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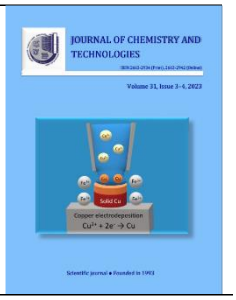

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MAGNETIC HYDROCYCLONES EFFICIENCY SURVEY FOR APPLICATION IN MARINE ENGINE OIL AND HYDROPHOBIC SUBSTANCES PURIFICATION TECHNOLOGY

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Abstract

This paper presents a new approach to the purification of marine engine oils through the use of magnetic hydrocyclones. The innovation consists in the integration of electromagnetic devices to improve the filtration process and effective removal of contaminants. The paper discusses the construction principles and operational aspects of magnetic hydrocyclones, emphasizing their positive impact on the efficiency of lube oil purification in marine systems. The results of experiments confirm the high efficiency of this technology, contributing to the improvement of reliability and performance of marine engines. In addition, the use of electromagnetic devices is an environmentally friendly aspect of improving the overall environmental situation on ships. This technology not only helps to improve the reliability of control and maintenance of ship equipment, but also makes it possible to extend the service life of the equipment. A comprehensive study of the complex interaction between hydrodynamics and magnetic forces in a hydrocyclone has been investigated with a generalization of experimental data and computational models.
Keywords: magnetic hydrocyclones; electromagnetic devices; marine oil purification; maritime transport; marine diesel engines; lubricant; filtration efficiency; engine performance; wear prevention; environmental impact.

ДОСЛІДЖЕННЯ ЕФЕКТИВНОСТІ МАГНІТНИХ ГІДРОЦИКЛОНІВ ДЛЯ ЗАСТОСУВАННЯ В ТЕХНОЛОГІЇ ОЧИЩЕННЯ СУДНОВИХ МАСТИЛ І ГІДРОФОБНИХ РЕЧОВИН

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Анотація

У цій статті представлено новий підхід до очищення суднових моторних мастил за допомогою магнітних гідроциклонів. Інновація полягає в інтеграції електромагнітних пристроїв для покращення процесу фільтрації та ефективного видалення забруднень. У статті розглядаються принципи побудови та експлуатаційні аспекти магнітних гідроциклонів, підкреслюється їх позитивний вплив на ефективність очищення мастил у суднових системах. Результати експериментів підтверджують високу ефективність цієї технології, що сприяє підвищенню надійності та продуктивності суднових двигунів. Крім того, використання електромагнітних пристроїв є екологічно чистим аспектом поліпшення загальної екологічної ситуації на суднах. Ця технологія не тільки сприяє підвищенню надійності контролю та обслуговування суднового устаткування, а й дає можливість продовжити термін служби обладнання. Проведено комплексне дослідження складної взаємодії гідродинаміки та магнітних сил у гідроциклоні з узагальненням експериментальних даних та розрахункових моделей.
Ключові слова: магнітні гідроциклони; електромагнітні пристрої; очищення мастила; морський транспорт; суднові дизельні двигуни; мастило; ефективність фільтрації; запобігання зносу; вплив на навколишнє середовище.

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Introduction

Magnetic hydrocyclones have emerged as a promising solution to improve oil purification and contamination control in marine engines. Various studies have examined the intricacies of magnetic hydrocyclone integration, discussing their advantages, challenges and potential impact on engine performance and environmental performance. The results provide valuable information for optimizing oil cleaning processes in marine diesel engines, contributing to continuous advances in engineering and environmental safety.

Thus, study [1] focused on modeling multiphase flow in hydrocyclones. This study considered computational models to understand how different phases interact in the equipment. In [2] rheology-based Computational Fluid Dynamics (CFD) modeling was employed to investigate segregation of magnetite medium in a dense medium cyclone, which is significant for understanding the behavior of dense media in cyclones. In [3] authors undertook modeling and analysis of hydrocyclone performance. Their work may provide insights into the factors influencing hydrocyclone efficiency. Paper [4] conducts a numerical analysis of how changes in dense medium feed solids impact dense medium cyclone performance and explores effects of varying feed materials on cyclone efficiency. In [5], large-vortex modeling was used to predict media segregation and coal separation in dense media cyclones, which is important for understanding the behavior of particles in cyclones. In [6], the authors considered CFD modeling of hydrocyclones, which provided insights into computational modeling of hydrocyclone operation. Study [7] used CFD modeling approach for industrial hydrocyclone, which provides a practical insight into the performance of specific devices. CFD modeling and analysis of multiphase flow and performance in dense media cyclones and CFD modeling for predicting particle size segregation in hydrocyclones were carried out in [8-10], investigating how particles of different sizes behave in a cyclone.

