Inertial force in separators used for oil treatment units

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Abstract. The paper studies the force of inertia to appear both in individual parts and assemblies of separators exploited for oil and gas treatment, and in separators as such. The concept of the force of inertia is important due to the possibility of considering it from deeper scientific points of view and practical positions.

1. Introduction
The concept of the force of inertia is widely used in various fields of science. In physics and mechanics it is used to explain the absence or tendency to prevent various changes. In the context of philosophy or fiction, and sometimes in colloquial speech, the combination of the words ‘force of inertia’ is used to refer to some kind of influence that ensures a status quo to be maintained. In this usage, forces of inertia are not only unrelated to any motion (i.e., a change in position in space), but also to the concept of force, as it is used in physics or mechanics.

The duality of the force of inertia lies both in the very definition and in the way it appears. On the one hand, the force of inertia is a consequence of the property inherent in any body – inertia: to varying degrees to resist a change in its velocity and direction of motion relative to inertial reference frames when external forces act upon it. On the other hand, according to Newton’s first law (law of inertia): a material point isolated from external influences continues in its state of rest or in uniform rectilinear motion unless it is compelled to change that state by forces impressed thereon. Motion made by a point in the absence of an external motive power is called inertial motion [1].

In STEM fields, the concept of the force of inertia is a force that there occurs when accelerated motion of bodies is considered. Usually the concept of the force of inertia is used in the framework of classical (Newtonian) mechanics. The Newtonian force of inertia, due to the inertia of a body, is the total measure of inverse action (reaction) exerted by a given body on all other bodies (in particular, on interactions in accordance with Newton’s third law). The d’Alembert force of inertia of a material point (d’Alembert principle) is not a physical force and in this sense is not real (fictitious force), which is not directly related to the interaction of material points (bodies) and is introduced into mechanics entirely conditionally in order to simplify theoretical constructs when dynamic equations are compiled and solved for a material point.

2. Materials and methods
In order to study and apply the concept of inertial forces in the oil and gas industry, consider equipment applied for oil treatment units. The units consist of separators, heat exchangers, settling tanks, electric hydrators, furnaces or heaters, pumps, control and shut-off valves, tanks for mixing
liquids and reagents. The structure of treatment installations also includes some devices and equipment that enhance the performance [2]. Oil is treated by different methods that are based on thermal, chemical and mechanical influences on fluids and, as a result, oil treatment includes separation, settling and demulsification. The main stage in oil preparation is demulsification, i.e., the separation of a dispersed system (emulsion) in the separator by changing the direction of motion, and in the droplet separator due to the chemical action of surfactants [3]. Highly effective demulsifiers used in oil fields and oil refineries for dewatering and desalting oil contain a mixture of surfactants of various structures and modifications that most often are synergistic.

The theories explaining the way demulsifiers work are divided into two groups:
- physical, involving physical adsorption of demulsifier molecules on colloidal particles, loosening and modifying action of demulsifiers on the interphase layer, which contributes to the displacement and migration of stabilizer molecules (particles) into one or another phase;
- chemical, based on the assumption that chemisorption of demulsifier molecules is predominant on the components constituting the protective layer with strong chemical bonds being formed, followed by natural oil stabilizers losing their ability to emulsify water.

According to the current generally accepted theory developed under the leadership of academician P.A. Rebinder, when a surfactant is introduced into an oil emulsion, the following processes start at the ‘oil-water’ interface.

Having higher surface activity, the surfactant displaces natural stabilizers from the interface, adsorbing on their colloidal or coarsely dispersed particles. The demulsifier molecules change wettability, which facilitates the transition of these particles from the interface into the aqueous or oil phases. The result is coalescence. Thus, the destruction of oil emulsions is physical rather than chemical and depends on:
- component composition and properties of protective layers of natural stabilizers;
- type, colloidal-chemical properties and specific consumption of a demulsifier used;
- temperature, intensity and time the oil emulsion travels with a demulsifier.

A technological benefit from using a demulsifier is to ensure fast and complete separation of oilfield water with its minimum consumption.

Having displaced natural emulsifying substances from the surface layer of water droplets, the demulsifier forms a hydrophilic adsorption layer, whereby the droplets coalesce (merge) upon collision into larger droplets and settle. The more effective the demulsifier, the more it reduces the strength of the armored layer and the more intensively the emulsion is destroyed. In oil treatment units, the pivotal equipment includes horizontal separators [4] that are designed for oil degassing (Fig. 1).

