MEK 4600 - Noiselab

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April 2021

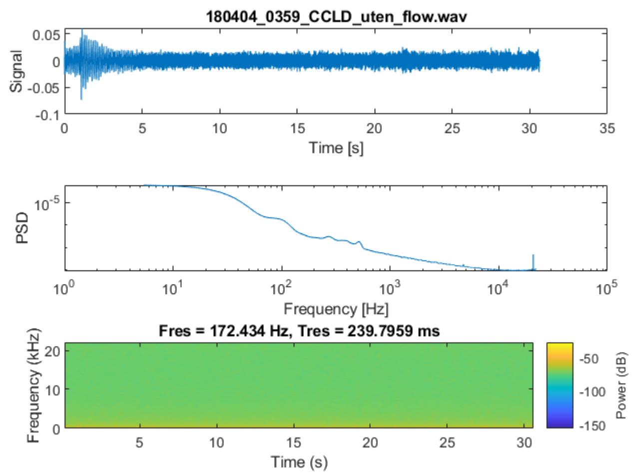
Introduction and set up

The purpose of this exercise is to identify the sounds of different flows through a pipe using a contact microphone. We will investigate whether we can identify when flow is turbulent by analysing signal and PSD. Beneath is a picture of the set up, where water flows from the jug through a tube

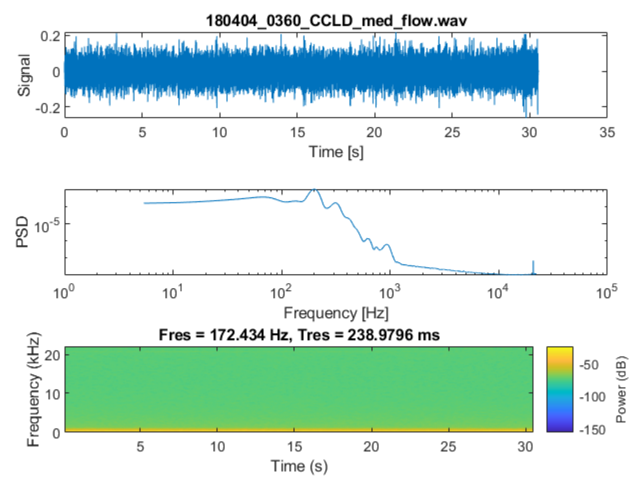
Figure 1: The experimental set up

Pre-lab activites

We were asked to analyse some existing sound files and compare them to the plots found on the exercise sheet (Noiselab.pdf). They behave the same way as on the sheet. We observe that the signal is higher on the recording with flow



(a) without flow



(b) with flow

Figure 2: Comparing sound of flow vs non flow through the tube

Main points

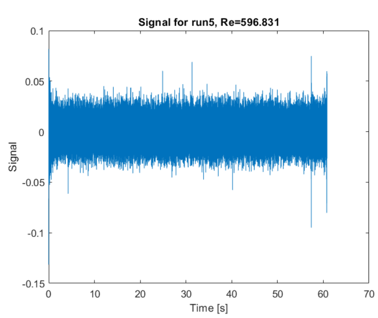
1. In fluid mechanics, turbulent flow is described by some characteristic traits rather than being defined concretely. One trait is that the fluid undergoes mixing, as opposed to laminar flow where the fluid particles moves in straight lines. Flow is characterised as turbulent by evaluating the Reynolds number. When Reynolds number (Re) is about 4000 or more we have turbulent flow. From around 2300-4000 we have what we call the transition fase, and at lower than 2300 we have laminar flow.

2. The microphone can detect signals from the environment, like the air conditioning system, sound from digital devices like a computer or even changing sounds due to change in pressure in the room

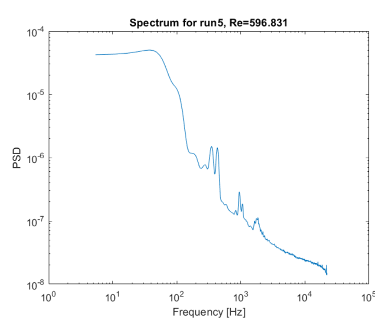
3. The sound of turbulence has been studied for a variety of different applications, for instance in medical research. One subject of interest was to identify to which degree blood flow in the human body is laminar, and to which degree it is turbulent. A paper by Paul D Stein and Hasi N Sabbah published in 1976 [1] investigated whether turbulence does occur in the human body, and found that it does occur and is more prevelant in patients with a heart disease know as aortic stenosis.
   There are also more recent studies. Chenyang Weng and Susann Boij in 2013 [2] compared experimental results a model derived from analytical solutions to the equations for turbulent Reynolds stress on sound waves. They used a frequency depended eddy viscosity model to predict the attenuation of sound propagating in fully developed turbulent pipe flow and found that their predictions matched well with experimental data.

