ROCKET-SCIENCE FOR FRENCH FRIES

How computational fluid dynamics helped in the development of innovative jet mixers for tanks

01

> NOT MANY people understand that the oil used to fry chips meets many challenges on its route from the field to the frying pan. Some of them arise during the liquid bulk storage phase, such as layering of the oil and building of sediments in the shore tank due to inefficient mixing. This, in turn, leads to the decomposition of oil quality and direct costs, as well as negative externalities associated with the need for cleaning the shore tank, sediment utilisation, and related production idle time. Efficient mixing is a critical component of the storage phase of many products besides vegetable oils, e.g. biofuels, refined oil products, crude oil, distillates, dairy products, paints, aromatics and many others. This is where computer algorithms help to provide for efficient mixer design.

WHAT IS COMPUTATIONAL FLUID DYNAMICS?

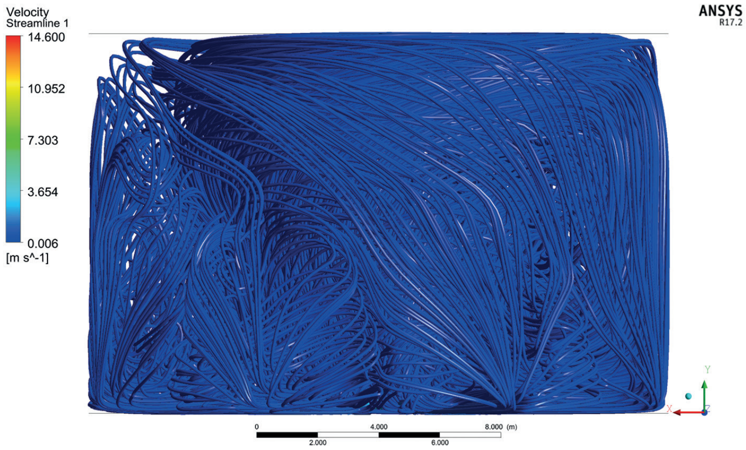
Computational fluid dynamics (CFD) is the area of the fluid dynamics science for the analysis of a fluid's behaviour by using an extended range of numerical methods and data structures. The choice of application of an individual numerical method, or a combination of methods, varies according to the type of fluid and the environment to be analysed. Different methods, or a combination, achieve better results when studying the interactions of liquids and gases. This approach has found valuable application in a wide range of industries, from weather prediction to complex aerodynamics, not excluding the interdisciplinary applications in biology, nanoscale- or micro-engineering (Halbleib M., ETH Zurich, 2020). More importantly, the application of CFD can obtain precise results for liquids and environments which are impossible or difficult to experiment with, such as hazardous products.

02

Elements of the CFD process and its parameters

	Problem formulation	What is the main objective of the analysis?
Preparation	**Geometry selection**	Determination of the domain size and shape, assumptions and simplifications.
Preparation	**Flow physics**	Specification of flow conditions (viscous, turbulent, etc.) and key fluid parameters (density, viscosity, temperature, etc.); set of initial and boundary conditions.
Preparation	**Mesh/Grid design**	Mesh or Grid has to be modelled precisely for eh chosen geometry and taken into account the fluid parameters. The more detailed mesh provides for more precise fluid model.
Preparation	**Numerical solution**	Appropriate solvers (or numerical equations) to be chosen fro the given specific objective.
	Simulation/Reporting	Performance of the simulation using commercial code.
	Post-processing	Verification and validation of the obtained flow model and visualisation of the liquid flow.

03



The prototypes of modern CFD methods lie within the first explorations of the behaviour of liquids by Archimedes, Leonardo da Vinci, Isaac Newton, Daniel Bernoulli, and many others. The true birth of the methodology came more than 200 years ago, after the completion of the Navier-Stokes equations describing the physics of viscous fluid substances. The French engineer Claude-Louis Navier introduced complex equations describing such elements as conservation of mass, momentum, pressure, species, and turbulence, which were further developed by the British physicist and mathematician Sir George Gabriel Stokes.

The Navier-Stokes equations were fully exploited only with the development of computing power and modern supercomputers. Thus, a great breakthrough was achieved by NASA during the 1960s, by completing CFD methodology with a full spectrum of numerical methods, including particle-in-cell, vorticity-stream function, and ubiquitous turbulence model, to name a few. Today, modern CFD uses a wide range of computational methods and algorithms, which makes its application a true art. The choice of the applied assumptions and associated equations have a major effect on the outcome of a particular problem-solving task. Figure 2 serves as a good example of the key building blocks of any CFD task.

CFD APPROACH IN STUDYING INDUSTRIAL MIXERS

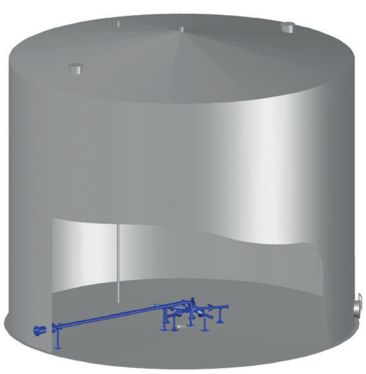
The application of CFD modelling to industrial mixing processes gained popularity in the 1990s, supported by the ample availability for validating its numerical forecasts. The range of goals

Efficient mixing is a critical component of the storage phase of many liquid products

pursued by mixing of the products stored in shore tanks is surprisingly broad – from keeping the whole blend homogenous or at certain target physio-chemical characteristics, to ensuring the bonding of the two (or more) ingredients of the compound liquid.

