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Full scale experimental model investigation in an anechoic chamber of the generation of aeolian tones in aerodynamic sound by airflow around glass fins mounted on the façade of the new Headquarters of the Interuniversity Micro Electronics Centre, Leuven, Belgium.

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Summary

Airflow at high speed through small openings or around more or less aerodynamically shaped objects can give rise to sound with tonal components. Shedding vortices develop immediately behind the opening or object. In these vortices sound pulsations are generated. We distinguish two types of aeolian tones. The first type has a frequency directly related to the air flow velocity. It generally occurs at lower frequencies. The second type has a frequency more or less independent on air flow velocity. It occurs at higher frequencies and is generally present along grating structures.

The Interuniversity Micro Electronics Centre (IMEC), a world-leading R&D and innovation hub in nanoelectronics and digital technologies with world-class infrastructure, has recently completed its new Headquarters in Leuven Belgium. The façade is built entirely from several metre high windows with glass ‘fins’ providing an attractive play of lines.

To prevent any form of annoying aerodynamic noise for both the environment and the occupants of the building, a 1:1 scale model of a façade element was tested in a semi-anechoic chamber. It was found that at high wind speeds of 15m/s or 50km/h and grazing incidence, aeolian tones were generated with a fairly constant frequency between 2 and 2.5kHz. The sound power is independent of the wind speed and the distance between the glass fins and the façade, clearly confirming the repetitiveness of the structure as the noise source.

Several parameters were varied such as wind speed, air gap between glass fins and façade and the shape of the glass fins. In an optimized situation the linear sound power is measured to be LWA=54dB/meter, generating a sound pressure level of Lp=49dBA at 1m distance from the façade. This is considerably lower than the incident traffic noise level on the site of 59-66dBA.

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1. Introduction

The new headquarters of Imec has recently opened in Leuven, Belgium. The architectural design is an inverted tower with remarkable glass fin façades.
Both the future occupants of the tower as the people living in the neighborhood were concerned about the possible generation of annoying aerodynamic noise generated by the wind blowing over and between the fins.

. It is well-known that intense whistling tones may be generated by a high speed air flow around an object, due to shedding of vortices. The frequency F of these tones is related to the air speed and the dimensionless Strouhal number S:

$$F = S.\ v/D$$

v is the wind speed in m/s in front of the object
D is a characteristic dimension of the object perpendicular to the air flow

Here the frequency of the aeolian tones are directly dependent on the wind speed, usually occurring at lower frequencies.
Another mechanism, frequently occurring, is the generation of aeolian tones by airflow over grating structures. These high pitched tones are relatively independent on the wind speed.

For none of the above mechanisms a simple prediction method exists. Therefore a 1:1 scale model is investigated in a semi anechoic chamber.

