Geek Hub

Figure 1. Industrial example of two stacks

Spiralled Skyline

By Mike Gruetzmacher, Technical Marketing Engineer, Mentor Graphics

Ever wondered why some industrial stacks have spiral structures snaking skyward? Well, since these are industrial plants, designer or artistic reasons can be eliminated. So it must be scientific.

The spirally arranged extensions are called Scruton strakes, named after the British engineer, Christopher Scruton. Working together with D. E. J. Walshe at the National Physics Laboratory in Great Britain, he invented the helical strake and first published the results in 1957[1]. These helical strakes are used to prevent vibrations caused by alternating vortices caused by the wind.

Vortex-induced vibrations (VIV), are caused by vortex shedding and can occur when long slender structures such as chimneys or car antennas are exposed to a flowing fluid. The repeated pattern of wind causes alternating eddies or vortices, also known as a Kármán vortex street. But what do those helical strakes actually do and why are they needed?

For the purposes of this investigation, I used Mentor Graphics' FloEFD 3D CFD Analysis Software, to better understand these structures.

For low Re numbers the vortices downstream the cylinder are steady (figure 2), for higher Re numbers >100, the vortices begin to oscillate (figure 3). The Strouhal number describes the frequency of the vortex shedding:

$$St=\frac{fd}{U}$$

f=frequency of vortex shedding
d=hydraulic diameter
U=flow velocity

These alternating shedding of vortices produce periodic forces across to the flow direction. Each elastic component, including industrial stacks, has a natural frequency. If the excitation frequency generated by the vortex shedding approaches the natural frequency of the stack, resonance and vibrations can occur. This can, at worst, cause damage to the structure.

According to Scruton, another dimensionless quantity was named, the Scruton number:

$$Sc=\frac{2\delta_s m_e}{p b_{ref}^2}$$

δ_s=structural damping by the logarithmic decrement
m_e=effective mass per unit length
p=density of the fluid
b_{ref}=characteristic width of the structure

The Scruton number is an indicator for the design engineer to assess whether further measures must be taken to avoid the effects of vibration damage. Constructive measures may include, for example, damping or other structural engineering measures. Massive, stable stacks seem to be more resistant against these effects, as seen in figure 1. The stack with the larger diameter on the left side is not equipped with the Scruton spirals.

Focusing on the fluid dynamics, the aim of the helical strakes is to interrupt the alternating shedding of the vortices and thus a suppression of the oscillating lateral forces. I was able to quickly set up a simple FloEFD model with the following boundary conditions: Stack diameter: 1.5m, ambient air velocity: 2 m/s (wind velocity 7.2 km/h), as seen in figure 4.

Figure 5 shows a cut plot for velocity and at the top left a curve of the lateral forces depending on the time. We can see the oscillating force in y-direction caused by the alternating vortices.

In comparison, a further variant, which is equipped with exemplary helical strakes. This is demonstrated in figure 6. As we can see in the velocity plot, the alternating vortices don't occur anymore and the curve does not show the oscillating course.

The example in figure 6, has three helices, each 120 degrees apart around the cylinder with a pitch of 7m and 1.2 revolutions each. The helices are not constructed all the way to the top, since in the upper region the vortices are already interrupted by the flow above the stack.

Comparison of the lateral force, time dependent can be seen in figure 7.

As we can see in the graph in figure 7, the stack that is equipped with the helical strakes shows much lower lateral forces and does not oscillate around the x-axis. These are, of course, exemplary results for a slice of the stack, but the qualitative difference is clearly visible.

Thus, the Scruton strakes seem to present an economical solution as opposed to a structural reinforcement of the stack, while at the same time minimizing additional load. Increasing mass often provides remedies, but clever solutions are often the most efficient and here we could explain and present the clever solution using FloEFD with its SmartCells technology.

Additional applications of the described Scruton strakes can be found in measurement technology to avoid the damage of protection tubes, in oil rigs, car antennas and electrical transmission towers.