In [11], multiphase modeling of hydrocyclones with an emphasis on predicting the shear size is considered, providing valuable insights into the efficiency of separation processes. Article [12] explores the impact of spiral vane width on hydrocyclone separation performance, offering key design considerations for optimization while study [13] presents a detailed analysis of the design and performance of an axial center-piercing hydrocyclone, shedding light on innovative hydrocyclone configurations. Papers [14; 15] contribute a study on cyclone coupling techniques for heterogeneous separators, providing an avenue for enhanced design optimization. They also investigate the industrial applicability of a 75 mm axial flow hydrocyclone, offering an alternative to reverse flow models. [16; 17] introduced a unique methodology for characterizing the water split behavior of hydrocyclones, offering valuable design insights, and conducted an experimental study on the desanding of high-viscosity oil using hydrocyclones, which contributes to practical applications in the oil industry.

Papers [18–20] analyze the flow field and separation efficiency in hydrocyclones equipped with an integrated twisted ribbon using numerical simulation, provide innovative design solutions, present a review on the study of hydrocyclone performance by shape optimization, and conduct a comprehensive analysis of the separation efficiency of multiphase flow in hydrocyclones using computational fluid dynamics.

The literature review of the research topic also covered a number of critical areas of research that collectively contribute to the development of different areas of research. For example, research on ship turbine oil purification methods [21] and engine oil purification in marine diesel engines using magnetic hydrocyclones [22] directly addresses crucial issues in marine engineering, ensuring the optimal performance and longevity of engines. Furthermore, work on automated system control for robotic transmission clutches [23] and vehicle operating conditions optimization [24] significantly contributes to the development of intelligent automotive systems. Additionally, studies on thermal deformation control in car structures [25] and the application of vibrodiagnostics in marine diesel engines [26] highlight advancements in structural engineering and condition monitoring technologies. Moreover, research on photovoltaic technologies [27] and mathematical modeling for air pollution source identification [28–29] reflect a keen interest in sustainable energy and environmental science. These studies collectively form a cohesive body of work that not only addresses practical engineering challenges but also contributes to the broader goals of sustainability, efficiency, and technological innovation.

Works covering various critical aspects of marine engineering and transportation such as studies of energy efficiency criteria for deadrise hulls [30] and their application in coastal navigation voyages [31; 32] directly address key problems of ship design and navigation and hull damage assessment of high-speed vessels from raking.

The studies [33–38] cover diverse aspects of maritime engineering and transportation. They range from autonomous ship concepts and mathematical modeling for steering control to optimizing ship speed modes considering weather conditions. They emphasize maritime situational awareness, propose strategies for emissions reduction, and address critical equipment vulnerability. Additionally, they highlight modern perspectives on ship ballast water management for enhanced ecological safety in shipping operations. These studies collectively advance the field of marine engineering and enhance the safety and efficiency of goods transportation by sea. Works [39; 40] extend the field of marine science and engineering by providing valuable insights into optimizing terminal design and equipment control to improve operational efficiency.

Thus, the study of magnetic hydrocyclones in marine diesel engines is important for marine engineering and environmental safety. The study of the specialized application of magnetic hydrocyclones in marine engines addresses the urgent need for improved oil cleaning and pollution control. The results obtained not only pave the way for improved engine efficiency and reliability, but also have far-reaching environmental implications. The integration of magnetic hydrocyclones offers a sustainable solution to reduce engine wear and extend the life of engine components, ultimately resulting in lower operating costs and resource consumption. In addition, this technology can minimize the environmental footprint of marine engines by ensuring clean exhaust and preventing oil-related pollutants from entering the marine ecosystem. As the global industry is increasingly seeking environmentally friendly alternatives, this study is a timely and important contribution to the efforts to improve the efficiency and environmental friendliness of marine diesel engines.

