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Design and Analysis of a Removable Sludge Making Coal Machine

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Abstract: This paper designs an operational workflow, and key performance metrics of a novel removable sludge making coal machine, with parameters for the moisture content of 84.27%, at the rate of 10.08% of oil as the design object. The machine can be moved to the stacking site for treatment, recovering oil and making low oil content sludge to coal. The separated water will be used for oilfield injection, and can be processed for reuse. It not only access to the environmental benefits, it will also produce the enormous economic benefits. It designed for flexible, on-site deployment in oilfields and refineries, this integrated unit eliminates the need for costly and risky off-site transportation of hazardous oily sludge. The system, which is 1.8 meters in height and diameter, integrates a mechanical clarification tank, an automatic continuous discharge centrifuge, and a coal mixer. The operational workflow involves chemical pre-treatment and clarification at 50^{0}C, followed by centrifugal dewatering, and then blending the resulting solid cake with pulverized coal. Based on the design, the system achieves a high 98.89% oil removal rate and a 90% solid recovery rate, successfully transforming tank bottom mud with 10.08% oil content into a valorized sludge-coal mixture suitable for use as a solid fuel. The machine was successfully designed with the turbine as power with molding briquette, to convey solid-liquid separation in separation chamber to sludge for automatic continuous centrifuge, then to mud discharging pipe, and into the coal mixing machine. The device has the advantages of simple operation, good effect of processing factors and small human influence.

Keywords: Oily sludge; movable sludge making coal machine; Mechanical clarifier; Coal mixing machine; Continuous discharge centrifuge

I. INTRODUCTION

Oily sludge is a semi-solid, hazardous waste from the petroleum industry, composed of oil, water, and solid particles, including toxic pollutants like heavy metals and polycyclic aromatic hydrocarbons (da Silva, Alves & de França, 2012). It poses significant environmental and health threats and requires specialized treatment to mitigate its toxicity and recover valuable components (Abdulqawi, Yunus, Ismail & Bin Mokaizh, 2024). Treatment methods aim to separate the oil and water for reuse and stabilize or dispose of the solid components, with applications including resource recovery, oil recycling, and the creation of beneficial products like gel systems for oilfield applications (Essang, Olaye & Zakariya, 2024). Waste sources "oil sludge and foot from oil extraction and refining", "sediment generated during mineral oil storage" and "waste oil and sludge from oil-containing wastewater treatment" shows that oil-containing sludge in oil fields belong to hazardous waste management surrounding (Teng, Zhang & Yang, 2021).

An increasing demand for oil in the world and new technologies stimulate oil resource countries to develop new resources (Kjärstad& Johnsson, 2009). Large amount of oily sludge will be produced in the process of oil extraction, transportation, refining and oily sewage treatment (Islam, 2015). The composition of oily sludge is complex, prone to corruption and stench, air pollution, and has a great role in production and environmental protection (Wang, Lai, Wang & Ji, 2024). As a result of the harm, the reduction, resourceization and harmless disposal of oily sludge have attracted more and more attention (Niu, Sun & Lin, 2022).

Oily sludge generated in the process of oil recovery sewage treatment, coupled with flocculants, equipment and pipeline corrosion products and dirt and bacteria formed by water purifiers added to sewage purification treatment (da Silva, Alves & de França, 2012). Oil-bearing sludge is generated during the oilfield collection and transportation process (Kundu & Mishra, 2018). Oil-containing sludge mainly comes from sedimentation tanks, oil tank sludge of joint stations, grease trap bottom mud, sewage tank bottom mud, oil sludge, oily sand removed from oily sewage treatment facilities in refineries, landing crude oil and oil and oil-containing sludge caused by drilling, operations and pipeline perforation (Zhong, Liu, Yuan, Wang, Teng, Zhang ... & Jiang, 2020; Islam, 2015).

