RHEOLOGICAL PROPERTIES OF FOAMING AGENTS USED BY UKRAINIAN FIREFIGHTERS

Stas S. V.
Cherkasy Institute of Fire Safety named after Chornobyl Heroes of National University of Civil Defence of Ukraine

Kolesnikov D. V.
Cherkasy Institute of Fire Safety named after Chornobyl Heroes of National University of Civil Defence of Ukraine

Bychenko A. O.
Cherkasy Institute of Fire Safety named after Chornobyl Heroes of National University of Civil Defence of Ukraine

Koval O. D.
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"

Abstract

Extinguishing Class B fires or fires of some other classes in a volumetric way both in the world and in Ukraine is carried out using air-mechanical foam. Air-mechanical foam consists of an aqueous solution of foaming agent, in which air is added to the supply devices. Traditionally, Ukraine uses 6% solutions of general or special purpose foaming agents, which are concentrates of surfactants with certain specified characteristics, in accordance with the conditions of use. Foaming agent solutions can be used both for creating air-mechanical foam, and directly for extinguishing fires with sprayed and compact jets from water trunks. Given the composition of the air-mechanical foam, it is clear that the rheological properties of the working solution of the foaming agent are determined by the type of foam concentrate or directly by the foaming agent itself. Rheological properties of working solutions of foaming agents can significantly affect the hydraulic characteristics of bag equipment, air-mechanical foam supply devices, such as foam barrels and foam generators of various multiplicities, sprinklers and injectors of stationary fire extinguishing systems, fire trunks, etc. As a rule, information about the rheological properties of modern foaming agents is incomplete. The article presents the results of research on modern foaming agents used for fire extinguishing purposes in Ukraine.

Keywords: rheology, surfactants, dynamic viscosity, strain rate

INTRODUCTION

In the practice of fire extinguishing, concentrates of surfactants, so-called foaming agents, are used to change the physical properties of water. When added to water in various ways collectively they form working solutions of foaming agents, which can be used for the direct extinguishing of fires of classes a, B, C from water trunks, which increases the efficiency of such use in comparison with water jets by reducing surface tension or used to create air-mechanical foam on special supply devices by adding air to the working solution of the foaming agent. Air-mechanical foam is effective for extinguishing Class B fires or for extinguishing Class A fires in a volumetric way. The development of new formulations of foaming agents is primarily caused by an attempt to increase their fire extinguishing efficiency, foam stability and ensure the possibility of generating and supplying extinguishing agents when using fire-fighting equipment and Fire-technical equipment. It is important that now there are numerous questions about the methods and features of supplying water extinguishing agents to the fire source [1-6]. The use of aqueous solutions of surfactants significantly affects the length of a continuous jet of extinguishing liquid and, as a result, the supply range and its characteristics.

Perhaps the biggest controversy in scientific circles over the past 10-15 years, sometimes with completely opposite conclusions, concerns the production and use of jets of finely sprayed liquids. Sometimes it is argued that extinguishing fires with finely sprayed water is significantly less effective than volumetric extinguishing with combustion – inhibiting compounds, sometimes – on the contrary-significantly more effective. Moreover, the possibility of implementing a volumetric method of fire extinguishing with sprayed water is discussed, which consists in evenly filling the protected volume with a stable suspension of an almost monodisperse teardrop-shaped medium. Without going into the details of the argumentation of certain views, we note that the difficulties lie in determining the possibility and features of generating such flows of extinguishing agents that would ensure the supply of extinguishing liquid to the fire source or cooled zone in the right amount, in the right state.

The technical implementation of obtaining such jets is significantly complicated by the need to use high-pressure systems, which is often economically unjustified. Partial solution of these contradictions can be based on physical and chemical research or synthesis of substances and additives to water that improve its properties for fire extinguishing [7-9].

In addition, it should be noted that the list of foaming agents currently used by units of the operational and Rescue Service of the state emergency service of Ukraine in fire fighting continues to grow in recent years. Under such conditions, it is appropriate to conduct a comparative analysis of the main characteristics of "new" foaming agents.