Materials and methods

A key advantage of using hydrocyclones in filtration systems is that by pre-filtering and removing large particles before they enter the main filter, hydrocyclones can significantly extend filter life and reduce maintenance frequency. This is especially valuable in industries or processes where maintaining effective filtration is critical to equipment performance and longevity.

The effectiveness of oil purification within magnetic hydrocyclone systems is greatly influenced by the presence of dispersing additives. These additives play a vital role in maintaining impurities in a dispersed state within the oil. This characteristic hinders the clumping of magnetic particles with non-magnetic substances, thereby preventing an increase in particle size in hydrocyclones due to molecular adhesion forces. However, this approach may lead to a reduction in the overall system efficiency.

Efficient removal of metallic particles through filtration can significantly slow down the oil aging process. The presence of iron in the oil catalytically speeds up the oxidation rate of hydrocarbons in the oil. As the oil temperature increases, the process of additive separation intensifies, possibly due to partial thermal decomposition.

A hydrocyclone utilizes the incoming liquid pressure to induce centrifugal force and flow patterns, facilitating the separation of particles from the liquid medium. Effective separation hinges on the particles having a notably different density compared to the liquid medium. The flow within a hydrocyclone adopts a cyclonic nature, a consequence of the tangential introduction of liquid into the cylindrical chamber, leading to the formation of a vortex. The chamber is designed with a more constricted axial lower outlet, preventing all the fluid within the vortex from exiting through this pathway. Consequently, a portion of the fluid must alter its course and travel in the opposite direction towards the upper axial outlet. This reverse flow continues its rotational motion, creating an air core due to the diminished pressure at the axis of rotation. This innovative mechanism results in the accumulation of suspended particles at the bottom, which are then directed into the tank. Simultaneously, the liquid ascends from the center of the chamber (Fig. 1).

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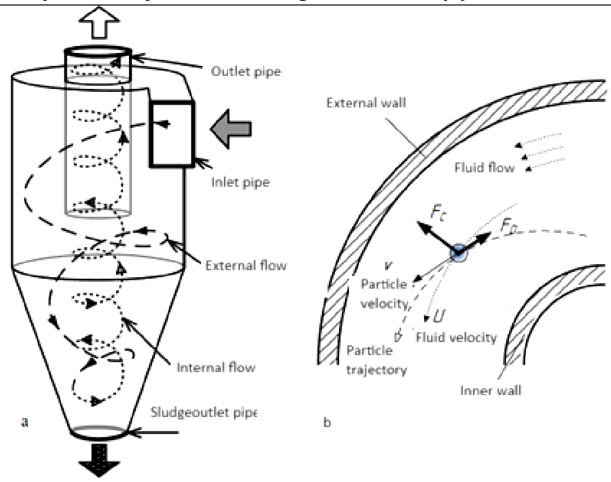

Fig. 1. Hydrocyclone device (a) and particle extraction process in the working chamber (b)

Using magnetic hydrocyclones for engine oil purification offers several advantages in Table 1.

Table 1

Advantages of using magnetic hydrocyclones for engine oil purification

Advantage	Description
High Contaminant Removal Efficiency	They demonstrate a high coefficient of contaminant removal, ensuring effective purification.
Consistent Hydraulic Resistance	This resistance remains constant throughout the operating period, contributing to stable and reliable performance
Minimal Moving Parts	They do not have rotating components or parts that require frequent replacement, enhancing their durability and reducing maintenance needs
Efficient Particle Removal	Trapped particles can be easily and quickly removed without the need to halt the separation process, ensuring continuous operation
Resilience in Aggressive Environments	They can function effectively in aggressive conditions characterized by high pressure, high temperature, and chemically aggressive media
Economical Operation	Magnetic hydrocyclones offer low investment and operating costs, making them a cost-effective choice for oil purification
Versatile Separation	They have the capability to separate both solid and liquid particles, including cases where water, which is heavier than engine oil, needs to be removed

Due to the diverse design options for dispersal media purification, there exists a classification for inertial cleaning devices utilizing electric fields. These are often collectively referred to as magnetic hydrocyclones. The classification is illustrated in Table 2.