When storing oil in oil storage tanks, a small amount of heavy oily components such as mechanical impurities, soil, sand particles, heavy metal salts, as asphalt and paraffins in the oil are deposited at the bottom of the tank, forming oil mud at the bottom of the tank (Pal & Naiya, 2025).

Oily sludge mainly comes from the ground treatment system, generated from the sewage treatment plant of the refinery (da Silva, Alves, & de França, 2012). It is commonly known as the "three sludge of the refinery", which includes: the slag generated by flocculant air flotation tank, the bottom mud of the grease trap tank, and the remaining activated sludge at the bottom of the aerated biochemical crude oil tank, which is flotation (Sein, 2011). Oily sludge, a hazardous byproduct generated during petroleum exploration, refining, transportation, and storage, poses significant risks to both the ecological environment and human health. Its complex composition, which includes hydrocarbons, heavy metals, and other toxic substances, makes it a persistent pollutant (Pal & Sen, 2024). Historically, a large portion of this waste in China has been stored on-site or disposed of by third-party companies, leading to potential environmental contamination (Kang, Ye, Wu, Wang, Yuan & Ye, 2025). However, this sludge also represents a valuable secondary resource.

A removable sludge making coal machine is an integrated and mobile device that can be transported directly to sludge stacking sites for on-site treatment (Gui, Liu, Cao, Miao, Li, Xing & Wang, 2015). The machine facilitates the recovery of oil, the conversion of low-oil-content sludge into coal briquettes, and the recycling of separated water for oilfield reinjection. This approach not only mitigates environmental pollution but also generates considerable economic benefits by transforming waste into usable products (Hu, 2016). Removable sludge making coal machine most likely refers to a mobile briquetting plant or a sludge briquetting machine that can be moved or has easily exchangeable parts. These machines are used to process sludge (such as sewage, mineral, or industrial sludge) and often combine it with coal or biomass to produce fuel briquettes (Sogah& Owusu, 2024). The final briquettes can be used in boilers, furnaces, and other applications that require fuel. Several types of machines are suitable for making fuel briquettes from sludge based on the material composition, moisture content, and desired production scale (Arachchige, 2021).

The purpose of this study is to design a device for a movable oil sludge coal machine, which can be moved to the stacked site for on-site treatment (Figure 1, and 2). While recovering oil, the low oil content sludge is made into briquette. The separated water is used for recharge of oilfield water. The oil can be treated and reused, which not only achieves environmental benefits, but also produces huge economic benefits.

