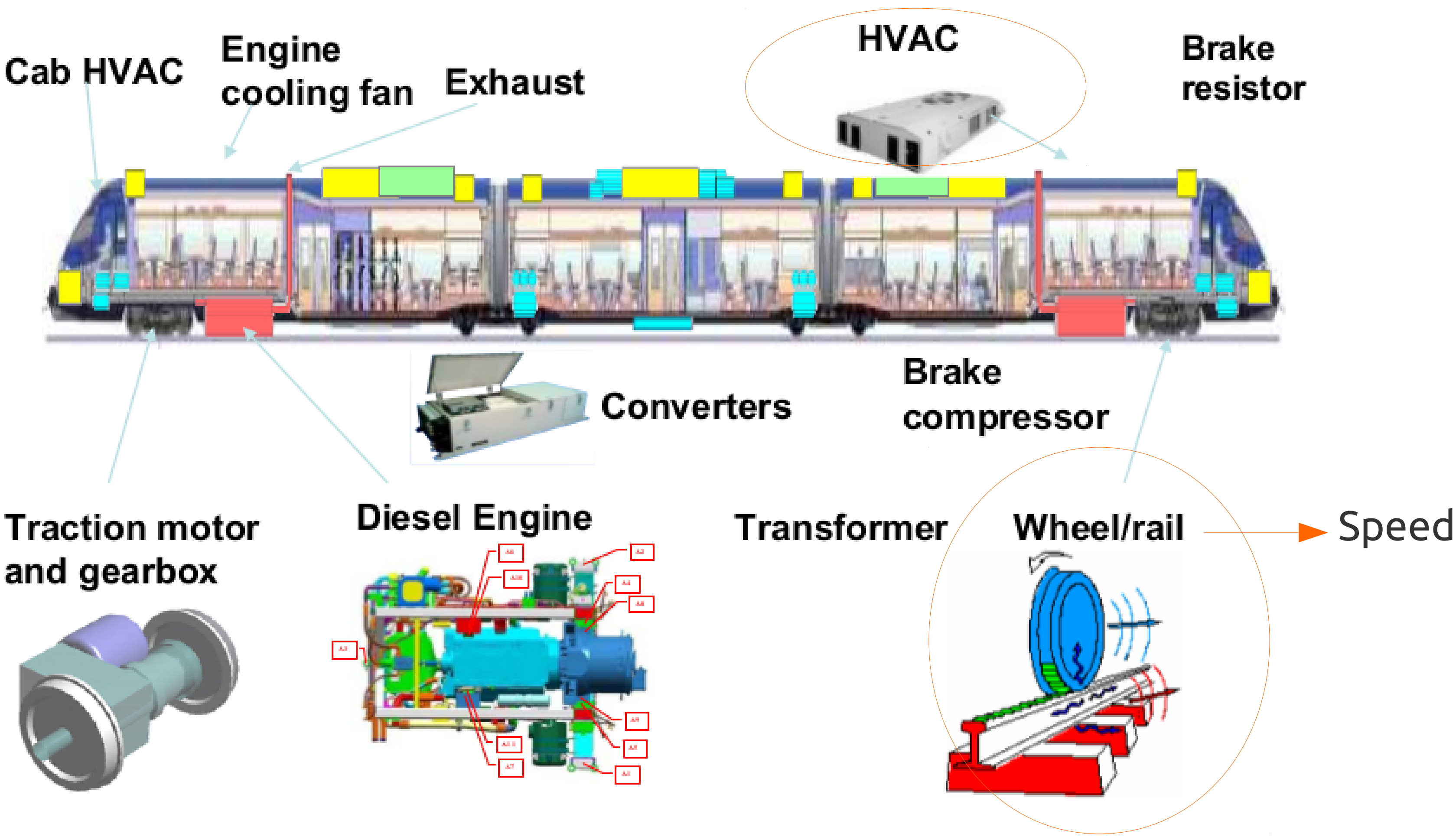
Prediction and simulation of internal train noise resulted by different speed and air conditioning unit

