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ON THE POWER CHARACTERISTICS OF A MODIFIED HELICAL-SCREW MIXER

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A new design of a helical-screw mixer has been presented. The experiments have been conducted to assess the energy-related characteristics of the proposed mixer. It has been shown that the energy-related characteristics of the modified and normalized helical-screw mixers appear to be close to each other. The results of the experiments are presented to prove this provision.

Mixer, helical-screw mixer, modified mixer, power factor, new design, concentrated aqueous solutions

In case of mixing the high-viscosity media the energy provided by a mixer normally used for mixing thin liquids, fades out in immediate proximity to the mixer blades and the major volume of liquid filling the vessel appears to be inapproachable for any mechanical effect, which entails mixing of the medium components. In this respect, in order to mix such media, it is necessary either to effect recirculation of the mixed medium through any external devices ensuring mixing of the medium components or to provide circulation of the mixed medium in the working volume of the vessel through a mixing zone, i.e. through a zone located in immediate proximity to the mixer blades. In practice such a function is performed by the ribbon-blade and helical-screw mixers [1].

The ribbon-blade mixers require, as a rule, the use of low-speed reduction gears designed for transmitting very high torques, which significantly restricts its usage due to the high cost of equipment.

The helical-screw mixers feature essentially smaller dimensions and, accordingly, they allow using more high-speed driving devices as the drives. However, the production of blades of these mixers causes great difficulties, since they require using special tooling normally absent at the chemical machine-building plants, which allow manufacturing of the helical-screw blades with constant pitch.

The design of helical-screw mixers as shown in Figure 1 can be significantly simplified, if every half of the helical blade pitch is replaced with an annular segment of a semi-circular disk. In this case, While in a standard helical-screw mixer the blade angle continuously

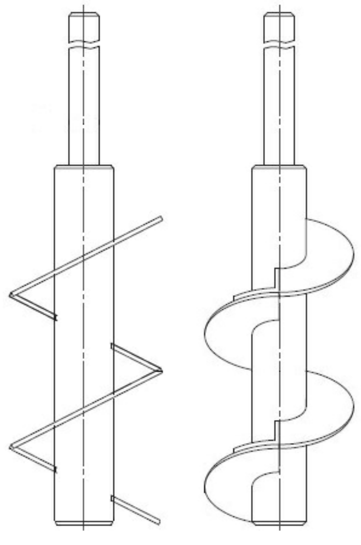

Fig. 1
Modified helical-screw mixer

varies from the screw root towards the outer rim of the helical ribbon, in the new design the discrete annular segments are flat and therefore exhibit a constant angle with respect to the screw root which equals 22.5 degrees. At that, a triangular clearance will get shaped in the area of interfacing two half-blades with a shaft, which will probably require usage of the special "plugs" (Fig. 2) to prevent flow of the medium through these clearances and ensuring its circulation across entire height of the mixer.

It can be expected that the resistance coefficient and, accordingly, the energy-related characteristics as well as the other parameters of the proposed mixer design can essentially differ from the similar characteristics of the standard helical-screw mixer.

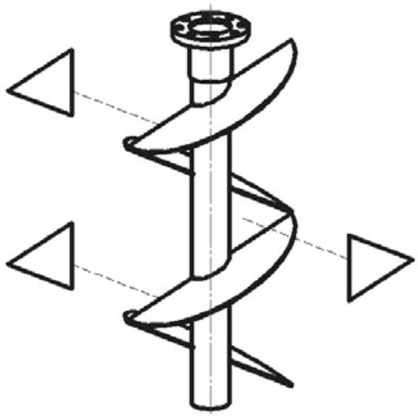

Fig. 2
Position of the "plugs" in the design of the modified helical-screw mixer

The measurement of power expended by the modified mixer (Fig. 1) has been performed at the installation, the diagram of which is shown in Figure 3.

Vessel (4) filled with high-viscosity liquid has been put on rotary table (5) with the driving shaft located in the bearings. The torque emerging in the course of mixer (3) operation has been determined by the torque sensor (2).

The mixer rotation (from 6 to 600 rpm) has been provided by the controllable electric motor (NORDAC controller) attached to an individual stand.