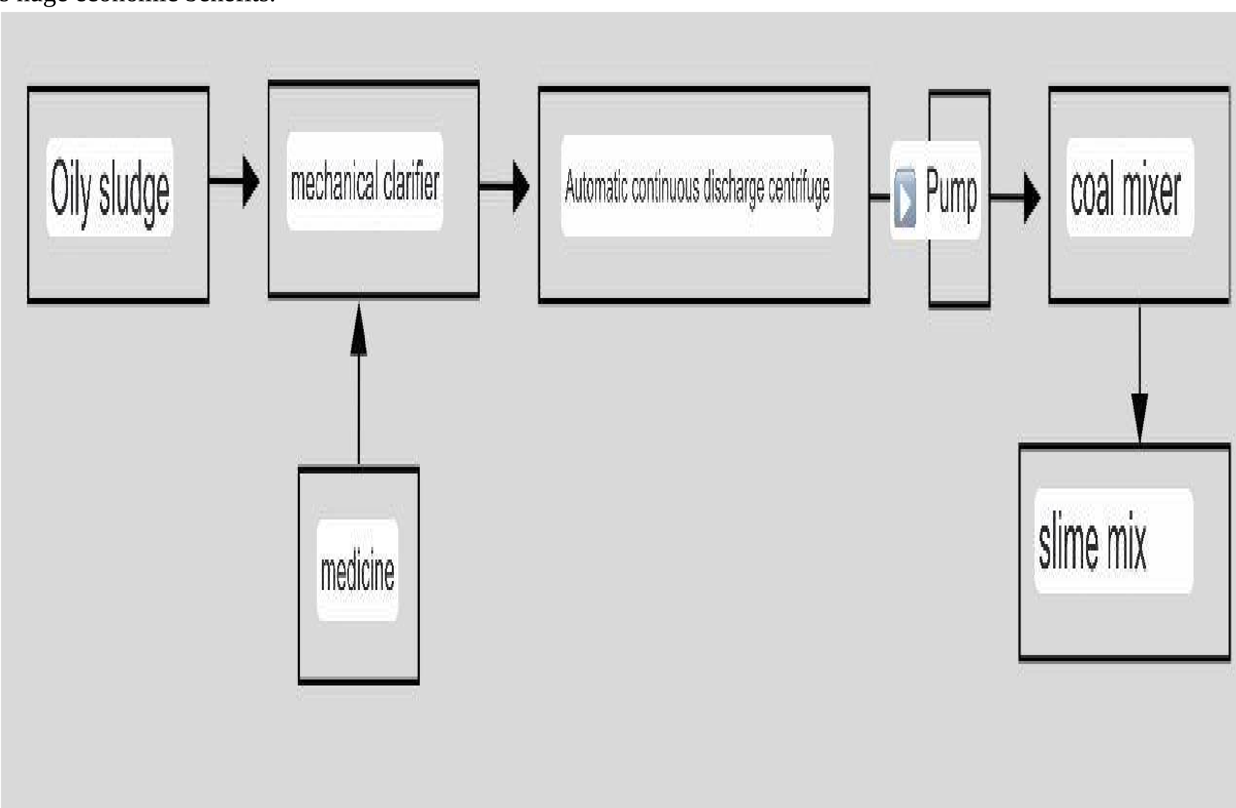

Figure 1: Preliminary Design of Movable Sludge Coal Machine

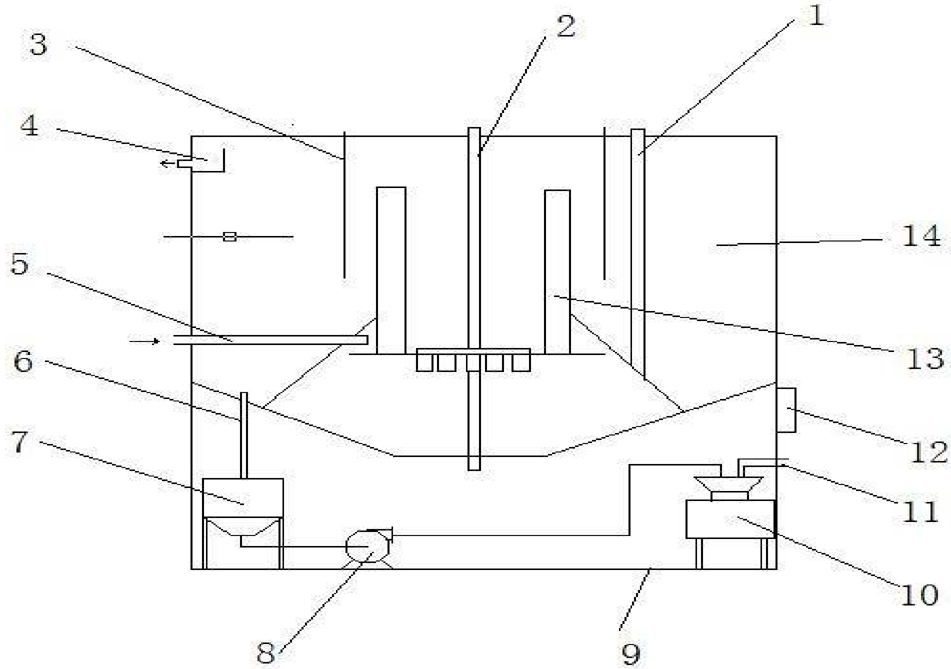

Figure 2: Schematic Diagram of Removable Sludge Making Coal Machine

II. MATERIAL AND METHODS

A. Study Area

Liaoning Shihua University is located in Fushun City, Liaoning Province, China. The university is also known as the University of Liaoning Shihua and was formerly known as Fushun Petroleum College. The university's campus overlooks the Hunhe River and is in the city's urban area, at 1 Dangong West Road, Wanghua District, Fushun, Liaoning. The university's campus is situated in Fushun, which is about 45 km (28 miles) east of Shenyang, the provincial capital.

B. Types and Sources of Data

The foundational characteristics and metrics used for the machine's design and performance calculations are detailed as: Raw material characteristics which involve the key physical properties of the tank bottom mud (sludge type, moisture, and oil content) used as the raw material are specified.Design parameters, comprises of the essential operational settings, including the clarification tank's flow rate, the liquid-to-sludge ratio, and the operating temperature. Performance data for the expected efficacy of the system, quantified through the oil removal rate and the solid recovery rate.

The design and deployment context for the Removable Sludge Making Coal Machine are described.

1) System Overview and Components

A summary of the integrated unit's physical specifications and six main components is provided

- Mechanical Clarification Tank: Serves as the primary reaction and solid-liquid separation vessel. Key sub-components include a water inlet pipe, stirring impeller, sink, diversion plate, dosing pipe, and mud drainage pipe.
- Automatic Continuous Discharge Centrifuge: A vertical centrifuge for further dewatering of the solid phase from the clarification tank.
- Coal Mixer: A mixing chamber where dewatered sludge is combined with pulverized coal.
- Constant Temperature Water Bath Heating Sleeve: Installed on the outer wall of the clarification tank's reaction chamber to maintain an optimal processing temperature (50°C).
