DPIE System to Improve Cooling Capacity of a Canola Oil to be Used as a Quenchant

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***Abstract:* -** In the paper a new approach in improving cooling capacity of vegetable canola oil is considered. It consists in processing of oil with a discrete–pulse input of energy (DPIE) technique which creates vigorous agitation of oil, high local pressure, and cavitations effect generated by DPIE technology. During processing of oil, which contains porous micro-particles, the oil penetrates effectively into micro-cavity and processed oil, containing micro – particles, looks like homogeny liquid. The cooling capacity of canola oil, processed by DPIE technique, were investigated by authors. The authors came to conclusion that investigation of cooling capacity of such oils must be done on the basis of registration the surface temperature of probe in different areas. Solving inverse problem, will provide engineers with accurate data for computer simulations. The method can be used for producing of magnetic liquids which in our case is less expensive . It is discovered by authors that DPIE processing eliminate film boiling.

Key- Words: - DPIE process, Canola oil, Cooling capacity, Inverse problem, Film boiling, Elimination.

1 Introduction

In the Institute of Engineering Thermophysics of NASU of Ukraine was developed a method of discrete–pulse input of energy (DPIE) into different kinds of liquids which is used in many branches of industry, namely in a technology of reception of biodiesel fuel and its mixes [1]. In this paper a possibility of use of DPIE for improving cooling capacity of different kinds of quenchants is widely discussed. The method consists in local input of energy which is discrete with passing of time. The method creates local high pressure, cavitations effect, and agitation of liquid which is so vigorous that oil or another liquid penetrates into micro cavity of micro particles. This effect can be used for preparing magnetic liquids which is very expensive technology. DPIE method can significantly decrease the cost of magnetic liquids. In the paper the advantage of DPIE was fulfilled in disks cylindrical system of rotor type for processing of quench ants (see Fig. 1 and Fig. 2). The experiments showed the possibility of regulation of cooling capacity of quenchants.

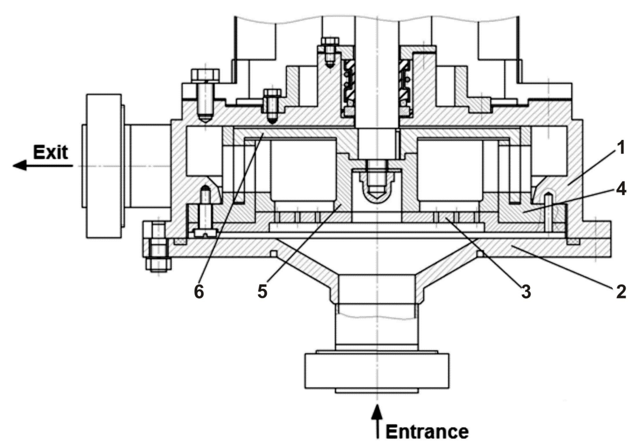

Fig. 1 Scheme of a new rotor - pulse system [1]: 1 – mounting frame; 2 – lid; 3 – stator of the disk's complex; 4 – stator of the cylindrical complex; 5 – rotor of the disk's complex with the wings; 6 – rotor of the cylindrical complex.

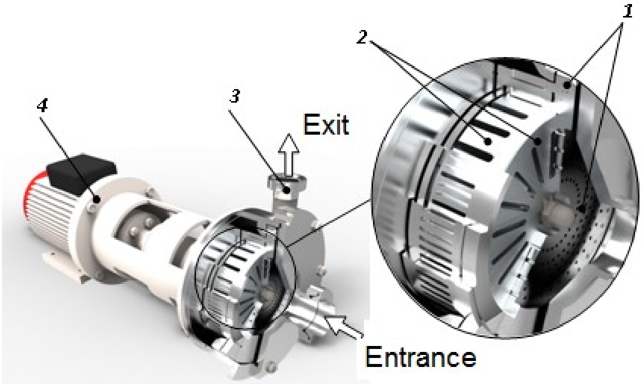

Fig. 2 General assembly of DPIE system [2] for processing different kinds of quenchants: 1 – stator; 2- rotor; 3 – mounting frame; 4 – electric motor.

The developed method will be used for global database elaboration of different kinds of oils processed by DPIE technique [1, 2].