Bagus Tris Atmaja, M.F. Puabdillah, W. A. Asmoro
VibrasticLab ITS

VibrasticLab
Vibration and Acoustics Laboratory

Motivation: rolling noise source



Source: Bombardier, 2008

Noise and speed dependence

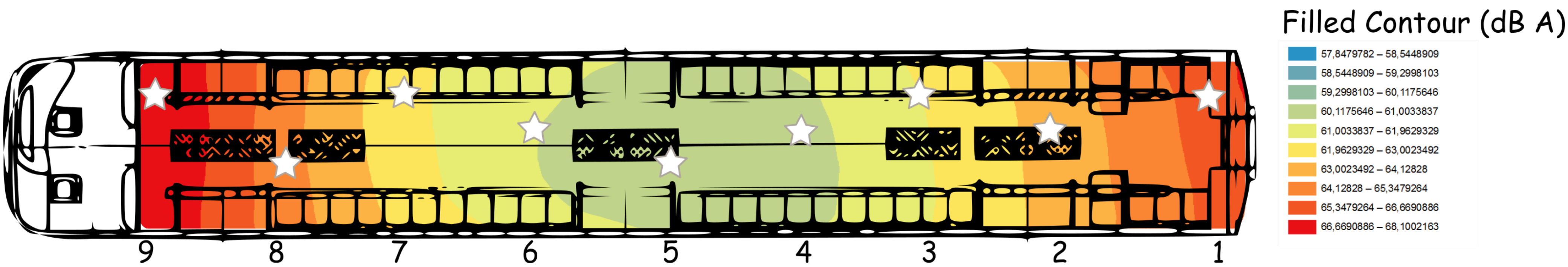
- Rolling noise levels increase with increasing train speed. The A-weighted sound pressure level is usually taken to be proportional to the logarithm of the speed.

$$L_p = L_{p0} + N \log_{10} \frac{V}{V_0} \tag{1}$$

- For the train when the speed is below 100 kmph, N = 20, for 100 < V < 300 kmph, N = 30[1]
- We choose N = 20 as train runs at low speed

[1]G. Xiaoan / Journal of Sound and Vibration 293 (2006) 1078–1085

Measurement at 37 kmph



x	y	125	250	500	1k	2k	4k
1	3	56.96	66.25	68.05	65.52	59.08	59.13
2	2	50.85	60.62	61.15	59.59	55.33	53.13
3	3	52.86	64.31	63.80	62.81	56.91	53.99
4	2	50.81	59.81	59.34	58.06	54.32	54.15
5	1	54.59	58.16	60.87	63.12	56.04	54.61
6	2	49.02	57.27	57.85	59.33	52.37	52.77
7	3	50.19	57.53	58.88	57.47	51.92	52.42
8	1	57.18	64.91	65.73	67.75	60.36	59.27
9	3	56.80	62.47	68.10	68.39	60.09	56.49

We choose **69 dB** as upper level

Prediction at 70 kmph

- By using noise data at 37 kmph, we can predict the noise at 70 kmph

$$L_p = L_{po} + N.\log\left(\frac{V}{V_{p0}}\right)$$
$$= 69 + 20\log\left(\frac{70}{37}\right)$$
$$= 74.5 \quad dBA$$

