Owing to their specific construction a 3D mesh was used, while the plain tube was studied easily with a 2D mesh. Despite this difference, the comparison of results was satisfactory.

There are different kinds of fouling and therefore, before applying a specific model, the results of a simple thermo-hydraulic analysis were used to plot the Ebert and Panchal correlation, one of the most important theories to predict fouling threshold using crude oil as a processing fluid. This first comparison already shows the higher fouling rate in the absence of twisted tapes but other models were used to verify this concept.

Crude oil components are responsible for chemical reactions, whose products create fouling. They happen on the tube wall, so the fouling layer begins to appear near the wall and its thickness grows with time.

Previous works experimented these aspects of fouling using species transport model, which allows results in terms of products concentration and their distribution on the wall to be obtained. It is important to note the higher values of coke and $salt_w$ concentration for the plain tube rather than the tube with twisted tape, and, looking at their trend, fouling deposits can be observed along tube wall and in a greater amount near the outlet section.

Another important parameter was determined to compare fouling in different situations: fouling resistance. It was determined using the total heat transfer coefficient and subtracting from it the value obtained in the absence of fouling, which corresponds to the initial value measured. In this case, for the brief time analyzed, the fouling resistance in the plain tube is twice that compared with the situation in the presence of twisted tapes.

Considering all the parameters employed, it can be stated that fouling phenomena are reduced using twisted tapes in tubular heat exchangers with crude oil in laminar regime and it is another advantage provided by this cheap and useful insert, widely used in industrial applications.

REFERENCES

[1] Kaliakatsos D, Cucumo M, Ferraro V, Mele M, Galloro A, Accorinti F. (2016). CFD analysis of a pipe equipped with twisted tape. International Journal of Heat and Technology 34(2): 172-180. https://doi.org/10.18280/ijht.340203

[2] Bott TR. (1995). Fouling of heat exchangers.

[3] Jamialahmadi M, Soltani B, Muller-Steinhagen H, Rashtchian D. (2009). Measurement and prediction of the rate of deposition of flocculated asphaltene particles from oil. International Journal of Heat and Mass Transfer 52(119): 4624-4634. https://doi.org/10.1016/j.ijheatmasstransfer.2009.01.049

[4] Ebert W, Panchal CB. (1995). Analysis of Exxon crude-oil-slip stream coking data. Fouling mitigation of industrial heat exchangers. San Luis Ebispo, CA (United States).

[5] Bayat M, Aminian J, Bazmi M, Shahhosseini S, Sharifi K. (2012). CFD modeling of fouling in crude oil pre-heaters. Energy Conversion and Management 64: 344-350. https://doi.org/10.1016/j.enconman.2012.05.003

NOMENCLATURE

D	mass diffusion coefficient, $m^2. s^{-1}$
h	enthalpy, $J. kg^{-1}$
h^0	enthalpy formation, $J. mol^{-1}$
k	fluid thermal conductivity, $W. m^{-1}. K^{-1}$
$\dot{m}$	mass flow rate, $kg. s^{-1}$
M_w	molecular weight, $kg. mol^{-1}$
$\dot{q}$	heat flux, $W. m^{-2}$
R	gas constant, $J. mol^{-1}. K^{-1}$
r	net reaction rate, $kg. m^{-3}. s^{-1}$
Re	Reynolds number
R_f	fouling resistance, $m^2. K. W^{-1}$
S_h	heat of chemical reaction, $W. m^{-3}$
T	temperature, K
T_{film}	film temperature, K
t	time instant, s
u	velocity in the x direction, $m. s^{-1}$
v	velocity in the y direction, $m. s^{-1}$
$\vec{v}$	velocity vector, $m. s^{-1}$
w	velocity in the z direction, $m. s^{-1}$
Y	local mass fraction

Greek symbols

α, β, γ	Ebert-Panchal constants
α	heat transfer coefficient, $W. m^{-2}. K^{-1}$
μ	dynamic viscosity, $kg. m^{-1}.s^{-1}$
ρ	fluid density, $kg. m^{-3}$
τ	shear stress, $N. m^{-2}$

Subscripts

asph	asphaltene
b	bulk
i	chemical species
s	surface
saltb	saltb
t	time instant, with fouling
w	wall
0	initial time instant, without fouling

Apexes

t	time instant, with fouling
0	initial time instant, without fouling