Non-contact methods and means of measuring the oil film thickness on the water surface

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Abstract. The article discusses options for solving the problem of ocean pollution by oil products. Currently, it is important to measure the thickness of an oil film to obtain information on the volume of spills and operations to eliminate them. The features of non-contact methods and the main characteristics and conditions of the use of means for measuring the thickness of an oil film are discussed. The accuracy of measurements in real conditions (in the presence of surface waves) was identified.

1. Introduction
More than 4 billion tons of crude oil is produced annually. Currently, the number of drilling platforms is more than 6500. More than 3 thousand tankers are used for the transportation of petroleum products. Every year, 2-10 million tons of oil are discharged into the World Ocean (oil losses during transportation and pumping, offshore production, destruction of platforms). The pollution rates are increasing due to the growth in the volume of sea transportation of oil products.

The assessment of damages caused by oil films should be comprehensive, since oil spills have a harmful effect. Upon contact with water, petroleum products spread and form a film up to 1.0-0.1 mm in thickness. Light fractions are eroded, and aromatic hydrocarbons are partially dissolved in water. This entails the spread of oil over a large area, while thinning of the oil film may occur up to the monomolecular layer. Heavy fractions undergo various processes: photochemical oxidation due to the action of ultraviolet radiation, natural self-oxidation, biochemical oxidation by marine microorganisms. Due to continuous mixing and the above processes, an aqueous emulsion is formed on the water surface. They form clots that hold on the surface or move in the water thickness.

Oil products have a negative impact on the ocean flora and fauna, while they change the gas exchange between the ocean and the atmosphere, affect the thermal regime of water basins, upset the oxygen balance of the planet.

To solve the problem of ocean pollution, it is necessary to measure the degree of pollution and remove oil products from the surface and the aquatic environment. The most common methods for cleaning water areas are as follows: burning, collecting with special devices or using special chemical cleaning agents. Almost all existing methods can be used only under the condition that oil pollution exists on the water surface in the form of a film.

Currently, many countries are developing remote sensing oil spill detection methods and means [1, 2]. Oil products form films whose thickness can reach the monomolecular layer. Prompt information about the amount of oil spilled, the source of pollution and the most affected areas will help eliminate pollution.
The environmental monitoring of marine areas should provide the following information:  
1. The presence of the film  
2. The area and shape of the oil spot  
3. Film thickness  
4. Type of oil product  
5. Age of pollution  
6. Direction and speed of the spot  

The urgent task is to design tools for measuring the thickness of an oil film on the water surface to assess the volume of spills and plan operations for their liquidation.  

The most promising is the use of non-contact methods and measuring instruments. The article discusses the implementation of methods of measuring the thickness of an oil film, and assesses the accuracy of measurements in real conditions.

2. Results and Discussion  
Means of measuring the thickness of an oil film, their main characteristics and application conditions are presented in Table 1.  
In radiometric measuring instruments, the polarization method has been implemented - the thickness of the oil film is determined by the ratio of reflection coefficients on the vertical and horizontal polarizations.  
The PRINT-3 three-frequency radiometric device [3] which implements the polarization method is a registered remote sensing instrument for measuring the thickness of an oil film on the water surface. Its work is based on passive radiometric remote sensing which allows you to measure the intrinsic radiation of the earth surface characterized by the brightness temperature of the radiation. The use of three frequencies eliminates the ambiguity in determining the thickness of a film caused by the interference frequency of the received signals reflected from the media: air-film - film - water. The use of the receiver response makes it possible to identify the source of surface inhomogeneity and calculate the film thickness without using additional information about weather conditions.  
The KTS RMK-N device [4] is a portable radiometric meter for measuring the thickness of an oil layer on the water surface. The methodology for determining the thickness of the oil film is based on the dependence of the reflection coefficient of radio waves on mutually orthogonal polarizations (horizontal and vertical) on the oil film thickness.  
The PRINT-3 and the KTS RMK-N were tested in order to approve the type of measuring instruments and were included in the State Register of Measuring Instruments.  
Oil and oil products fluoresce when excited with light in the ultraviolet range, and the fluorescence spectra of different types of oil products have various intensity degrees and shapes. The multifunctional fluorescent lidar makes it possible to identify oil products by their composition, as well as evaluate the thickness of the oil film [5].  
The four-wave and two-wave laser sensor measures the thickness of the oil film in the range (0.1 ... 140) μm [6, 7].  
In a laser ultrasonic device, the film thickness is determined by the propagation time of the acoustic wave between the upper and lower boundaries of the oil slick [8]. To implement this method, three lasers are used, one of which is attached to the interferometer to measure the thickness of the oil film.  
The multi-frequency radar complex Mars determines the thickness of the oil film by radar contrasts of oil spots obtained using radio waves of various lengths [9]. Radar tools allow you to work in various weather conditions and explore significant water bodies.
Table 1. Main characteristics of oil film thickness measuring tools

| Name of the tool                              | Wave range                  | Measurement range | Measurement accuracy | Note                                                                 |
|-----------------------------------------------|-----------------------------|-------------------|----------------------|----------------------------------------------------------------------|
| PRINT-3 Three-Frequency Radiometric Sensor    | (10.7…11.7); (11.7…12.7); (33…35) HHz | (0.2…0.6) mm; (0.6…4.0) mm; (4.0…6.0) mm | ±0.1 mm; ±0.2 mm; ±0.4 mm | 1. The type of a measuring tool was approved. 2. Portable tool 3. Measurements are performed manually. 4. Excitement - up to 2 points. |
| Portable radiometric tool for measuring oil layer thickness on the water surface KTS RMK-N | (11.7…12.7); (33…35) HHz | (0.2…0.6) mm; (0.6…4.0) mm; (4.0…6.0) mm; (6.0…12.0) mm | ±0.1 mm; ±0.2 mm; ±0.4 mm; ±0.6 mm | 1. The type of a measuring tool was approved. 2. Portable tool |
| Multifunctional Fluorescent Lidar             |                             |                   |                      | 1. Distance - up to 100 m (when placed at a height of 30 m).        |
| Laser                                         | 1.53; 1.43; 1.406; 1.33 μm; 2.86 и 5.76 μm | (0.1…4.0) μm; (4…140) μm | 20 %; 20 %           | 1. Project.                                                          |
| Laser ultrasound device                       |                             |                   |                      | 1. Three lasers are used, including powerful CO₂ laser. 2. Research is conducted in the laboratory. 3. A prototype is planned to be installed on the plane. |
| Mars                                          | 0.8; 3; 23; 180 cm          | от 200 μm         |                      | 1. Complex procedure for calibrating radars and choosing the optimal shooting mode. 2. Complex information processing procedure. |

3. Conclusion
The analysis of the above data allows for the following conclusions:
- to control pollution, the initial stages of the existence of an oil film are of interest;
- laser tools allow you to measure the thickness of the oil film at a distance of several hundred meters;
- the most promising is the development of radiometric tools for measuring the thickness of an oil film on the water surface;
- the method for measuring the thickness of an oil film on the water surface using multi-frequency radars requires further research and development.

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