Although the scope of objectives is vast, currently there are only two major types of mixers widely presented on the engineering solutions market – propeller mixers and jet flow mixers. The invention of the latter may be the outcome of the successful development of CFD

04



modelling techniques, as without such it would not be possible to achieve an optimal approximation of the fluid flows generated by the jet nozzles and thus to precisely calculate the configuration of the mixer. A jet mixer may seem to be very simple in its design, however, it contains a far greater share of its value in the modelling, simulation, and computational efforts preceding manufacture – the computational stage may last up to a few weeks depending on the inputs.Figure 3 shows the final results of the CFD software fluid flows visualisation.

Far better results are achieved with properly designed jet mixers. A CFD study on mixing by a combisystem of jet and agitator mixers in a large 19,000 m^3 capacity crude oil storage tank found that the homogenisation speed of crude oil was four times faster when applying the combi jet plus agitator system, compared to the incumbent sole agitator use[1].

According to Saber Evnat's experience and computational data, similar efficiency gains have been proven by the comparison of stand alone jet mixers with agitators usage in a wide range of tank size, from 500–20,000 m^3.

CFD AND JET MIXERS BY SABER EVNAT

Innovations are born in two dimensions, by the invention of a new technical order, completely new tools and solutions, or by the interdisciplinary combination of existing tools to obtain more efficient solutions or solve earlier avoided problems. Saber Evnat is an example of the latter.

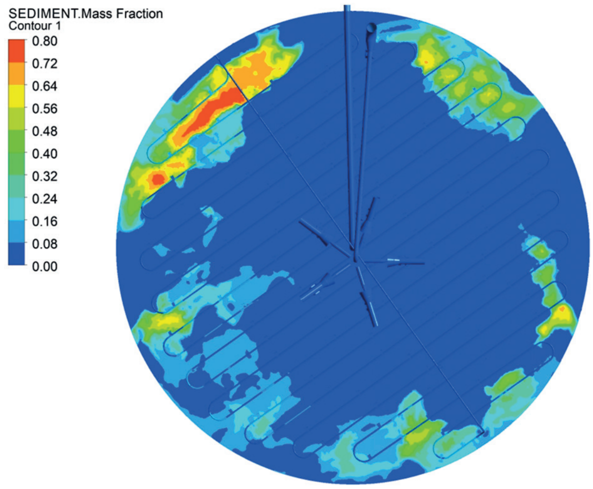
The underlying idea was that if a jet engine can move an aircraft forward by compressing the air and creating airflow, then it should be possible to make a liquid flow by compressing it with a jet force.

Having accumulated extended experience in CFD modelling, Saber Evnat focuses on one core problem – to design a super-fast and efficient jet mixing device which could be applied in a wide range of industries and for a long list of products.

Saber Evnat has proved its profound understanding and mastering of CFD tools by designing, manufacturing, and installing dozens of units for shore tanks ranging from 500–20,000 m^3 in capacity, operating with products such as fuel and crude oils, gasoline, rapeseed, sunflower and soya oils, lecithin, and bitumen.

Saber Evnat uses ANSYS modelling software to individually design each mixing device. It takes up to 300 hours of computational power to create a working 3D model for each specific case, taking into account a full range of parameters

05



of both the product characteristics and storage geometry (Figure 5). All employees involved in modelling and design are experienced engineers who are also certified ANSYS users, ensuring a high level of quality and precision during this vital stage.

As a result, Saber Evnat clients receive high-tech production equipment that achieves excellent results and savings from day one. The EVNAT jet mixer offers product mixing up to four times faster than traditional propeller mixers. For instance, different quality of fuel oil batches of a total volume of 4,000 m^3 can be homogenised just in two hours, compared to 10–12 hours for a propeller mixer.

As each EVNAT jet mixer is individually designed and built, it leaves no blind zones, which typically cannot be achieved with propeller mixers. It again adds to production speed and quality level. When used regularly, the jet mixer prevents the accumulation of product sediment inside the shore tank, which maintains the shore tank floor to prolong its life, and eliminates the problem of the tank cleaning and utilisation of the bottom sediments, which also saves associated costs.

In addition to the high production speed and high level of quality, Saber Evnat clients also appreciate the high level of security and reliability. The jet mixer does not contain any moving parts, neither mechanical nor electric. Hence, there is nothing that can break and cause production delays or stoppages, there is no need for maintenance or repairs and no associated costs.

For shore tanks with a capacity of more than 10,000 m^3, it is usually necessary to install two or more propeller mixers to achieve an acceptable level of mixing. Both mixers use energy and add to CO_2 emissions. EVNAT jet mixers are energy efficient, and and are compliant with the ISO 50001.

The solutions offered by Saber Evnat are a good example of the application of digital technologies in the liquid storage and transhipment industry, which besides its core efficiency gains, offers additional benefits, such as the minimisation ofunwanted product loss (residues).

Reference

1. Rahimi M and Parvareh A. (2006). CFD study on mixing by coupled jet-impeller mixers in a large crude oil storage tank. *Computers and Chemical Engineering 31* (7), 737-744.

For more information:

This article was written by Ekaterina Tuzovskaya, and Eugene Starokaznikov from SIA Saber Evnat. saberevnat.eu

01 The EVNAT jet mixing device

02 Elements of the CFD process and its parameters

03 Example of fluid behaviour visualisation obtained though ANSYS software

04 EVNAT jet mixer

05 The final result of the ANSYS software use for the purpose of calucalting optimal EVNAT jet mixing device parameters

06 An example of a Saber Evnat jet mixing device

06