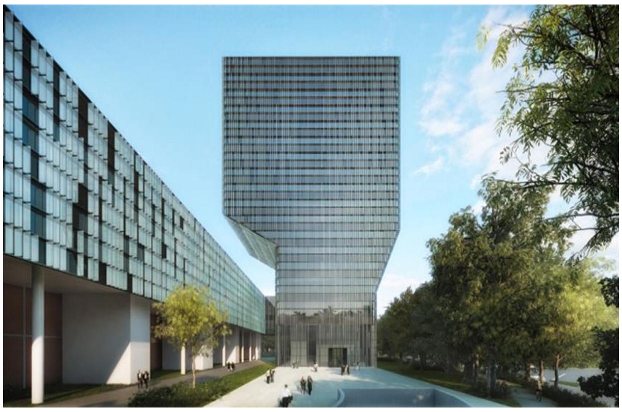


Figure 1. Overall view of the Imec Tower, Leuven

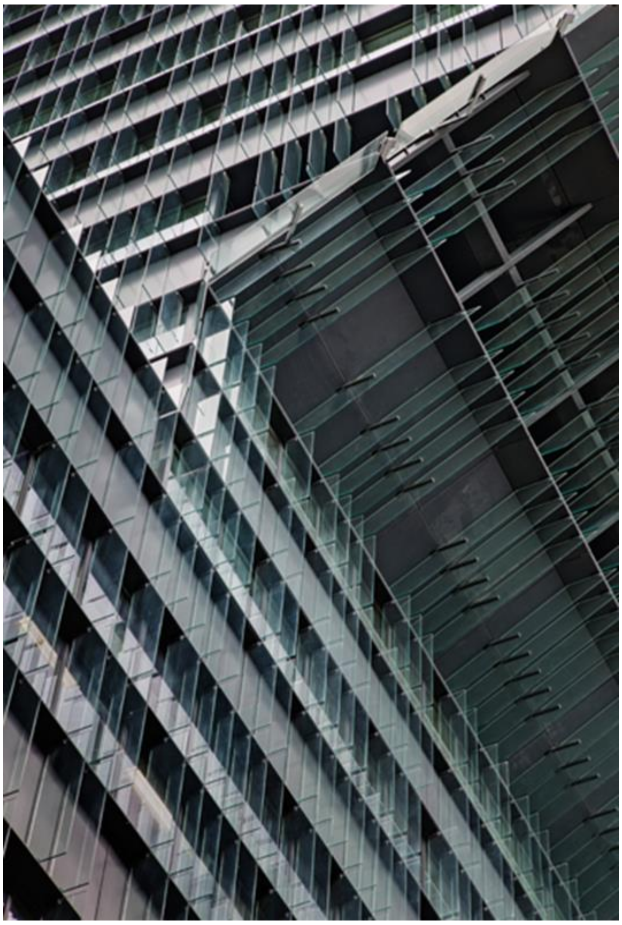


Figure 2. Glass fins on the façade

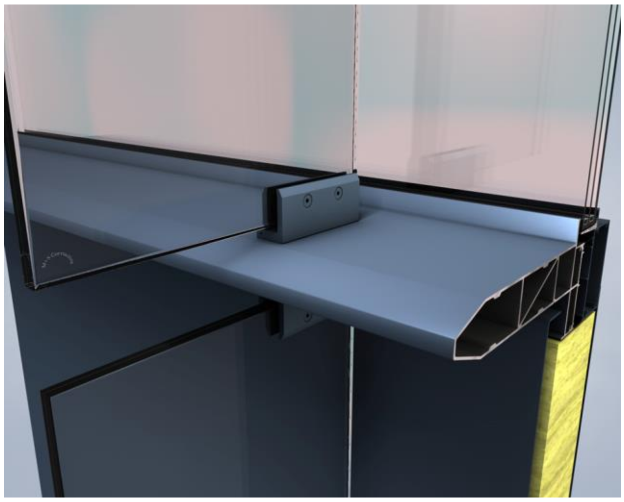


Figure 3. Detail of glass fin

2. Setup of the scale model

A module with a width af 1m20 and a height of 1m80 incorporating 4 clamped glass fins was layed down on the floor of the semi-anechoic measurement room.

The geometric characteristics are as follows:

- Depth of the vertical laminated glass fins is 450mm
- Gap between glass fins and façade plating is 25mm. This is the most critical distance. At other places the distance between fins and façade glazing was a comfortable 68mm and a lot less critical from the point of view of aerodynamic noise.
- Distance between fins is 208mm
- Thickness laminated glass fins 20mm
- Two fins are composed of laminated glass plates with chamfered edges on the outside. The other two are composed of glass plates with V shaped edges at both sides.
- The gap between the glass fins and the facade can be adjusted by means of clamp screws

