Transform-dispersion analysis of the grain-size composition of mechanical admixtures in the cooling lubricant when investigating purification processes

Evgeny Bulyzhev¹,*, Andrey Bogdanov² and Leonid Khudobin¹

¹ Ulyanovsk state technical university, Ulyanovsk, Russia
² Ulyanovsk state university, Ulyanovsk, Russia

* eugbul1946@gmail.com

Abstract. This article presents the potential solution of the one of the most complicated issues arising by studying the purification processes efficiency of fluids and by producing cleaning agents. The result is that the procedure is substantially simplified, the reliability and the computational accuracy are enhanced when estimating statistical primary ($\bar{d}$) and secondary ($\sigma$) couples of the grain-size composition of mechanical admixtures in original and purified cooling lubricants and other fluids and also when determining the efficiency of cleaning agents work.

When formulating and studying water cleaning agents (including but not limited to cooling lubricants) eliminating mechanical admixtures it is necessary to carry out the dispersion analysis of the grain-size composition of mechanical admixtures (chippings and abrasives) in fluids before and after the purification. Interestingly, that the estimation of statistical couples "before the purification" is much more complicated than the estimation of statistical couples "after the purification".

As things stand, two approaches to the resolution of such issues are devised: direct and indirect ones.

Direct method.

Number of particles is calculated, sizes of these particles are measured, statistical processing, the estimation of frequency, the relative frequency of appearance and the specific fractions weight are carried out and analyzed. Then the estimation of statistical couples is carried out [1]. For obtaining data microscopic, sedimentation and photo-sedimentation analysis methods are widely used.

Taking into account the results of the analysis cleaning agents are selected. When dispensing suspensions (purification processes) the process physics is that normally it is necessary to measure not the size but volumes or weights of particles determining the process efficiency. As things stand, the influence of the latest is perverted by surface interactions "fluid – particles surface" "particle – fluid – particle". That is why, for example, sizes measured using the microscopic method, usually, differ from sizes measured using the photo-sedimentation method. Moreover, things are becoming serious by the fact that during the dispersion analysis particle aggregates are fractured using dispersers while during the purification these aggregates are formed specifically and have a profound influence on the purification.

¹ The microscopic analysis represents the relative frequency distribution while the sedimentation analysis or the photo-sedimentation analysis represents the mass distribution.
process efficiency. That is why when calculating the purification rate there are some underestimating inaccuracies which skew the results of studying the cleaning agents efficiency. Researchers of fluid purification processes know that:

1. The purification fineness is determined when the grain-size composition of mechanical admixtures in original and purified fluids is known and corresponds to the hands-on experience.
2. The grain-size composition of mechanical admixtures in purified fluids is much more stable and the variability interval of particle sizes in them is far less, that is why the grain-size composition is estimated much simpler and more accurately [1].
3. The purification rate $\varepsilon$ and the relative purification fineness $\varphi_d$ are functionally connected with each other by the exponential function $\varphi_d(\varepsilon) = \frac{\bar{d}_i}{\bar{d}_i}$ (Figure 1, [1]).
4. Function $\varphi_d(\varepsilon)$ depends on the distribution law and the variation coefficient (Figure 1) numerically equal to the ration between the quadratic mean $\sigma$ and the arithmetic mean $\bar{d}$ for this very distribution.
5. In specific practical dispersion situations, distributions with the statistically hardly varying type of the distribution law are formed. Usually, statistical couples $\bar{d}$ and $\sigma$ change upon that, but the distribution law itself does not change much.

![Figure 1](image1.png)

**Figure 1.** Dependence of normalized values of original, central and relative distribution couples by sizes on the purification rate obtained during the gravitational purification of mechanical admixtures [1]: a, b, c – functions $\varphi_d(\varepsilon)$, $\varphi_\sigma(\varepsilon)$ and $\varphi_\nu(\varepsilon)$, as such, obtained using the calculation method; $\rho = 7800$ kg/m$^3$; $C_u = 100$ mg/dm$^3$; $\eta = 0.001$ Pa; $T = 20$ °C; $\bar{d}_u = 10$ мкм; $\sigma_u = 3.3$ мкм; $\nu_u = 0.33$

Provisions described above gave an opportunity to form another (indirect) approach to estimating the grain-size composition. Please see below the algorithm of the indirect method of the analytic and experimental analysis [1, 2] in the form of the flow chart (Figure 2). The most important characteristics of the grain-size composition (statistical couples $\bar{d}_u$ and $\sigma_u$ and the mechanical admixtures particles distribution in the original fluid by sizes) are determined without their measuring using the dispersion analysis method. Interestingly, the cleanser itself is used as the device. Estimation of statistical couples corresponds to the physics of the process.

The described method was called by its authors as the transform-dispersion analysis.

