TECHNICAL REPORT

White paper

CAVITATION

Energy from cavity collapse

A TOOL FOR PROCESS INTENSIFICATION

E-PIC Srl - 2023

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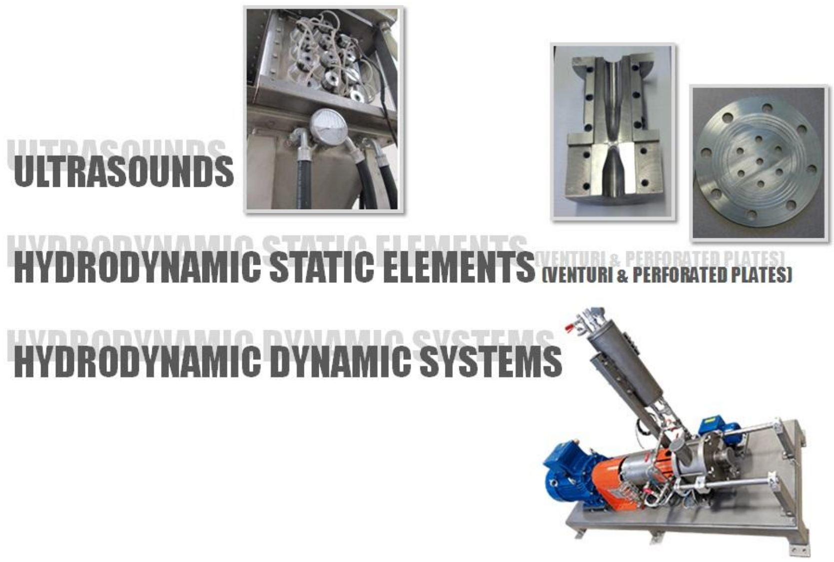
INTRODUCTION



Cavitation-based technologies are gaining interest in industrial processes, due to their cost effectiveness in operation and their ability to work as energy concentrator. The main concept is to exploit the localized energy released by cavitation in a positive way.

These systems induce and control cavitation.

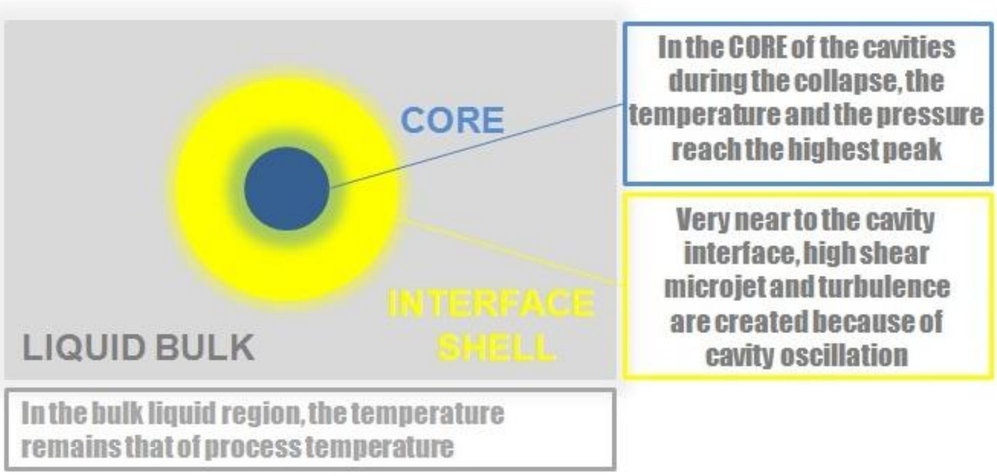
They generate intense shear, microjet streaming, high intensity local turbulence, localized high pressure and temperature and highly oxidizing radicals and for these reasons, they can be used as process intensification technique thanks to their ability to improve yields, reduce time and costs.

DEFINITION OF CAVITATION

Cavitation involves the formation, growth and collapse of vapour bubbles (cavities) occurring in a few milliseconds at multiple locations in a liquid. During this phenomenon high-pressure and high-temperature conditions are created and a large amount of energy is realized in a very short duration.