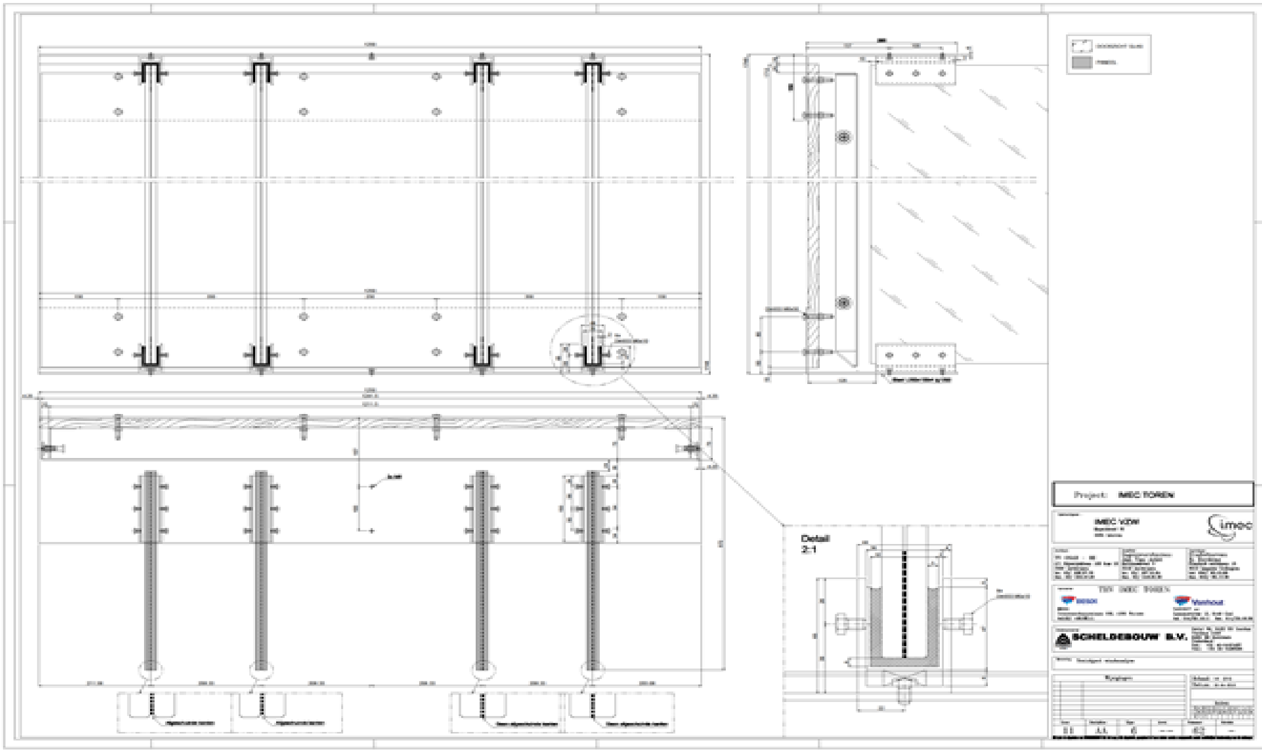


Figure 4. Drawings of tested model

Figure 5. Fin with chamfered edges on outside

Figure 6 Fin with V shaped edges

The module is excited by a low noise in line ventilator, blowing air with a variable speed and a maximum air volume of 600m³/h in a silenced tube of diameter 100mm. Wind speeds up to 15m/s or 60km/h can be generated.

Figure 7. Measurement setup

Sound measurements are conducted beyond the gap under an angle of 45° outside the main air stream. Following conditions are measured:

- Wind speed of 8,12 and 15m/s
- Gap of 25 and 16mm
- Glass fin with or without V shaped edges

3. Measurement results

3.1 Laminated glass plates with chamfered edges on the outside, gap 25mm

For each of the 3 windspeeds, A weighted third octave band sound levels are compared with a reference situation with no obstruction of the same airstream.
An increase of the sound energy at low frequencies between 50-200Hz is caused by broadband wind noise. These low frequencies are not dominant in the overall noise level.
The ventilator noise at 630Hz is always present.
The most important increase is in the region of 2000-2500Hz, clearly originating from the façade geometry itself. This frequency is independent from the wind speed. Therefore the repetitiveness of the facade geometry is the source mechanism, rather then the shape of the composing objects.

3.2 Laminated glass plates with chamfered edges on the outside, gap 16mm

There are no significant changes not of the overall sound levels nor the dominating frequencies.
It is therefore clear that the high pitched tones at the frequencies of 2000-2500Hz are not influenced by the width of the air gap between fins and façade nor by the wind speed.
It is rather the interval distance of 200mm between the fins which is the determining factor.

3.3 Laminated glassplates with V shaped edges at both sides, gap 25mm

Overall sound levels remain unchanged. However the frequency region of high pitched tones broadens from 2000-3150Hz. An additional tone at 5000Hz is present.

3.4 Further testing

At certain wind speeds and wind directions, whistling tones are generated by the fins fixation systems.