![Figure 1. Horizontal separator schematic: 1 – feed pipe; 2 – primary liquid scrubber; 3 – mist extractor (gas separator); 4 – louver nozzles; 5 – pressure gauge; 6 – safety valve; 7 – casing; 8 – float; 9 – defoamer; 10 – inclined rods.](image-url)
In most oil separators, the key working elements are sections that are divided into four types [3, 4]. The name of each section reflects the technological process implemented by its elements that are highlighted in Fig. 1 in Roman numerals I, II, III, IV:

Section I is the main separation section. It serves to separate substances in different aggregate states. To increase the efficiency, a feed pipe is located tangentially, and given that production fluid is directly injected, a reflecting baffle is installed in front of it [5]. Liquid is separated from gas by changing direction of flow in separators with a direct inlet or by centrifugal force – with a tangential inlet. Here oil and gas are separated from each other once acted by centrifugal force, gravity force and inertial force subject to a type of separators;

Section II is a settling section. The associated gas entrained in oil from the separation section is further separated here. For this purpose, a thin oil flow is fed by the inclined rods. The efficiency of the section is determined by the total area and a gas fraction in production fluid[6]. The main principle of separation in the section is gravity settling that appears at low gas velocities. The main requirement of gravity settling is to reduce turbulence, due to which, in some separator designs, special equipment is provided to straighten liquid flows;

Section III is an oil collection section. It serves for uniform and smooth collection of oil from separators by means of diverters that are called ‘level dampers’ and oil is selected when the actuator is automatically triggered by a level sensor [7]. The section accumulates and removes the separated liquid. For this it must have a sufficient volume and be located so that the separator functions normally with an uneven flow, and the separated liquid does not prevent the gas flow;

Section IV is a mist extraction section. It is an accumulator of the smallest liquid droplets carried away by associated gas. Since oil and gas separators work with a pulsating flow of incompressible liquid, it is required to take measures to reduce flow pulsations and ensure uniform degassing of oil [8, 9]. It will be more effective to use three-phase separator for oils with a high content of oilfield water, forming stable emulsions [10]. This section serves for coagulation and trapping small drops, for which various types of louvred nozzles are used based on inertial forces. Small droplets (less than 100 microns in diameter) are carried away from the louver and are captured in a mist extractor consisting of a set of wire meshes.

Thus, out of the four sections considered, inertia forces are applied in two:
- in the first (main separation section), where oil and gas are separated from each other under the action of centrifugal force, gravity force and inertial force, depending on the type of separators in which inertial forces appear;
- in the fourth (mist extraction section), where various nozzles are used to capture and coagulate small drops.

Further, note that inertial forces are used in field installations for the preparation of a gas-liquid mixture, herein oil and gas [11]. When transporting a gas mixture, it is necessary to extract water and liquids from it. For this, separator structures are used, based on the difference in the physical properties of the components constituting the mixture. Besides, the gravity and inertial solutions are most widely used in them for separating gas impurities.

By configuration, separators used at field facilities relying on the inertial preparation of a gas-liquid mixture are divided into three types:
- louvered, in which the liquid is separated from the gas due to multiple reversals of the direction of gas flow;
- cyclonic, in which separation is provided by creating a swirling gas flow;
- combined separators, in which both of the above principles are applied.

Inertial forces appear not only in the principal equipment, i.e., separators, but also in individual parts and units of subordinate equipment, like dust collectors, rolling bearings and filters. The devices for cleaning gas from mechanical impurities are referred to as dust collectors. By their operating principle, they are divided into the following groups:
- dust collectors that work via “dry” dust separation. In such devices, dust is removed by using the
forces of inertia and gravity. These also include cyclone dust collectors, various filters, etc;
- dust collectors that work via “wet” dust collection. In this case, the removed gas mixture is wetted with a washing liquid separated from the gas stream, removed from a regeneration and cleanout device, and then circulated back;
- dust collectors that use the principle of electro-deposition. These devices are fairly used to clean out natural and associated gas.
Thus, of the three types of dust collectors, inertial forces are used only in the first type working via “dry” dust separation.

Another example of the force of inertia is gas cleaning with filters. Industrial foams made from plastics, metals and ceramics are sometimes used as filter elements. In the chemical and petroleum industries, packings made of woven flat and volumetric mesh has proven itself well. Packing materials of different wettability (hydrophobic and hydrophilic) are known. It is believed that the efficiency of capturing oil droplets in packings of this kind increases. With a sharp change in the direction of motion of a gas containing liquid droplets, the inertial forces make them move in the same direction, and the particles collide with the surface of a lyophilic barrier. As the gas changes its direction more quickly, it slides more easily in the new direction. The liquid accumulated in this way on the labyrinth surfaces made of shaped elements flows into a liquid section of the separator [12]. Gas can be separated from liquid both following a sharp decrease and an increase in the flow rate. In both cases, the effect of difference in the inertia of liquid and gas flow is used, which increases the concentration of droplets per unit of gas volume and causes their more effective collision with each other and with the surface of coalescing elements (packings, baffles, etc.). In corner-type baffles and mesh volumetric elements, all three effects are implemented: adhesive, changes in the direction of motion, changes in the direction of flow velocity and adhesive (the first two are inertial). The baffles throttle all sections of the upper part of the separators. As the gas moves through, the liquid collides with the wire and coalesces into larger droplets falling into the lower part of the separators.

3. Conclusion
Considering the examples of the inertial force applied in the oil and gas industry, the authors came to the conclusion that inertial forces appear when a centripetal force acts on a body – the cause of a change in the direction of motion, and the force always acts only in one direction – from the center of rotation (for example, separators). Besides, inertial forces appear when the velocity of a moving body changes (for example, liquid and gas). In both cases, there is always a real force that can be used in various processes and is completely “free”.

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