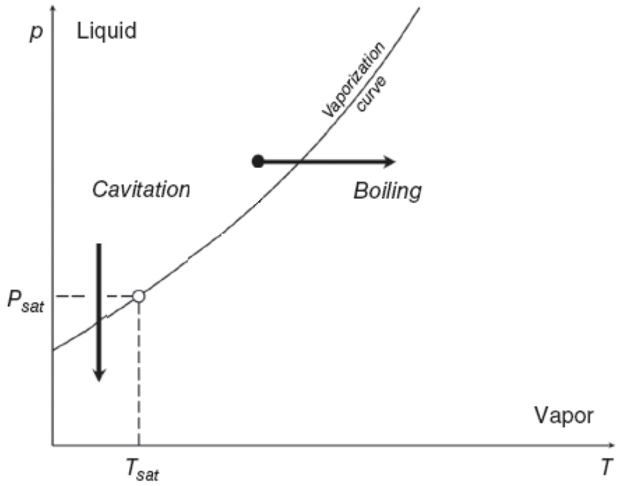
Each cavity acts as a microreactor, and follow its cycle.
1. formation of vapor cavities when the pressure drops to the local saturated vapor pressure
2. isothermal expansion of cavities up to their maximum size
3. compression and adiabatic collapse of cavities

HOT SPOT THEORY



Cavitation and boiling are a rapid phase-changing phenomena.

The pressure / temperature chart shows the difference between Cavitation and Boiling:



CAVITATION is the liquid to vapour passage at constant temperature - vertical path - the driving phenomenon for phase change is a pressure reduction.

BOILING is the liquid to vapour passage at constant pressure - horizontal path - the driving phenomenon for phase change is an increase in temperature.

The next step is to understand why the pressure in a flow can drop to the vapour pressure promoting cavitation.

STATE OF ART OF MODERN CAVITATIONAL TECHNOLOGIES

Depending on the way of generation, different of cavitation processes are known: optical, particle, acoustic and hydrodynamic cavitation. The cavitation phenomena realized by optic and particle methods are not widely used.

Why the pressure in a flow can drop to the vapour pressure promoting cavitation?

- In acoustic cavitation it is due to sound waves passing through the fluid (ultrasounds)
- In hydrodynamic cavitation (HC) it is due to the fluid passage through constrictions, with different geometries (static and dynamic HC)

Dynamic HC

Ultrasounds

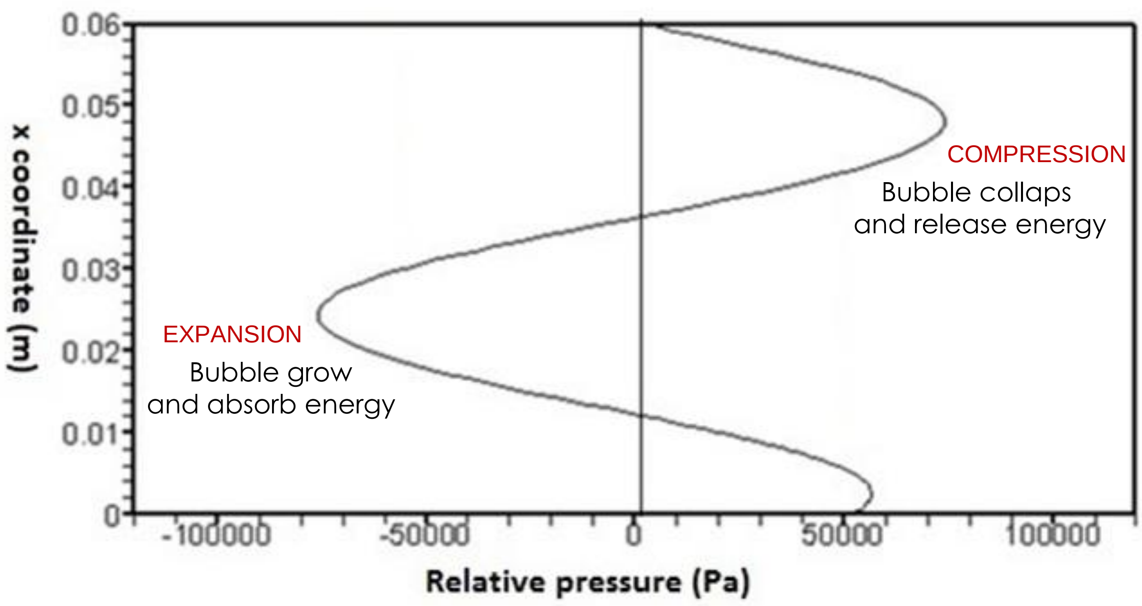
Static HC

ACOUSTIC CAVITATION

ACOUSTIC CAVITATION uses ultrasound for generating cavitation.