ANALYSIS THE LATTER ACHIEVEMENTS AND PUBLICATIONS

The use of surfactants makes it possible to radically change the surface and interfacial properties of the aqueous solutions that they form. Fire extinguishing foams of various multiplicities are used for surface and volumetric extinguishing. The main mechanism of fire extinguishing action of pin is insulation. For the most part, low-and medium-multiplicity foams are used in fire extinguishing practice. According to some sources, in such cases, 75-97% of the pin volume is air, that is, their multiplicity ranges from 4 to 33 [10].

Studies of the rheological properties of foams used for fire extinguishing have a long history. So, since the mid-40s of the last century, studies and comparisons of the pins used at that time were conducted [11, 12]. The foam viscosity values obtained by the Joint Fire Research Organization and the US Naval laboratory were compared using vane and ball Viscometers.

The study of water additives that can lead to viscosity anomalies can be carried out by determining the rheological characteristics of liquids on rotary Viscometers, in particular on Rheotest–2.

The effect of additives on the dispersion of droplets of water-based extinguishing agents can affect the reduction of the amount of extinguishing agent without reducing the effectiveness of fire extinguishing. Thus, Zhartovsky S. V. et al., studying the rheological properties of the water extinguishing agent FSH–2, found a 4-fold decrease in the size of droplets when a 31.5% solution of this fire-protective substance was introduced into the water [9, 13]. Some physical and chemical properties were identified, which led to the provision of a high fire extinguishing capacity of the FSH-2 substance during the extinguishing of mock–up foci of Class A, and an increase in water efficiency by 4.6 times was achieved when it was used for active fire protection of objects [14]. At the same time, the practice of using solutions with surfactants used to eliminate combustion is most often limited to the use of significantly lower concentrations of the working solution, most often 3-6 %.

A little earlier in [9], individual foaming agents used in the early 2000s in Ukraine were studied [15, 16]. According to the measured shear stresses τ and shear rates $\dot{\gamma}$ the dynamic viscosity $\mu=\tau$ was determined/$\dot{\gamma}$ and constructed rheological curves. However, most of the foaming agents studied at that time are no longer used by the fire and rescue units of the operational and Rescue Service of the state emergency service of Ukraine.

EXPOSITION

Highlighting previously unresolved parts of the general problem to which the article is devoted. In the domestic market, the number of general and special purpose foaming agents offered for use in fire fighting is increasing. However, both foreign and domestic developers of such substances do not fully indicate the data that characterize them that are important for firefighters, noting only the most basic ones in their opinion. It is known that changing the rheological properties of foaming solutions can significantly change the hydraulic characteristics of hose equipment, feed devices such as water and foam barrels, foam generators, sprinklers and injectors, both improving them and worsening them.

Setting a goal. The purpose of this work is to obtain rheological curves of some new foaming agents for the domestic market in order to further establish the possibility and expediency of their use by technical means available in the divisions of the operational and Rescue Service of the state emergency service of Ukraine.

Presentation of the main research material with full justification of the results obtained. In a viscous material (liquid), the stress is proportional to the strain rate and is described by Newton's law

$\tau = \mu\dot{\gamma}$,

where $\dot{\gamma}$ - deformation rate, 1 / s;

μ - coefficient of dynamic viscosity, PA * s.

Liquids whose flow begins simultaneously (i.e., without delay, instantly) when forces are applied to their movement, and whose viscosity coefficient does not depend on the direction and speed of shear, are called Newtonian. Otherwise, when the law of fluid flow differs from Newton's law, they are called non-Newtonian.

The viscosity of a non-Newtonian liquid does not remain constant at a given temperature and pressure, but depends on other factors, such as the rate of deformation, the design features of the equipment in which the liquid is located, and so on.

A qualitative picture of the dependence of the tangential stress on the strain rate is shown in Fig.1.