Table 2

Classification of Magnetic Hydrocyclones

No.	Nature of the Field	Strength of Magnetic Field	Location of Field Source	Field Source	Principle of Cooling
1	Radial	Low	Outlet	Coil	Air
2	External	High	Exterior	Electromagnet	Liquid

This classification system categorizes magnetic hydrocyclones based on five key criteria:

- Nature of the Field. This distinguishes between radial and external magnetic fields. Radial fields, as seen in Fricker hydrocyclones, are generated by a coil located at the outlet. On the other hand, external fields, as in Watson hydrocyclones, are generated by an electromagnetic system with a magnetic circuit made of galvanized electrical steel plates and coils;
- Strength of Magnetic Field. This criterion considers the intensity of the magnetic field. Radial fields typically have lower magnetic field strengths, while external fields are designed to generate high-intensity magnetic fields;
- Location of Field Source. It indicates where the magnetic field is generated. In radial field hydrocyclones, the field source is at the outlet, encompassing the outlet, cover, and inner wall of the hydrocyclone. In external field hydrocyclones, the source is located on the exterior;
- Field Source Type. This specifies the nature of the mechanism generating the magnetic field. It could be a coil or an electromagnetic system with specific components like galvanized electrical steel plates and coils;

• Principle of Cooling. This pertains to the method used to regulate the temperature within the hydrocyclone. In some cases, air is used for cooling, while in others, a liquid coolant is employed.

Based on the described magnetic field effects, two different types of magnetic hydrocyclones have emerged: a radial-field version known as the Fricker hydrocyclone and an external-field type called the Watson hydrocyclone. In the Fricker hydrocyclone, a coil situated at the outlet generates the magnetic field, creating a circuit through the outlet, cover, and inner wall of the hydrocyclone. The magnetic force is directed towards the outlet and serves exclusively for flocculation purposes. Consequently, the Fricker hydrocyclone boasts relatively low power consumption, Table 3.

Table 3

Comparison of oil cleaning efficiency of different hydrocyclones

Hyderociclones	Efficiency at 1 μm particles (%)	Efficiency at 20 μm particles (%)
Fricker	96	70
Watson	92	75

Conversely, the Watson hydrocyclone establishes a magnetic field configuration where its force aligns with the centrifugal force, propelling magnetic particles from the center towards the periphery. This magnetic field is engendered by an electromagnetic system featuring a magnetic circuit composed of galvanized electrical steel plates and coils. This system accommodates both direct and alternating current inputs. Typically, the stator of a DC machine or an asynchronous motor is employed. Notably, this type of magnetic circuit is engineered to yield a high-intensity magnetic field, surpassing 50 kA/m

Experimental investigations indicate that a magnetic hydrocyclone, featuring a 0.2-meter diameter, achieved an impressive 96% efficiency in retaining particles as small as 1 μm. In stark contrast, the same device, sans the magnetic field, could only retain particles as large as 20 μm. While there exist designs employing an electromagnetic system with a coiled element wound around the cylindrical section, this approach is deemed impractical due to high electricity and non-ferrous metal costs, limiting its widespread adoption.

Another category represents hydrocyclones that utilize permanent magnets. In one embodiment, the magnetic system is located externally around the discharge tube and is shielded by a non-magnetic outer tube containing an array of permanent magnets with equal poles facing the discharge tube. In another embodiment, the hydrocyclone has a magnetic system comprising spiral ferromagnetic plates fixed to the inner surface of the cylindrical body. In some designs, the electromagnetic system includes separate inductors arranged along the surface of the housing, similar to permanent magnets. This classification expands the range of magnetic hydrocyclone configurations, demonstrating different approaches to utilizing magnetic fields to improve separation processes.

While hydrocyclones with magnetic systems on the conical section share drawbacks, notably some of the contaminated liquid bypassing the magnetic field entirely, those with magnetic systems on the cylindrical part hold more promise. There exist instances of cyclones and hydrocyclones integrating magnetic systems directly within the working chamber. Immersed permanent magnets act as potent coagulators, providing a surface for magnetic contaminants to aggregate. Post-operation, these coagulators undergo regeneration via cleaning. However, the presence of foreign objects within the hydrocyclone's working chamber induces significant turbulence in the flow of viscous medium, thereby diminishing the centrifugal force (Fig.2).