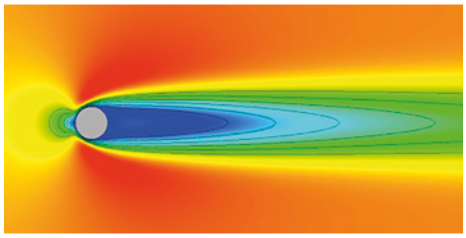

Figure 2. Steady flow at low Re number

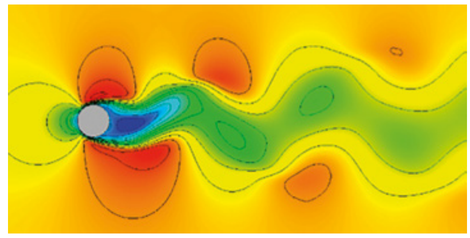

Figure 3. Oscillating at Re>100

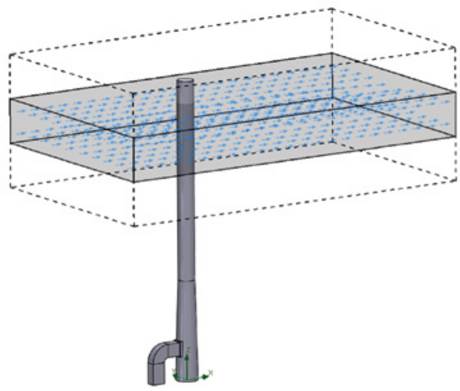

Figure 4. FloEFD simulation for one slice

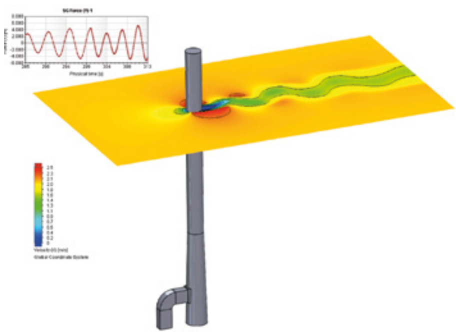

Figure 5. Stack without strakes

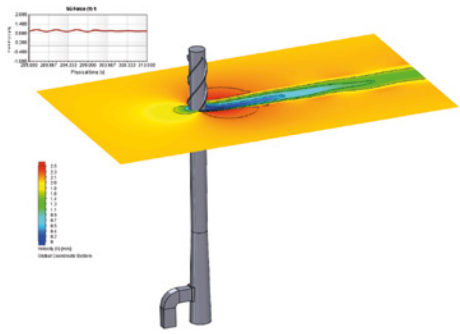

Figure 6. Stack equipped with helical strakes

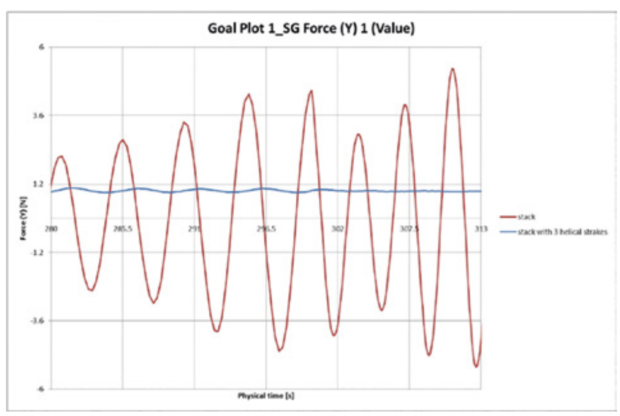

Figure 7. Time dependent lateral forces

References

[1] C. Scruton and D.E.J. Walshe, A Means for Avoiding Wind-excited Oscillations of Structures with Circular Or Nearly Circular Cross-section, National Physics Laboratory (Great Britain), 1957.

https://www.youtube.com/watch?v=rlpUhgfEZPU

http://www.helicalstrakes.com/

https://en.wikipedia.org/wiki/Scruton_number

https://en.wikipedia.org/wiki/Strouhal_number