2 Main equations used for solving inverse heat conduction problem

The values of heat transfer coefficients (HTCs) were calculated by solving an inverse heat conduction problem (IP) using a nonlinear heat conductivity equation (1) with a boundary condition (2), initial condition (3) and symmetrical condition (4) in the case when experimental data are provided at the surface or near the surface [3, 4]:

$$\frac{\lambda}{a}\frac{\partial T}{\partial \tau} = div\left(\lambda gradT\right)$$
(1)

$$\left[\frac{\partial T}{\partial r} + \frac{\alpha}{\lambda}\left(T - T_m\right)\right]_{r=R} = 0 \quad (2)$$

$$T\left(r,0\right) = T_o$$
(3)

$$\frac{\partial T}{\partial r} = 0 \quad (4)$$

There are several methods for solving the inverse heat conduction problem, which are analyzed in Ref. [4]. For solving the inverse problem, thermal properties of AISI 304 steel and Inconel 600 were used as a function of temperature. (see Table 1).

Table 1 Thermal properties of AISI 304 steel and Inconel 600 material as a function of temperature.

Properties	100°C	300	500	700	800°C
Steel 304 $\lambda, W/mK$	17.5	19.6	23	26.3	27.8
Inconel 600 $\lambda, W/mK$	14.2	17.8	21.7	25.9	28.3
Steel 304 $a \cdot 10^6, m^2/s$	4.55	4.7	5.3	5.8	6.2
Inconel 600 $a \cdot 10^6, m^2/s$	3.7	4.5	5.1	5.6	5.8

An average effective HTC can be obtained using a regular thermal condition theory [5] based on Eqs. (5), (6), and (7):

$$\frac{1}{a}\frac{\partial T}{\partial \tau} = div\left(gradT\right)$$
(5)

$$\left[\frac{\partial T}{\partial r} + \frac{\bar{\alpha}}{\lambda}\left(T - T_m\right)\right]_{r=R} = 0$$
(6)

$$T\left(r,0\right) = T_o$$
(7)

In this case, average values of thermal conductivity $\bar{\lambda}$ (W/mK) and thermal diffusivity $\bar{a}$ (m²/s) were used.
The regular thermal condition theory [6] provides simple Eq. (8) for evaluating an average HTC α (W/m² K):

$$\bar{\alpha} = \frac{5.783\lambda Bi_V}{D} \quad (8)$$

3 Choozing appropriate additives to canola oil to be processed by DPIE method

For investigation, several variants with several additives were chozen (see Table 2). Number 1 variant was just raw still canola oil at 20 °C. The number 2 variant was raw canola oil processed by DPIE technique. The number 3 variant was raw canola oil with small amount of aeroseel processed by DPIE. The number 4 variant was canola oil with small amount of chloride ($MgCl_2$) processed by DPIE. This variant was chozen since in Ukraine many companies use two step quenching of tools . In the first step tool is quenched in water salt solution to accelerate cooling, and then tool is immersed into oil to decrease significantly cooling rate during martensite transformation. With a time oil changes its cooling properties due to accumulation salt in oil that can be connected with the possibility of crack formation. The authors want to see how DPIE process can change the cooling capacity of canola oil with small additives of salt. The 5th variant was canola oil with small amount of methyl – silicon acid hydrogel and processes by DPIE. The 6th variant was canola oil with methyl – silicon acid xerogel, and processed by DPIE techniqe [2].

Table 2 Quenchants to be tested and testing condition

Quenchant Закалка	Number
Canola at 20 ºC	1
Canola+DPIE	2
Canola+aeroseel	3
Canola+$MgCl_2$ + DPIE	4
Canola + MSAH +DPIE	5
Canola + MSAX +DPIE	6

Notes: DPIE – Discrete - Pulsate Input of Energy; MSAH – Methyl-Silicon Acid Hydrogel; MSAX – Methyl- Silicon Acid Xerogel

4 Results of experiments and their explanation

The quenchants after processing were tested by standard probe. Results of testing are presented in Fig. 3 and Fig. 4. Effective heat transfer coefficients at the temperature 700 ºC and 450 ºC are presented in Table 3.

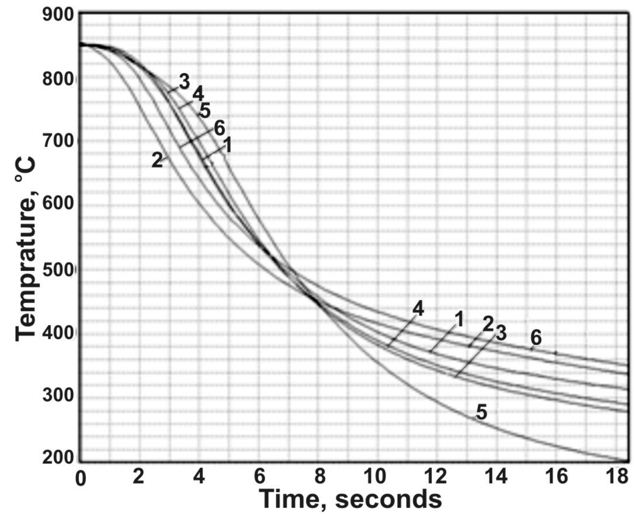

Fig. 3 Cooling curves obtained for standard probe when quenching in different quenchants (see Table 2).