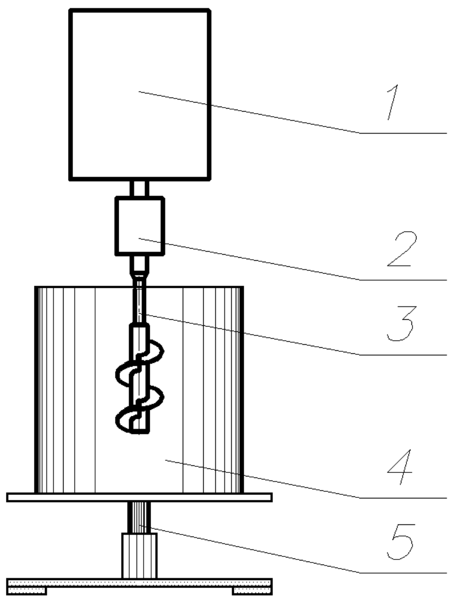

Fig. 3
1 – Mixer motor; 2 – Torque sensor; 3 – Mixer; 4 – Vessel; 5 – Rotary Table Shaft

A modified helical-screw mixer featuring diameter of 50 mm (Fig. 1) has been used for mixing both with a draft tube (inner diameter of 57 mm, tube wall thickness of 4.5 mm), and without it located into a cylindrical glass vessel with flat bottom featuring inner diameter of 140 mm.

Since the interfacing of the radial end faces of flat neighbouring half-blades of such a mixer is only possible at the radius equal to the mixer radius, then the open cavities (windows) not covered by the blades occur along the mixer's height. In this case there appears a possibility for overflowing a medium through "windows", which can decrease the consumed power and the total circulation of medium in the vessel. In order to overlap these cavities the triangular vertical plates (plugs) can be used (Fig. 2).

Thus, there appear 4 structural variants for investigating operation of the mixer: 2 variants of mixer structural arrangement – including plugs and without plugs, and 2 variants of vessel structural arrangement – including draft tube and without tube .

Both concentrated and diluted aqueous solutions of starch syrup and glycerine were used as the mixed medium. The viscosity of mixed media has been determined with the use of viscosimeter Rheo-Viskometer nach Hoppler, which makes it possible to measure viscosity at different values of fluid shear rates of the investigated media. The performed measurements have shown that the viscosity of media used for investigation and the aqueous solutions thereof does not depend on the fluid shear rate and the used liquids can be attributed to a class of Newton liquids.

The processing of experimental data on measuring loads have been conducted according to the following diagram:

$$M_{TR} \rightarrow P = 2\pi \cdot N \cdot M_{TR} \rightarrow \begin{array}{c} Ne = P/(\rho \cdot N^3 \cdot d_m^{\ 5}) \\ Re_C = \rho \cdot N \cdot d_m^{\ 2}/\mu \end{array}$$

Figure 4 shows the results of measuring power factor in the form of a dependence $Ne=f(Re_c)$. It proceeds from this chart that at $Re_c < 30$ the power criterion Ne is inversely proportional to the Reynolds criterion, which corresponds to a laminar flow regime (the same range of Reynolds numbers covers the normalized methods of calculation as well [2]). This dependence in the region $Re_c < 30$ can be presented as follows in an analytical form:

- for a vessel with draft tube at $d_p/d_m = 1.14$ and $D/d_m = 2.62$:
  $Ne \cdot Re_c = 220$;
- for a vessel without a draft tube at $D/d_m = 2.62$:
  $Ne \cdot Re_c = 140$.

CONCLUSIONS

Let us make a point that the presence of open cavities at the splits of the half-blades practically does not make any considerable influence on the power expenditures, since the dependences $Ne = f(Re_c)$ coincide both with the presence of blanks and without them. Let us also note that the values of $Ne \cdot Re_c$ make accordingly 187 and 138 for the standard helical-screw mixers [1] of a similar configuration ($d_p/d_m = 1.14$; $D/d_m = 2.62$). Thus, the energy-related characteristics of the modified and standard helical-screw mixers appear to be rather close to each other, which makes it possible to use the calculation methods in a first approximation (apart from a section of calculating power for mixing using the value of Ne determined directly by the graph in Fig. 4**) presented in the standard documentation [2].