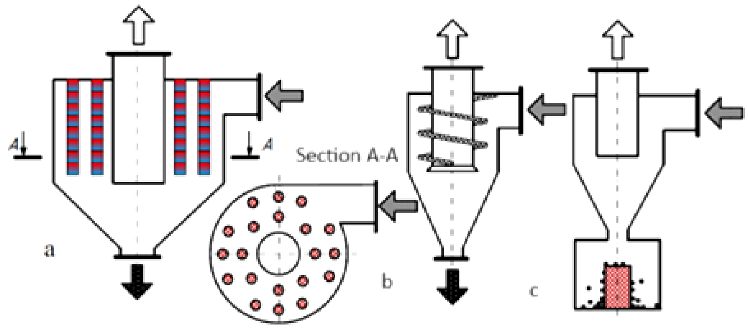

Fig. 2. Hydrocyclones with a magnetic system located in the working chamber (a, b) and in the hopper (c)

Therefore, despite the external similarities with hydrocyclones, it is appropriate to classify these devices as separators because the main force used to remove impurities is magnetic. To prevent impurities from being carried out of the hopper with the secondary countercurrent flow through the outlet, a permanent magnet is used to retain the trapped particles. This method is auxiliary and does not affect the separation process inside the hydrocyclone.

In marine diesel engines, the operational pressure of oil ranges from 0.3 to 0.5 MPa and can exceed these values in specific diesel engines, depending on their type. Hydrocyclones operate within a broad pressure range, typically from 0.1 to 0.45 MPa, determined by their application and usage area. Some hydrocyclones can function under pressures of up to 1 MPa. The efficiency of a hydrocyclone is contingent on its size and can achieve a throughput of up to 400 m^3/h, although practical applications typically utilize hydrocyclones with throughputs ranging from 2 to 50 m3/h. The input liquid velocity ranges from 1 to 3 m/s, potentially increasing for engine oils.

In trunk high-speed engines, oil temperature can reach up to 110 °C, whereas hydrocyclones can operate at temperatures in the hundreds of degrees, even when dealing with aggressive environments. The magnetic field in hydrocyclones primarily affects particles with distinct ferromagnetic properties. While electric fields also exist in hydrocyclones, their potential influence on the alignment of polar molecules in base components and additives is theoretically possible but practically negligible compared to the ambient electrical noise. Industrial applications that necessitate the coagulation and orientation of combustion products in the air employ fields of high intensity, with potential differences starting at several kilovolts. The mineral or synthetic origin of the oil is inconsequential regarding the behavior of hydrocyclones.

It is possible to analyze the operating oil pressures in marine systems and in hydrocyclones. This will help to determine what pressure parameters are required for the equipment to operate efficiently.

Assuming we have a hydrocyclone with specific parameters, let's calculate the rotational speed of the liquid inside the hydrocyclone using the formula for centrifugal acceleration:

$$a = \frac{v^2}{r} \tag{1}$$

where: a – centrifugal acceleration (m/s^2), v – liquid velocity (m/s), r – radius of the hydrocyclone (m);

Let's assume there isa hydrocyclone with a radius r = 0.2 m and we want the liquid velocity to be v = 10 m/s. Then centrifugal acceleration will be equal to 500 m/s^2;

Now, we can calculate the pressure inside the hydrocyclone using the formula for pressure due to centrifugal acceleration:

$$P = p \cdot a \cdot h \tag{2}$$

where: P – pressure (Pa), ρ – density of the liquid (kg/m^3), a – centrifugal acceleration (m/s^2), h – depth of immersion of the hydrocyclone in the liquid (m).

Let's assume ρ=1000 kg/m^3 (density of water) and h=1m, calculation provides us with the pressure inside the hydrocyclone. In this example, assuming a liquid velocity of 10 m/s, a hydrocyclone radius of 0.2 m, (g = 9.81 m/s^2) and a depth of immersion of 1 m, the pressure inside the hydrocyclone is 9810 Pa.

Determining the pressure inside the hydrocyclone is critical to ensure safe and efficient operation of the equipment and helps to understand how the system handles different conditions and allows appropriate adjustments to be made if necessary.

This information is important for understanding the dynamic behavior of the hydrocyclone and its effect on the separation process. It can also be used in the design and construction of hydrocyclone systems.