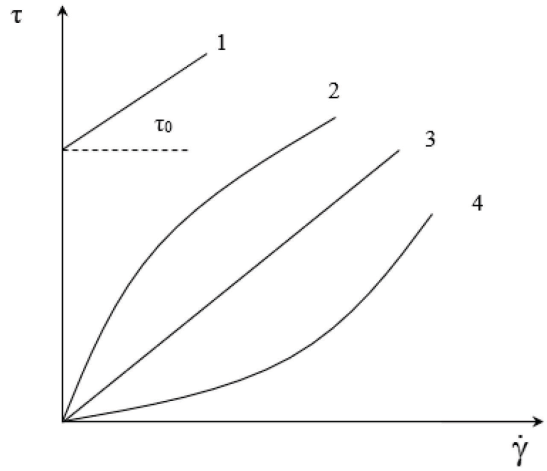

Fig.1. *Rheological curves for different types of liquids:*

1-Bingham plastic
(τ_0 - initial yield strength);
2-pseudoplastic fluid (n<1);
3-Newtonian fluid (n=1);
4-dilatant liquid (n>1).

Pseudoplastic fluids (pseudoplastics) do not show a yield strength. For them, a dependence was established in the form of a step law, which was first proposed by Oswald de Vil and later improved by Rayner. It has the form

$\tau = k\dot{\gamma}^{\,n}$,

where k - measure of liquid consistency;

n - a value that characterizes the degree of non-Newtonian behavior of materials.

Note that the higher the viscosity value, the greater the k, and the more n it differs from one, the more non-Newtonian properties are revealed.

Dilatant fluids are somewhat similar to pseudoplastic fluids because they also lack a boundary fluidity (free flowing). Dilatant fluids can also be described using the Oswald de Ville equation, but for them the value of $n > 1$.

A Rheotest–2 Rotary viscometer was used to conduct rheological studies of foaming agents.

Among the studied foaming agents were domestic–made foaming agents Pyrena-1, as well as Alpen and Sofir.