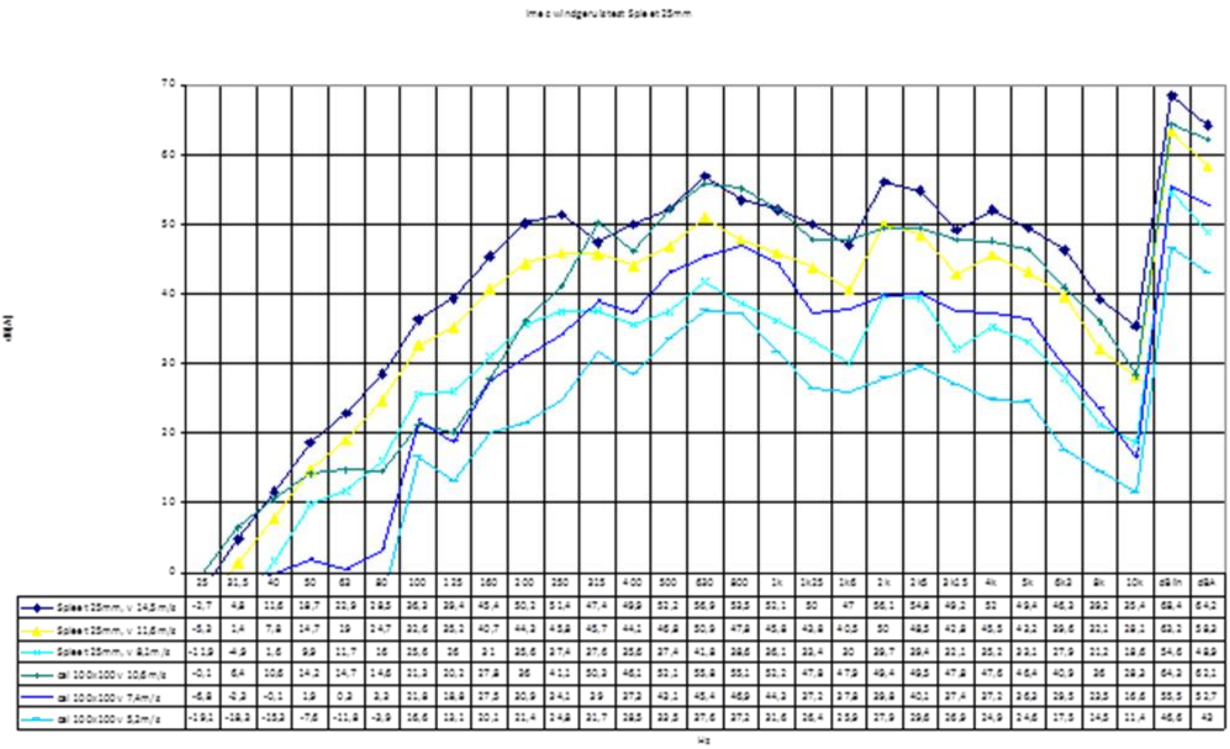
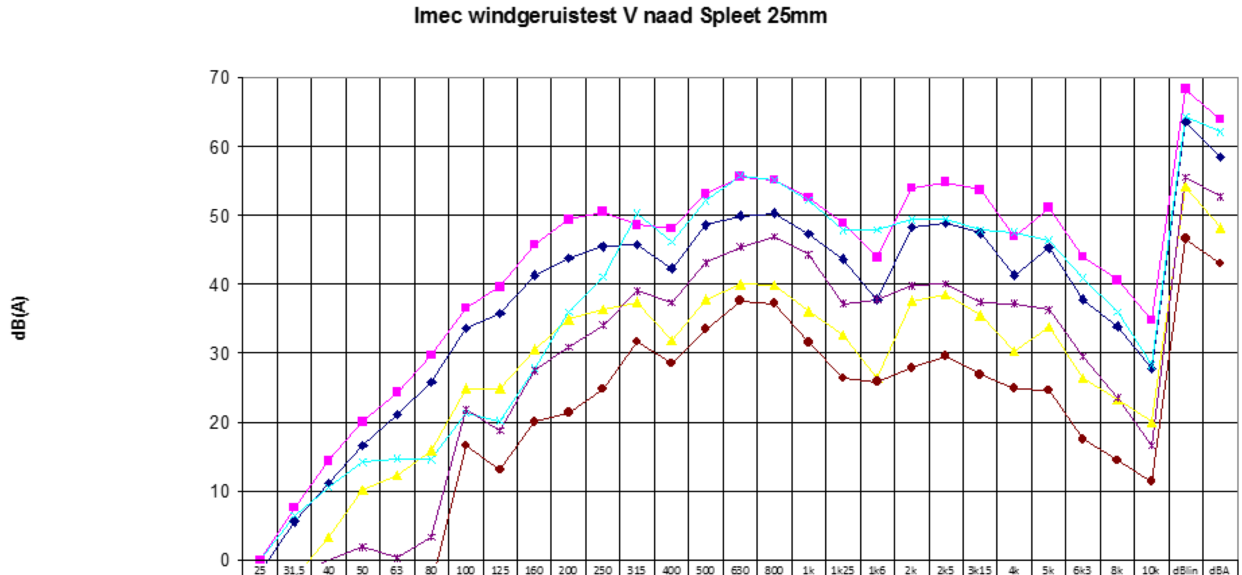