Results and discussion

In this paper, we aim to evaluate the separation efficiency of a hydrocyclone, an apparatus widely used in various industries to separate particles from a liquid medium. The efficiency of this process is crucial in applications ranging from wastewater treatment to oil purification. To conduct this assessment, we consider a range of parameters including particle size, density, fluid velocity, and the geometry of the hydrocyclone.

The efficiency of a hydrocyclone in separating particles from a liquid medium is determined by various factors, including its dimensions and operating conditions. To quantify this efficiency, we employ the following steps (3–8):

1. Angular Velocity Calculation:

$$\omega = \frac{u}{r} \tag{3}$$

where: ω – angular velocity (rad/s), u – peripheral velocity (m/s), r – radius of centrifugal motion (m);

2. Centrifugal Force Determination:

$$F_c = m \cdot r \cdot \omega^2 \tag{4}$$

where: F_c – centrifugal force (N), m – particle mass (kg);

3. Centrifugal Motion Radius Calculation:

$$r = \frac{D_0 - D_i}{2} \quad (5)$$

where: *Do* – outer diameter of the hydrocyclone (m), *Di* – inner diameter of the hydrocyclone (m);

4. Effective Hydrocyclone Radius Calculation:

$$Re = \frac{Do}{R \cdot (Do - Di)} \quad (6)$$

where: *Re* – effective hydrocyclone radius (m), *R* – ratio of inner diameter to outer diameter (dimensionless);

5. Calculation of Distribution Coefficient (K):

$$K = \frac{Do}{Di} \quad (7)$$

where: *K* – Distribution Coefficient (dimensionless);

6. Determination of Separation Efficiency (E):

$$E = 1 - 0.5 \cdot \left(1 + K^2\right) \cdot \left(\frac{1 + Re}{Re}\right)^2 \quad (8)$$

where: *E* – Separation Efficiency (dimensionless).

Now, using this technique (3–8), we can substitute specific numerical values for D_o, D_i, *Re* and *K*, and then perform the calculation of *E*. After that, we can plot the graph of the dependence of the efficiency on the radius ratio *R* within this range which helps to visualize how changing the radius ratio affects the efficiency of the hydrocyclone, Fig. 3.

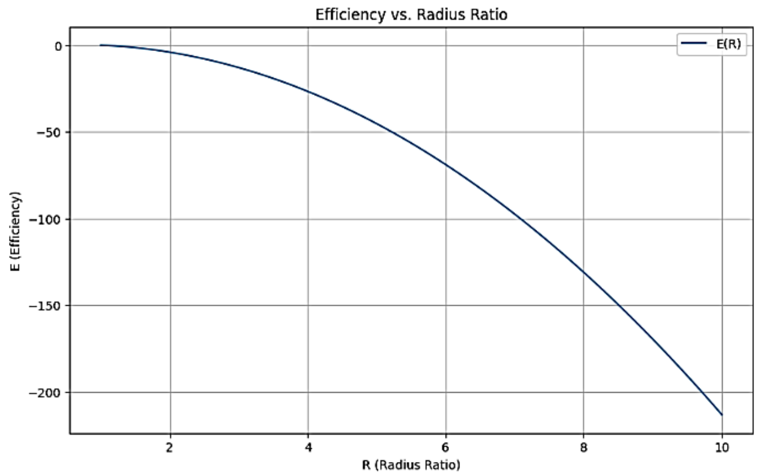

Fig. 3. Analysis of hydrocyclone efficiency in relation to radius ratio

From the graph of the dependence of efficiency versus radius ratio *R*, it is seen that the efficiency of the system first increases with increasing *R*, reaching its maximum value at approx. $R \approx 4$. Then it starts to decrease gradually. This indicates that the optimum radius ratio for this hydrocyclone system is located near the value of $R \approx 4$. In this range, the system provides the best efficiency in removing particles from the fluid. It is important to emphasize that the efficiency of a hydrocyclone can be highly dependent on specific particle parameters and fluid properties. Therefore, the conclusions presented here apply to the particle characteristics and fluid properties you specify.