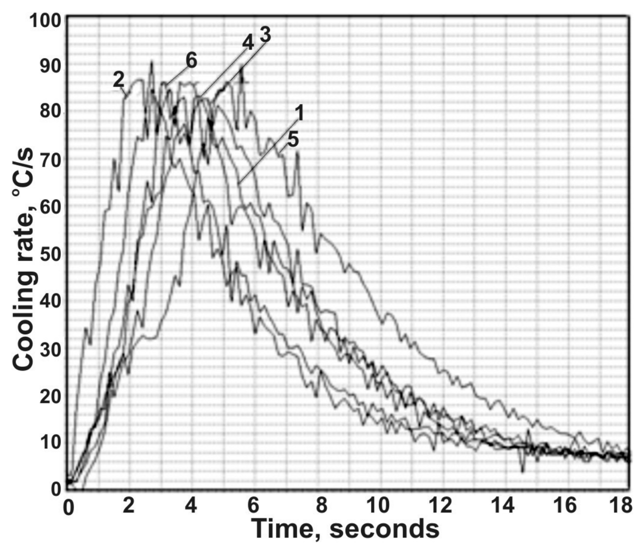

Fig. 4 Cooling rate of core standard probe versus time for canola oils which were processed according to plan shown in Table 2.

Authors [3] tested a canola oil which was purchased at the local market in Sao Carlos , Brazil, using the same standard probe (12.5 mm diameter). The testing was made in non – agitated condition at temperature 60 ºC. Authors [3] reported that film boiling was absent at all and HTC at 700 ºC was 2455 $W/m^2 \cdot K$ and at 450ºC was 1810 $W/m^2 \cdot K$.

Table 3 Heat transfer coefficients (HTCs) of canola oil with and without additives and processed by DPIE.

#	Cooling rate, Max	Core temperature, ºC	α, W/m^2K Max	α, W/m^2K at 450 ºC
1	83	660	2082	1150
2	86.3	740	1925	958
3	82.5	670	2057	1320
4	83	690	1925	1340
5	86	650	2198	2107
6	86	710	2045	650

Table 4 Effective heat transfer coefficients (HTC, W/m^2K) of non – processed and processed canola oil within the interval of temperature 350 ºC – 200 ºC

Raw canola oil and its processing	Quenchant Number	HTC within 350 ºC-200 ºC in $W/m^2 \cdot K$
Raw canola at 30ºC	1	430
Canola+DPIE	2	302
Canola oil+ aeroseel+ DPIE	3	305
Canola oil + $MgCl_2$ +DPIE	4	297
Canola+ MSAH +DPIE	5	988
Canola+ MSAX +DPIE	6	300

When testing canola oil in non –agitated condition, film boiling was observed. Tests were made at temperature 30 ºC. We compare results of testing obtained for processed by DPIE technique. In our case HTC were significantly less at 450ºC (see Table 5). DPIE processing decreases HTC at low temperatures. However, processing eliminates film boiling. In processed by DPIE technique, film boiling was absent.

Discussion

In the paper a standard ASTM D6200 probe was used for investigation the cooling capacity of quenchants. However, the standard probe doesn't provide full thermal characteristics of a quenchant. It provides only with the average effective heat transfer coefficients which can be used for cooling time calculation at the core of steel parts. Another shortcoming of standard probe is use of an average value of thermal conductivity and thermal diffusivity (see equations (5), (6) and (7)). That is why in the future authors plan to use probes similar to probe of LISCIC- NANMAC which can provide with the accurate data and a full information connected with the thermal processes taking place at the surface of steel probe.

5 Summary

1. The best results concerning the cooling capacity of the vegetable canola oil were received after processing oil by DPIE technique. Similar results were received when special additives of small concentration were added.

2. It is established by authors that processed by DPIE canola oil has better cooling capacity at high temperature since film boiling after processing is absent.

3. Using DPIE system, it is possible to prepare different kinds of mixtures to be used as quenchants. Further investigations are needed to explain absence film boiling after DPIE processing.

4. Further results of investigations connected with the effect of DPIE and non – linear wave mechanics [1, 9, 10, 11] on cooling capacity of quenchants will be discussed at the WSEAS Conferences.

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