4. Check

5. The recorded files lasts 60 seconds and the same procedure from the prelab activities are used. The figures for signal vs time and PSD (power spectral density) vs frequency are all saved. Beneath are plots for laminar, transitional and turbulent flow, respectively.

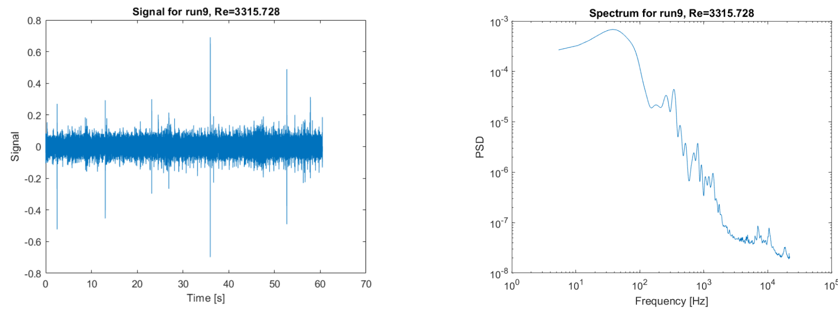


(a) Signal plot, laminar



(b) PSD, laminar

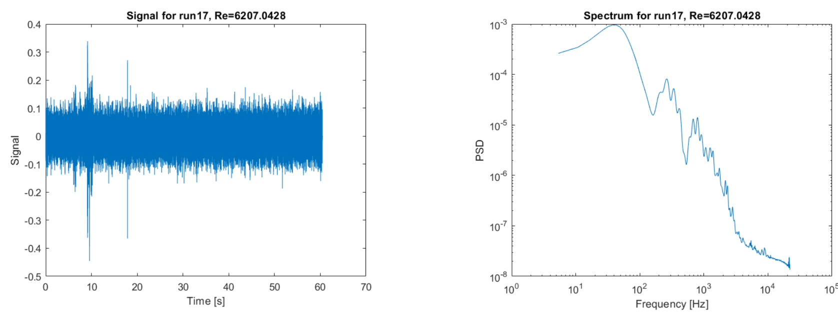
Figure 3: Signal vs time and PSD vs frequency for laminar flow



(a) Signal plot, transitional

(b) PSD, transitional

Figure 4: Signal vs time and PSD vs frequency for transitional flow



(a) Signal plot, turbulent

(b) PSD, turbulent

Figure 5: Signal vs time and PSD vs frequency for turbulent flow

6. Frequencies at 10 and 100 Hz are detected on every example, and from there we can see a gradual decrease. Our strategy for denoising will be to use the PSD spectrum and manually remove those frequencies below a certain PSD threshold. For these figures PSD-values beneath 10^{-5} for the laminar flow seems reasonable. For non-laminar we set 10^{-4} as a threshold. From reading up on the literature the turbulent spectra is the fluctuating PSD signals and the corresponding frequencies.

7. By using fast Fourier transform (fft) we detect frequencies, zeroing out "unwanted" frequencies, and then using reverse fft to get the cleaned up signal. Below are the results for the same three runs as before.