How cavitation is generated?

When a liquid is subjected to high frequency sound waves (20 kHz to 200 MHz) of adequate intensity, local pressure may dip to the vapor pressure and cavitation may occur.



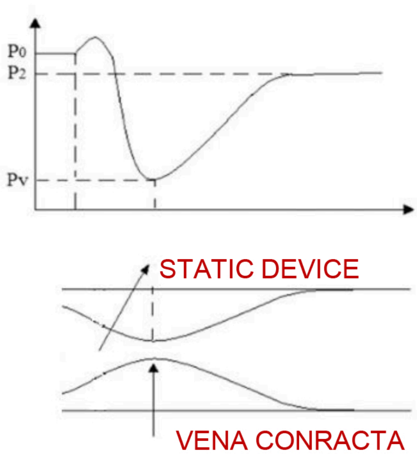
The trasmission of ultrasound waves consists in expansion and compression cycles.

HYDRODYNAMIC CAVITATION STATIC DEVICES

Cavitation is produced by forcing a fluid to flow through a constriction.

In static devices the variation of pressure through a constriction in a pipe (Venturi, orifice) with different geometries promotes the generation of cavities.

<u>How cavitation is generated?</u>



At the constriction, the kinetic energy of the liquid increases at the expense of pressure. The pressure decreases to the vapor pressure of the liquid at the vena contracta, causing flashing of the liquid and generating numerous vapor cavities.

Subsequently, as the liquid jet expands, the velocity decreases and the pressure recovers in the downstream section of the cavitating device resulting in the collapse of cavities.

HYDRODYNAMIC CAVITATION DYNAMIC DEVICES

A dynamic device achieves controlled hydrodynamic cavitation by forcing the process fluid through its rotor-stator apparatus. During high speed rotation, rotor channels are periodically aligned with stator channels.

How cavitation is generated?

The process fluid is accelerated in the radial direction in the cavitation chamber. As it flows through the free channels within the machine, the fluid is subjected to a pressure wave resulting in cavitation.

The inception and the intensity of cavitation depends on specific configuration of rotor – stator, rotating speed and flow rate of liquid through the device.

COMPARISON:
VENTURI VS PERFORATED PLATES

PERFORATED PLATES

- Single or multiple holes to control the intensity of cavitation and the number of cavitational events

VENTURI

- Different shapes (slit, circular, and elliptical) to obtain different cavitational conditions

-For slit and elliptical types there is the possibility to generate more cavities

-Ability to enhance cavity life

COMPARISON:
STATIC HC VS DYNAMIC HC

STATIC HC	DYNAMIC HC
-Risk of clogging when treated liquids contain suspended solids	-It can treat suspension, with a content of solid near 30%
-Cavitation bubble collapse occurs near the walls of the element	-Cavitation occurs in the bulk of the liquid
-The fluid to be treated has to be pumped at high pressure at the inlet of the element	-The fluid to be treated can be pumped at near atmospheric pressure
-Low efficiency	-More efficient: it generates thousands of cavitational events with a simgle passage

COMPARISON:
ULTRASOUNDS VS DYNAMIC HC

ULTRASOUNDS

-Limited depth of wave penetration into the liquid media

-Difficult scale up

-Lower performance at industrial scale compared to laboratory scale

-Effects generated: cavitation

-Low performance in turbulence in respect of laminar flow

DYNAMIC HC

-All the liquid treated is subjected to cavitation

-Reliable scale up

-Same efficiency at industrial scale compared to laboratory scale

-Effect generated: cavitation + shear stress + turbulence

-High performance also in turbulence flow

- Single step process

- Suitable for industrial-scale processing

- Easy scale up (especially HC cavitational systems)

- Non thermal processing technologies

- More energy efficient than many other conventional techniques

KEY BENEFITS OF CAVITATIONAL DEVICES