Module 1. Using the photo-sedimentation analysis the data massive about the frequency $m_i$ and the relative appearance frequency $n_i$ of mechanical admixtures particles in dimensional fractions $d_i$ - $d_{i+1}$ of the whole particles interval is identified

$$m_i = \frac{m_i}{\sum m_i}, \quad n_i = \frac{d_i^3 n_i}{\sum d_i^3 n_i}$$

where $i$ - is the number of the particles fraction.

Module 2. The average particles size $\bar{d}_o$ of the analyzed grain-size composition of the particles composition is determined

$$\bar{d}_o = \frac{\sum d_{oi} f_{oi}}{\sum d_{oi} n_i}$$

where $d_{oi}$ - is the average size of particles in the fraction equal to $\bar{d}_o = (d_{oi} + d_{o+1})/2$, micron.
Module 3. The quadratic mean of the analyzed grain-size composition of particles is estimated using the equation

\[ \sigma_o = \sqrt{\sum (d_i - \bar{d}_o)^2 \cdot f_{oi}} \] (3)

**Figure 2.** The flow chart of the data processing process algorithm at the transform-dispersion analysis

Modules 4, 5. Concentrations of mechanical admixtures particles in the volume unit of the purified and original fluid \( C_0 \) and \( C_n \), g/l, are estimated using the nephelometric or the gravimetric analysis method.

Module 6. The value of \( \varepsilon \) is estimated which is numerically equal to

\[ \varepsilon = 1 - \frac{C_0}{C_n} \] . (4)

Module 7. The value of \( \varphi_{d_0} \) is estimated using the graph \( \varphi_{d_0}(d) \) (Figure 3, [1])

Module 8. The value of \( \bar{d}_n \) is estimated which is numerically equal to
The value of $\varphi_\sigma$ is estimated similarly using the graph, then the value of $\sigma_\varphi$ is estimated

$$
\sigma_\varphi = \frac{\sigma_\circ}{\varphi_\circ}
$$

Over the range $\varepsilon < 0.9$ variation coefficients are $\nu_\circ = \sigma_\circ / \overline{d}_\circ$ and $\nu_\varphi = \sigma_\varphi / \overline{d}_\varphi$. Calculate and check values of variation coefficients $\nu_\circ$ and $\nu_\varphi$.

**Figure 3.** Dependence of the normalized average size of particles $\varphi_{d_\circ}$ by the purification rate: $\nu_\circ = 0.33$

Consider the following example.

To calculate average statistical couples of grain-size compositions of mechanical admixtures in purified and original fluids.

Based on the data massive $f(d)$ estim ate values $\overline{d}_\circ = 5$ micron and $\sigma_\circ = 1.65$ micron. The value $\nu_\circ = 1.65/5.0 = 0.33$.

The value $\nu_\circ = 0.33$ corresponds to the normal distribution law. The particles concentration in the purified and the original fluid obtained using the gravimetric method are 0.15 and 1.0 g/dm$^3$, as such. The purification rate is

$$
\varepsilon = 1 - 0.15/1.0 = 0.85.
$$

At $\varepsilon = 0.85$ using the graph (Figure 3 [1]) determine that $\varphi_{d_\circ} = 0.75$. Using the value of $\varphi_{d_\circ}$ calculate that $\overline{d}_\varphi = 5/0.75 = 6.7$ micron. Whereas $\nu = \text{const}$, then $\sigma_\varphi = 1.65/0.75 = 2.2$ micron, $\nu_\varphi = 0.33$.

The result is that we determined statistical couples $\overline{d}_\varphi$, $\sigma_\varphi$ and the central moment $\nu_\varphi$ of mechanical admixtures contaminating the original fluid.

It should be noted that:

1) the dispersion analysis of original fluids is considerably complicated because of the variability in the concentration and sizes of particles in the far wider range in comparison with the variability in the purified fluid;

2) the transform-dispersion analysis give an opportunity to significantly reduce and to simplify the estimation of $\overline{d}_\varphi$, $\sigma_\varphi$ and $\nu_\varphi$ with extensive experiments;

3) if $\overline{d}_\varphi$, $\sigma_\varphi$ and $\nu_\varphi$ are stable, it would be possible to estimate only values of $\varepsilon$. This fact gives an opportunity to further significantly simplify the estimation of values $\overline{d}_\circ$, $\sigma_\circ$ and $\nu_\circ$ in series of experiments;

4) obtained statistical data of $\overline{d}_\circ$ and $\sigma_\circ$ to a greater extent correspond to the physics of the purification process than data obtained during the microscopic analysis or the photo-sedimentation analysis.

**References**

[1] Bulyzhev E M 2010 *New generation of loaded cleansers of water process fluids* (Ulyanovsk: UISTU) p 419

[2] Bulyzhev E M and Bogdanov A Yu 2013 *Transform-dispersion analysis of purification processes of water process fluids from mechanical admixtures*, Mathematical modelling, v. 5(5), pp 85-98