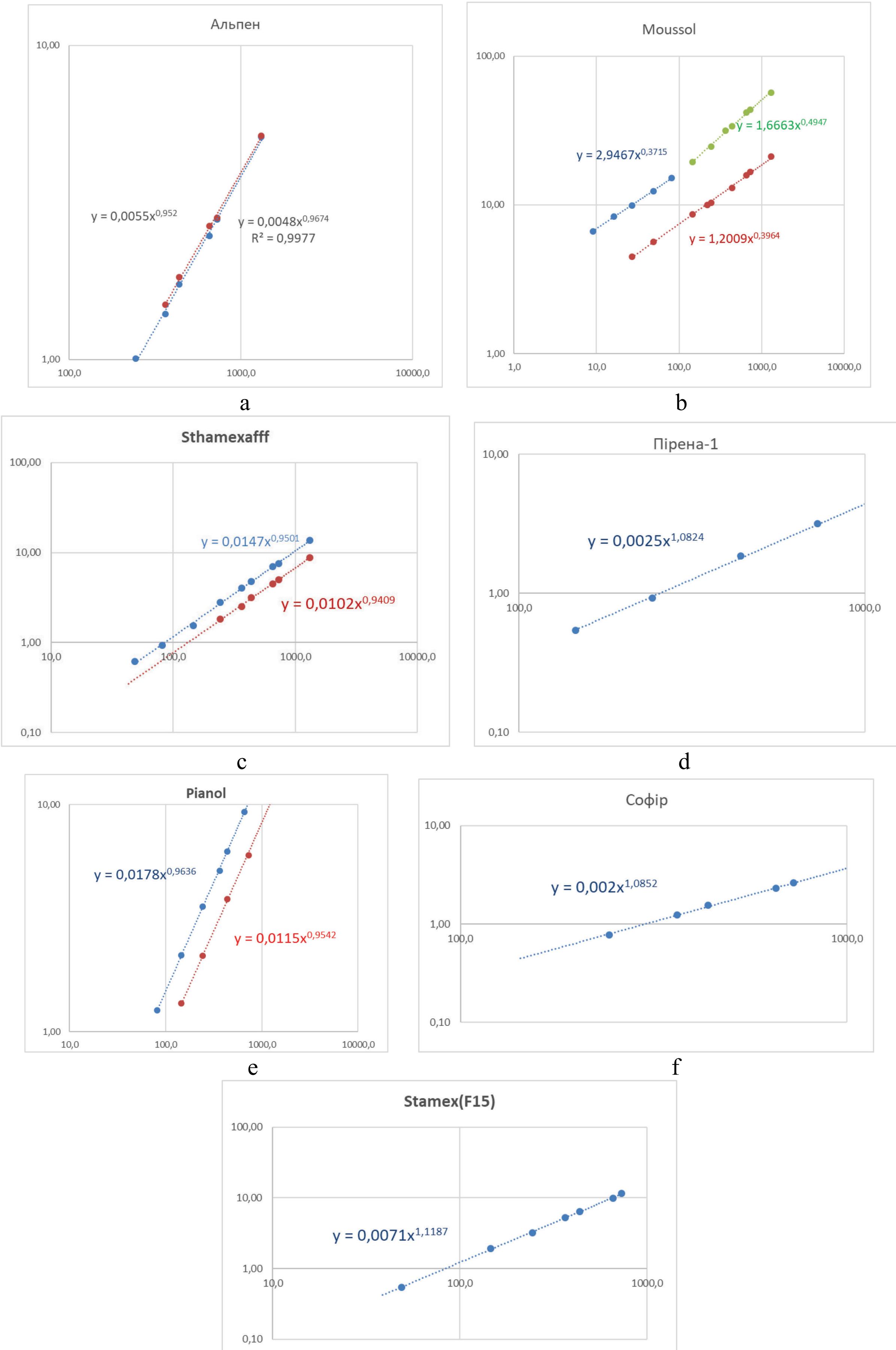

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Fig.2. *Rheological curves of the studied fluids: a-Alpen; B-Moussol; B-SthamexAFFF; G–Pyrena – 1; D – Pianol; e – Sofir; e-Sthamex(F15)).*

Table 1 - values of n and k for the studied foaming agents

Alpen	Moussol	SthamexAFFF	Pyrena-1	Pianol	Sofir	Sthamex(F15)
k=0,0055 n=0,955	k=2,9467 n=0,3715	k=0,0147 n=0,9501	k= 0,0025 n=1,0824	k= 0,0178 n=0,9636	k=0,002 n=1,0852	k= 0,0071 n=1,1187
k= 0,0048 n=0,9674	k=1,2009 n=0,3964	k= 0,0102 n=0,9409		k= 0,0115 n=0,9542		

Rheological curves, in order to obtain rheological constants k and n, were plotted in logarithmic coordinates. This made it possible to determine the degree of viscosity anomaly (table1). The ordinate axis reflects the shear stress τ (PA), and the abscissa axis is the strain rate $\dot{\gamma}$ (1 / s). The studies were conducted using two different devices, one of which was specially upgraded in order to increase the sensitivity of the measuring device. In Table 1 the device number corresponds to the index of rheological constants.

Obtaining rheological curves of foaming agents Pyrena–1, Sofir, Sthamex(F15), Alpen, Moussol, SthamexAFFF, Pianol made it possible to compare the results with previously conducted similar studies for foaming agents that are no longer used by units of the operational and Rescue Service of the state emergency service of Ukraine [15].

The study of the rheological properties of foaming agents makes it possible to continue studying the effect of foaming agent solutions of standard concentrations (3-6 %).

CONCLUSION

Based on the results of this work, the following was established:

1. The studied foaming agents exhibit properties in accordance with De Ville's law, both dilatant (Pyrena–1, Sofir, Sthamex(F15)) and pseudoplastic liquids (Alpen, Moussol, SthamexAFFF, Pianol).
2. A comparative analysis of the obtained rheological characteristics of foaming agents gives the right to assert their fundamental similarity with previously studied foaming agents [15-16], which indicates the possibility of their use by existing Fire-technical equipment under similar fire extinguishing conditions.
3. Prospects for further research are the study of the influence of rheological characteristics of foaming agents on the hydraulic characteristics of compact and sprayed jets of their aqueous solutions, the influence of rheological characteristics of foaming agents on the dispersion of drops of finely sprayed jets and the study of the influence of rheological properties of foaming agents on the hydraulic characteristics of bag equipment when using Working Solutions of foaming agents of different concentrations.

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