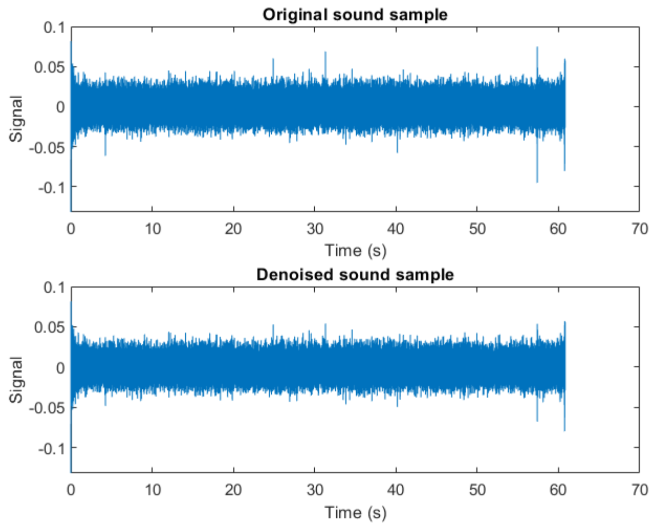


Figure 6: Original vs filtered audio sample, run 5

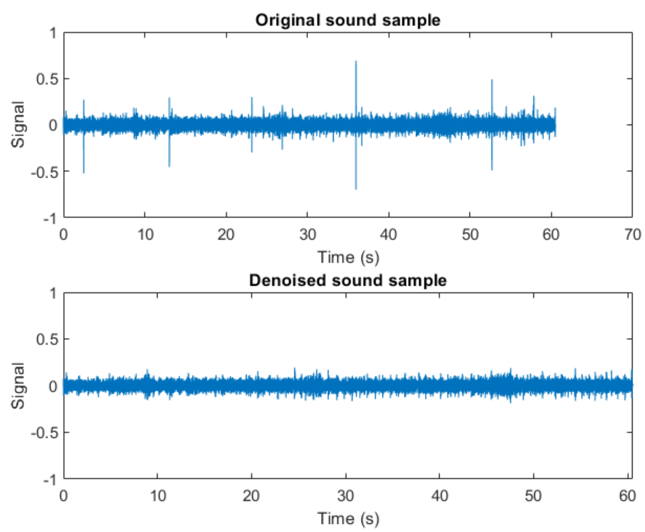


Figure 7: Original vs filtered audio sample, run 9

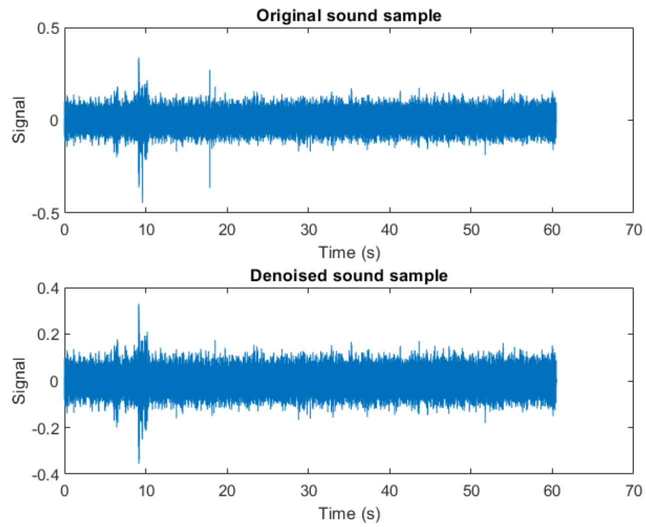


Figure 8: Original vs filtered audio sample, run 17

Short statistical analysis

By calculating the standard deviation on the signal for three of the turbulent flows I tried to investigate how the signal varies for similar types of flow, in this case turbulent. For runs 15, 17 and 19 the results were:

$$\begin{aligned} \sigma_{15} &= 0.0433 \\ \sigma_{17} &= 0.0407 \\ \sigma_{19} &= 0.0578 \end{aligned}$$

Table 1: Standard deviation, original samples

I did the same analysis for the signal for the denoised runs, with the following results. We see som variety but no consistent patterns between filtered and unfiltered samples

$$\begin{aligned} \sigma_{15} &= 0.0576 \\ \sigma_{17} &= 0.0406 \\ \sigma_{19} &= 0.0432 \end{aligned}$$

Table 2: Standard deviation, filtered samples

Conclusion

There are a lot of potential loop holes when doing experiments like these, but some differences between higher flow rates and lower flow rates were detected. The easiest one to spot from plotting the data was the increased signal level in the higher flow rates. However we could also observe some fluctuations in the frequency spectra for the higher frequencies in turbulent flow as the PSD values went down.

References

[1] Paul D Stein and Hani N Sabbah. Turbulent blood flow in the ascending aorta of humans with normal and diseased aortic valves. *Circulation research*, 39(1):58–65, 1976.

[2] Chenyang Weng, Susann Boij, and Ardeshir Hanifi. The attenuation of sound by turbulence in internal flows. *The Journal of the Acoustical Society of America*, 133(6):3764–3776, 2013.