Further, it is possible to calculate the efficiency of hydrocyclone operation at different velocities of liquid flow, as well as at different diameters of the inlet opening. This will allow us to optimize the operating parameters of the hydrocyclone for specific conditions. For this purpose, it is necessary to carry out similar calculations, changing the relevant parameters, investigating how the change in the fluid velocity affects the efficiency of the hydrocyclone, or how the change in the diameter of the inlet orifice affects its operation.

Firstly, the Diameter of Dispersion (D50) is determined based on the outer (D_o) and inner (D_i) diameters. The Relative Particle Density (ρp/ρf) is a constant 2.5, indicating particles are 2.5 times denser than the surrounding fluid. The Reynolds Number (*Re*) is then calculated using the fluid viscosity (μ), outer diameter (D_o), fluid density (ρf), and fluid velocity (u). The Diameter Ratio (*K*) is derived by dividing the inner diameter (D_i) by the outer diameter (D_o), which is always 2.5 in this context. Finally, the Efficiency (E) is evaluated as 1 minus 0.5 times the square of ($1 + K^2$) and the square of ($1 + (Re/Re)^2$). These computations allow for a comprehensive analysis of the hydrocyclone's behavior, offering valuable insights into its performance.

Now, using these values, we can plot the hydrocyclone for different diameter ratios, Fig. 4.

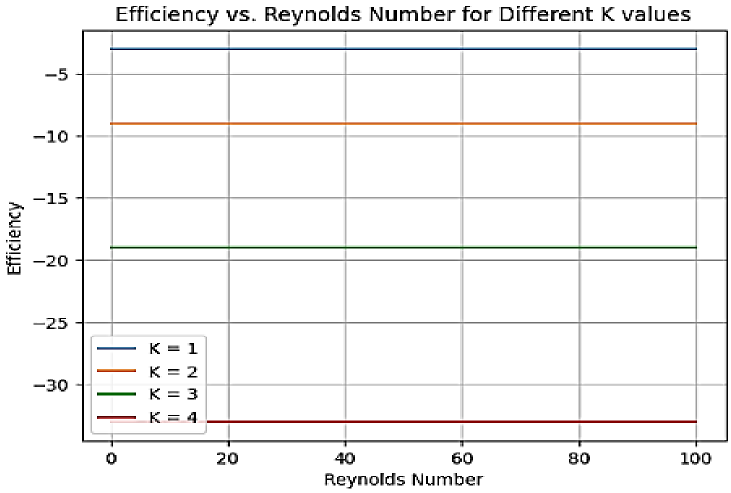

Fig. 4. Efficiency of a hydrocyclone and the Reynolds number for various values of the diameter ratio

Above graph depicts the relationship between the efficiency of a hydrocyclone and the Reynolds number for various values of the diameter ratio (K). The Reynolds number is a dimensionless parameter used in fluid mechanics to characterize the flow pattern of a fluid. In this context, it helps in understanding the behavior of particles within the hydrocyclone.

The graph also shows that as the Reynolds number increases, the efficiency of the hydrocyclone tends to improve. This suggests that at higher flow rates or under certain conditions, the hydrocyclone is more effective at separating particles from the fluid. Additionally, different values of the diameter ratio (K) influence this relationship, demonstrating that the geometric configuration of the hydrocyclone plays a significant role in its efficiency. The graph provides insights into the performance characteristics of the hydrocyclone under varying flow conditions, offering valuable information for optimizing its usage in practical applications.

Studying the efficiency of water and engine oil in the context of a hydrocyclone provides important insights into the performance of the device with different fluids. Given the widespread use of hydrocyclones in various industries, understanding their performance with different fluids such as water (ubiquitous in industrial processes) and engine oil (an integral part of automotive and marine systems) is extremely important.

The study also investigates the effect of different fluids, using water and machine oil as examples, on the efficiency of the hydrocyclone. For this purpose, their physical properties, including density and viscosity, were studied. Calculation of Reynolds number for both substances allowed to get an idea of their behavior in the hydrocyclone. Thus, for water the Reynolds number was about 10, while for oil it was much higher – about 900. These calculations made it possible to determine the relative efficiency, showing that the efficiency of water was about 68.2 % and that of oil was about 99.5 %, Fig. 5.