Figure 8. Sound levels with chamfered edges



	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1k25	1k6	2k	2k5	3k15	4k	5k	6k3	8k	10k	dBlin	dBA
V naad, Spleet 25mm, v 12,8m/s	0	7,6	14,4	20,1	24,3	29,7	36,5	39,6	45,7	49,4	50,5	48,6	48,1	53,1	55,6	55,1	52,6	48,9	43,9	53,9	54,8	53,7	46,9	51,1	44	40,6	34,8	68,3	63,9
V naad, Spleet 25mm, v 10,9m/s	-1,8	5,6	11,1	16,6	21,1	25,8	33,6	35,8	41,3	43,8	45,5	45,7	42,3	48,6	49,9	50,3	47,3	43,7	37,8	48,3	48,9	47,4	41,3	45,3	37,8	33,9	27,8	63,6	58,5
V naad, Spleet 25mm, v 7,4m/s	-8,8	-2,5	3,3	10,2	12,3	15,9	24,9	24,9	30,6	34,9	36,4	37,4	31,9	37,8	40	39,9	36,1	32,6	26,4	37,6	38,5	35,5	30,3	33,8	26,4	23,3	20,1	54,2	48,2
cal 100x100 v 10,6m/s	-0,1	6,4	10,6	14,2	14,7	14,6	21,3	20,2	27,8	36	41,1	50,3	46,1	52,1	55,8	55,1	52,2	47,8	47,9	49,4	49,5	47,8	47,6	46,4	40,9	36	28,3	64,3	62,1
cal 100x100 v 7,4m/s	-6,8	-2,3	-0,1	1,9	0,3	3,3	21,8	18,8	27,5	30,9	34,1	39	37,3	43,1	45,4	46,9	44,3	37,2	37,8	39,8	40,1	37,4	37,2	36,3	29,5	23,5	16,6	55,5	52,7
cal 100x100 v 5,2m/s	-19,1	-18,3	-15,3	-7,6	-11,8	-3,9	16,6	13,1	20,1	21,4	24,8	31,7	28,5	33,5	37,6	37,2	31,6	26,4	25,9	27,9	29,6	26,9	24,9	24,6	17,5	14,5	11,4	46,6	43

Hz

Figure 9. Sound levels with V shaped edges

4. <u>Conclusions and recommendations</u>

4.1 Sound power levels

It was found that at the highest wind speeds of 15m/s or 50km/h and grazing incidence, aeolian tones were generated with a fairly constant frequency between 2 and 2.5kHz. The sound power is independent of the wind speed and the distance between the glass fins and the façade, clearly confirming the repetitiveness of the structure as the noise source.

In an optimized situation the linear sound power is measured to be LWA=54dB/running meter, generating a sound pressure level of Lp=49dBA at 1m distance from the façade. This is considerably lower than the incident traffic noise level on the site of 59-66dBA.

4.2 Distance between glass fins

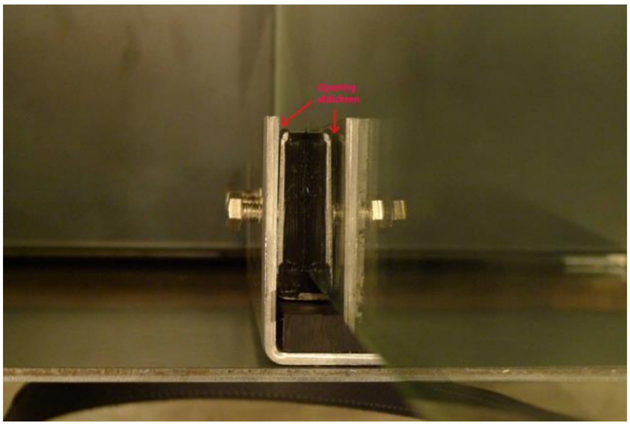
For the measured module, the distance between the glass fins was 208mm. Since the measured aeolian tones have a fixed frequency, it was advised to increase the distance between the fins so as to be equal or larger than their depth (450mm). In the constructed façade the distance between the fins was finally fixed at 415mm.

4.3 Shape of the fins

The V shaped glass plates showed an additional aeolian tone at 5000Hz. It was decided not to use the V shape but have simple chamfered edges on the outside.

4.4 Fixation system

To eliminate discrete tones from the fin fixation system, the small gaps between the U profile and



the clamping system were closed by means of silicone kit.

Figure 10. Gaps in clamping system