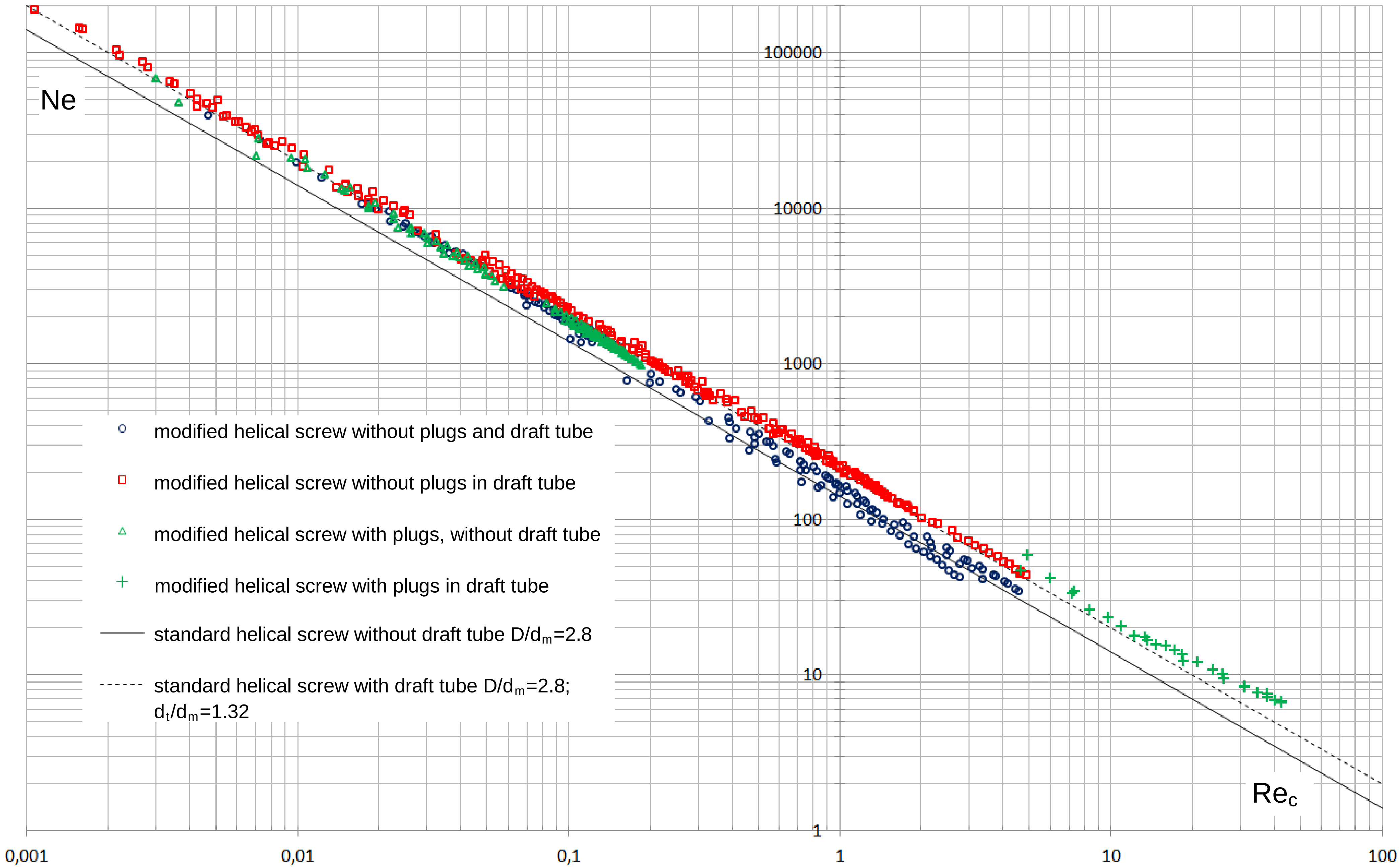

Fig. 4 Graph of Power Number Ne vs. Centrifugal Reynolds Number Re_c *for Modified Helical Screw*

NOMENCLATURE

M_{trq} – torque, N;
P – power, W;
Ne – power number (Newton number);
Re_c – centrifugal Reynolds number;
ρ – liquid density, kg/m^3;
N – mixer rotational frequency, 1/s;
D – inner diameter of a vessel;
d_m – mixer diameter, m;
d_t – draft tube diameter, m;
μ – liquid dynamic viscosity, Pa·s;
g – free-falling acceleration, m/s^2.

LITERATURE

[1] Braginsky L. N., Begachev V. I., Barabash V. M. Mixing in Liquid Media. – L.: Khimiya, 1984. – 336 pages.
[2] РД 26-01-90-85. MECHANICAL MIXING DEVICES. Calculation method. – L.: RTP LenNIIHimmash, 1986. – 256 pages.