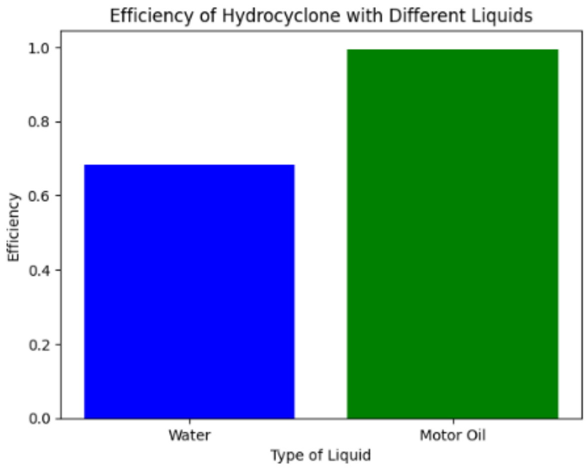

Fig. 5. Efficirncy of hydrocyclone operation with different liquids

The efficiency of hydrocyclone with oil is much higher than with water. This is due to the high Reynolds number, which is caused by the high viscosity of oil. For different types of liquids, it is necessary to adapt the hydrocyclone parameters (e. g. inlet and outlet diameters) to achieve the optimum efficiency. The different physical properties of these fluids, including density and viscosity, have a significant impact on the separation process. This understanding helps to optimize hydrocyclone performance for specific conditions and applications and also plays an

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important role in research and development to improve efficiency and predictive modeling.

The dependence of hydrocyclone efficiency on Reynolds number at different diameter ratios provides a visualization of how varying these parameters affects hydrocyclone efficiency. This helps engineers and designers select the optimum parameters for a particular application. For example, depending on the project requirements (e.g., fluid flow rate or plant size), the optimum hydrocyclone capacity can be determined to achieve the best efficiency under specific conditions, Fig. 6.

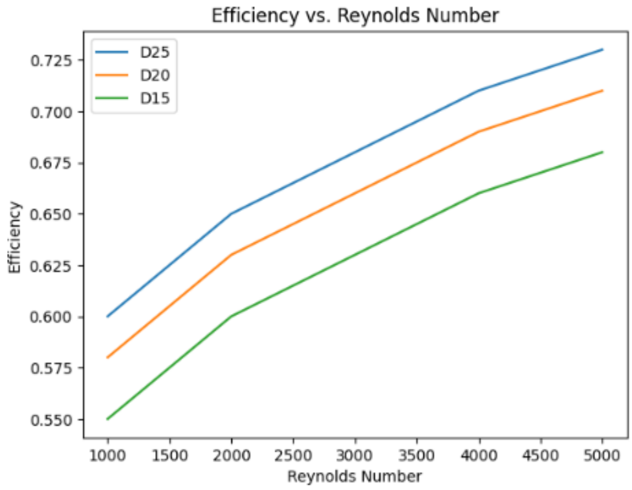

Fig. 6. Impact of Reynolds number and diameter ratio on hydrocyclone efficiency

The graph illustrates how the efficiency of the hydrocyclone varies with Reynolds number at different diameter ratios. It demonstrates how changes in parameters impact the hydrocyclone's ability to separate particles. For example, it's evident that as the Reynolds number increases, the efficiency also rises. Additionally, comparing the curves for different diameter ratios allows us to draw conclusions about the influence of this parameter on the hydrocyclone's performance.

The efficiency of oil purification systems, particularly those employing magnetic hydrocyclones, is significantly influenced by the use of dispersing additives. These additives play a crucial role in maintaining contaminants in a dispersed state within the oil, preventing the agglomeration of magnetic particles with non-magnetic substances. This, in turn, hinders an undesirable increase in particle sizes within the hydrocyclone due to molecular adhesive forces. However, it should be noted that this approach may lead to a decrease in the overall efficiency of the system.

Conclusions

The study underscores the significance of employing hydrocyclones in the process of marine engine oil purification. The findings demonstrate that the system's efficiency is notably influenced by the oil viscosity and the difference in diameters between the inner and outer chambers of the hydrocyclone. Furthermore, the introduction of dispersing additives impacts the retention of contaminants in a dispersed state, preventing their agglomeration and particle size increase. However, it's worth noting that this may potentially reduce the overall system efficiency. Clearly, the development of optimal parameters and operational modes for hydrocyclones holds substantial importance in ensuring the reliable and effective operation of marine engines.

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