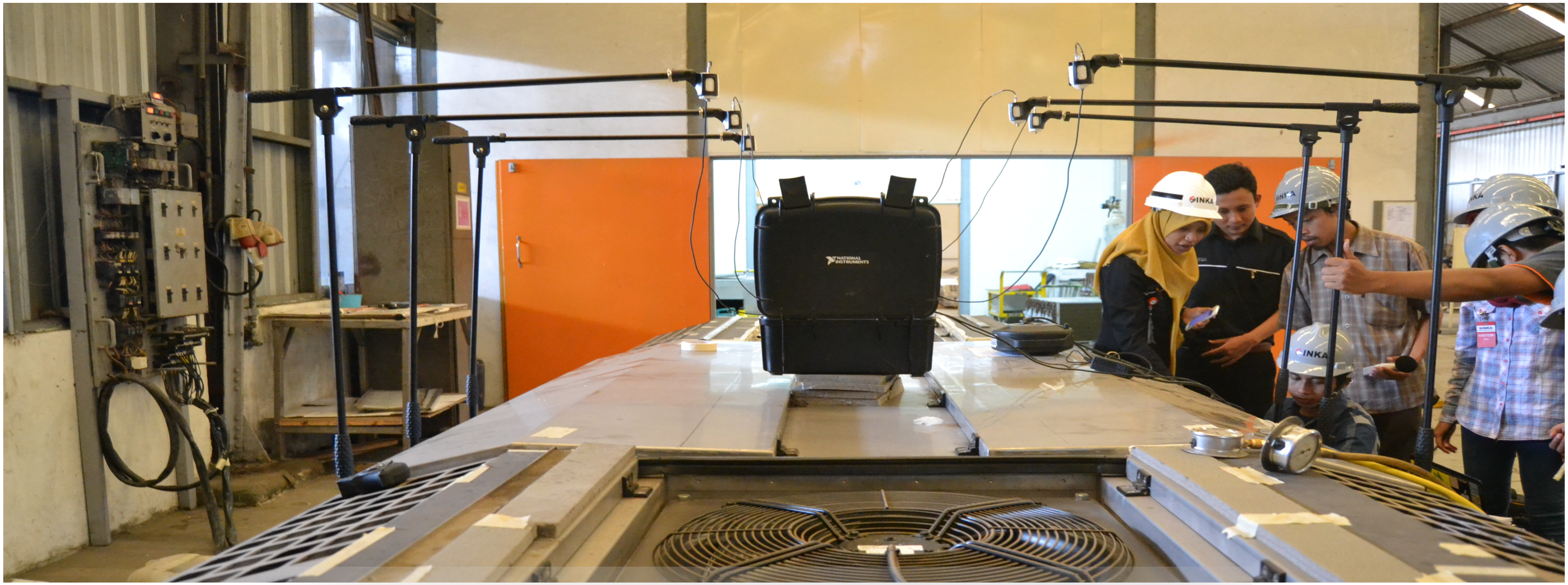
- Measurement at 70 kmph

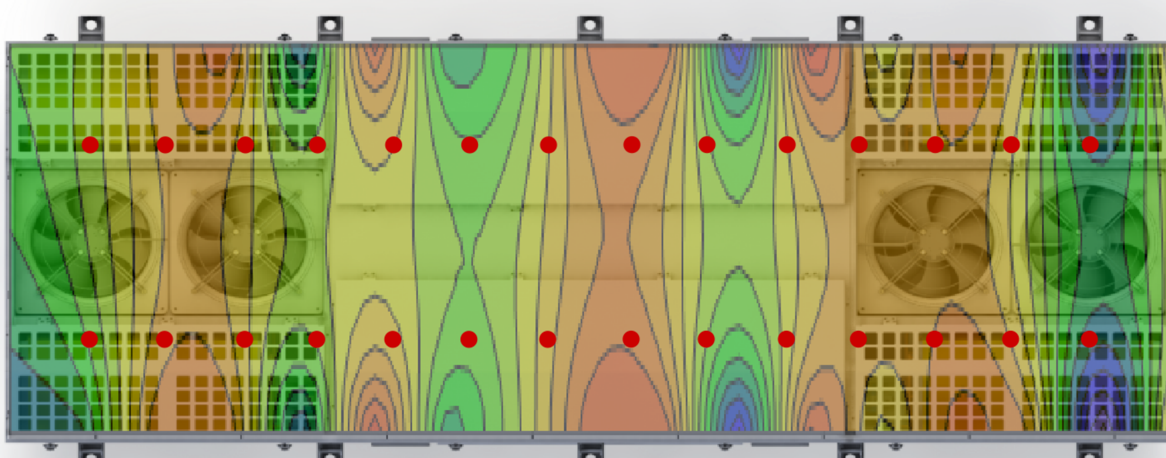
No	Speed [Kph]	Standard(dBA Max)	Result (dBA)			
			TC1	M1	M2	TC2
1	70	75 – 80	74.5	74	73.5	74.5

Average = 74.125 dB

Prediction (dB)	Measurement (dB)	Error (dB)
74.5	74.125	0.375

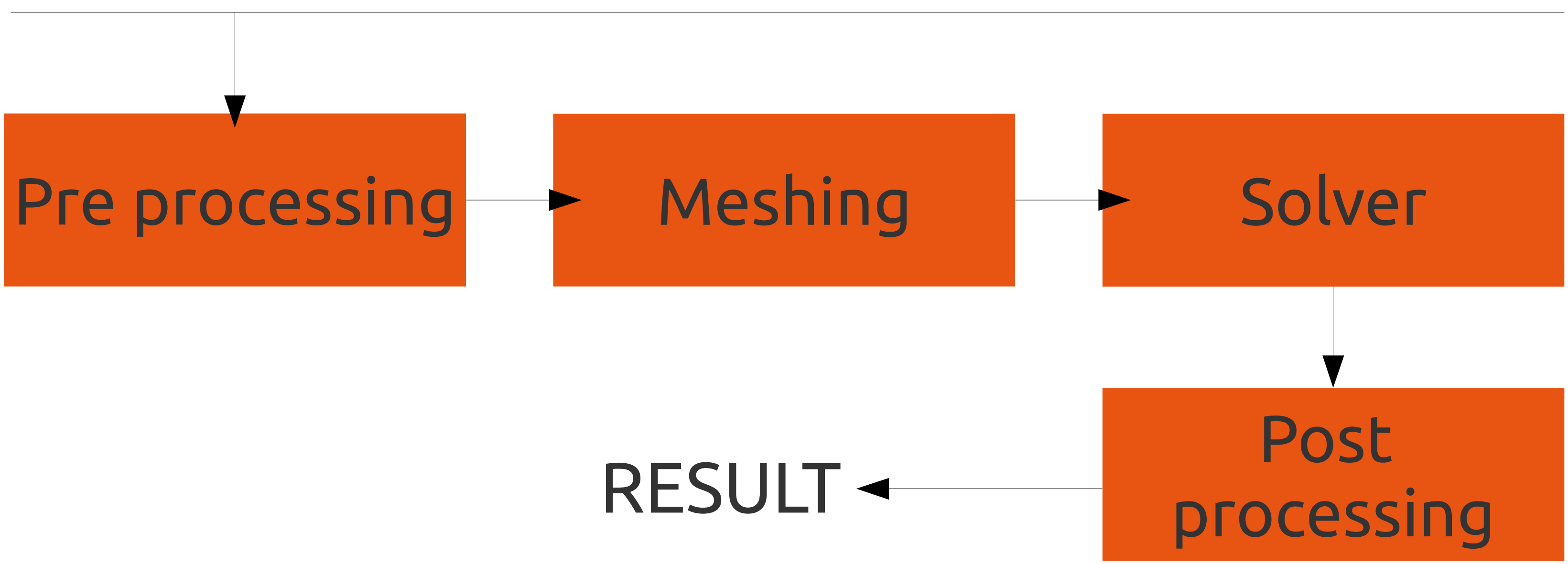
AC Noise measurement





CFD Simulation: specification and steps

- Output debit (each) = 90 m 3 /min
- Return air debit by AC = 64 m 3 /min
- Cooling capacity = 40000 kcal/h
- Evaporator coil temperature output = 27 o C
- Humidity = 65 %



Result: Air speed simulation

Circle shape diffuser

Table 2. Air speed on 1.2 m high above the train floor

Diffuser model	Statistics	Air speed (m/s) K-Epsilon Standard	K-Epsilon Realizable	K-Omega SST
KA_1	Max	3.99	3.88	4.267
	Min	0.00706	0.00792	0.004069
	Average	0.61	0.659	0.6701
KA_2	Max	4.31	3.825	4.32
	Min	0.00464	0.021	0.042
	Average	0.658	0.7049	0.741

Square shape diffuser

Result: Pressure comparison

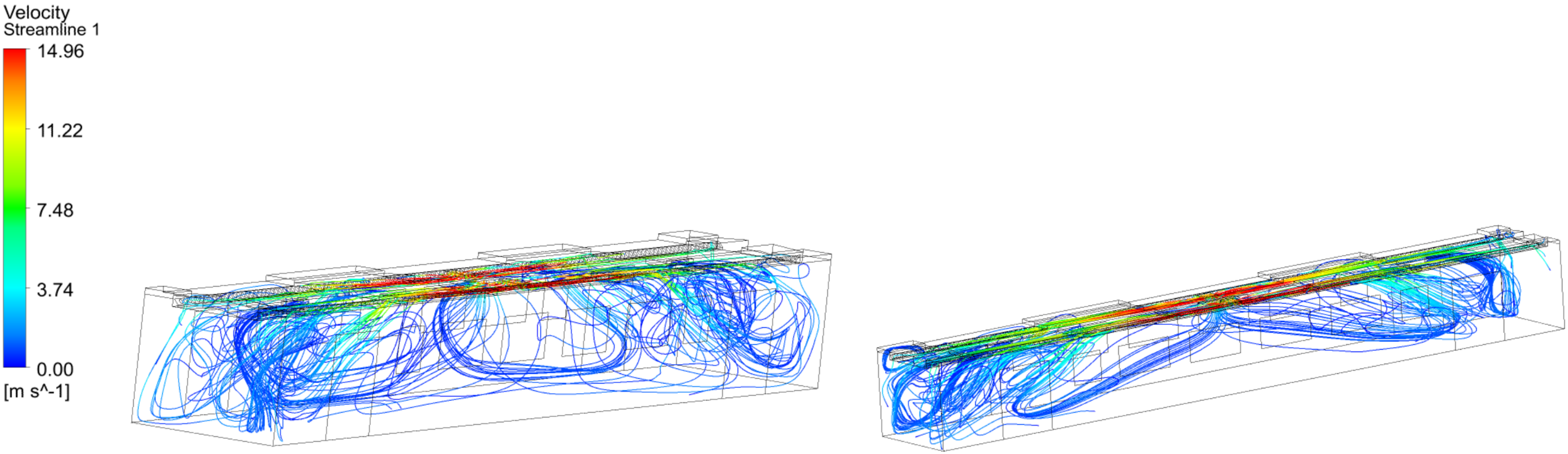
Table 3. Pressure comparison on 1.2 m high above the train floor

Diffuser model	Statistics	Pressure (Pa) K-Epsilon Standard	K-Epsilon Realizable	K-Omega SST
KA_1	Max	431.624	426.755	427.372
	Min	424.544	419.177	420.331
	Average	425.95	420.753	421.83
KA_2	Max	432.064	427.52	426.569
	Min	425.021	420.691	419.298
	Average	422.162	422.162	420.541

Table 4. Comparison of Noise level

Position	KA_1	KA_2
ducting	70 dB	70 dB
1.2 m	8 dB	6.15 dB
1.6 m	14.5 dB	16 dB

Result: Streamline



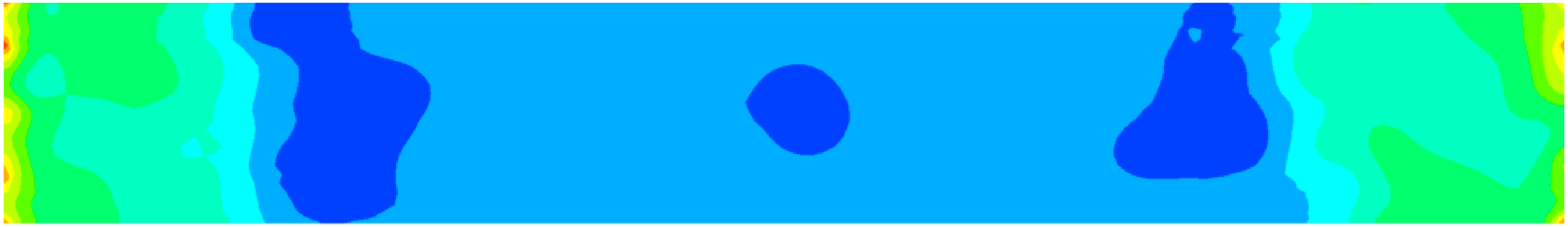
a. Air streamline from KA_1

b. Air streamline from KA_2

- Although the previous result shows the very similar air speed and pressure for both KA_1 and KA_2 diffure model, but from the streamline it is clearly shown that KA_1 (circle diffuser) more distributed widely than KA_2 (square diffuser).

AC noise prediction vs measurement

- CFD simulation (top view, railbound noise due to AC)



- Comparison simulation vs. experiment (measured at the corner of cabin for both)

Simulation	Measurement	Error (dB)
19.3	21.9	2.6
22.6	23.1	0.5

Conclusion

- Railbound noise inside train cabin can be predicted from its speed, by knowing internal noise at certain speed, the noise at another higher speed can be predicted accurately.
- Noise inside train also can be simulated by CFD method to obtain noise distribution. In this research we compare two shape of diffuser and three air speed calculation that close to measurement result.

Reference:

[1] David Thompson, Railway Noise and Vibration, 2009.

[2] Malgorzata Orczyk et. al. ASSESSMENT OF NOISE INSIDE A TRAM DURING A RIDE AND AT A STANDSTILL, 2015.

[3] G. Xiaoan, Journal of Sound and Vibration 293 (2006) 1078–1085.

[4] ISO – 3381

[5] ASTM E1332