- Control Panel: Centralized interface for operating all components.
- Pumps and Piping System: Facilitates the transfer of materials between components.

2) Operational Workflow

Pre-treatment and Reaction: Oily sludge and chemical reagents are fed into the mechanical clarification tank. The internal stirring impeller mixes the contents while the heating sleeve maintains a temperature of 50°C. This process occurs in the first and second reaction chambers, promoting flocculation. The sequential steps, from pre-treatment to final briquetting, that the sludge undergoes are outlined.

- Solid-Liquid Separation: The mixture flows into the separation chamber, where the flow velocity drops, allowing solids to settle by gravity. The separated liquid phase (oil and water) is collected via a perforated sink, while the solid phase (sludge) is discharged through a mud pipe.
- Centrifugal Dewatering: The sludge enters the automatic continuous discharge centrifuge. Under high-speed rotation, centrifugal force separates remaining liquid, producing a drier solid cake.
- Mixing and Briquetting: The dewatered sludge is pumped into the coal mixer, where it is blended with pulverized coal. The resulting homogeneous mixture is then ready to be pressed into coal briquettes using an external mold.

3) Theoretical and Reference Data

Information on sludge treatment technologies (thermal desorption, solvent extraction, hot washing, centrifugation) and equipment design principles were sourced from academic literature, patents, and engineering handbooks, as listed in the project's references.

III. DATA PROCESSING AND ANALYSIS

The specific engineering calculations and analyses performed to validate the system's design are presented.

A. Key Design Calculations

The calculated physical dimensions and operational specifications for the clarification tank, centrifuge, and coal mixer are outlined as:

1) Mechanical Clarification Tank:

Second Reaction Chamber: Diameter = 0.42 m, Height = 0.45 m.
Total Inner Diameter = 1.49 m, Effective Volume = 1.65 m³.
Lifting Impeller: Outer diameter = 0.3 m, Speed = 10 rad/min.

2) Automatic Continuous Discharge Centrifuge:

Drum Inclination Angle (α) = 60°, Drum Diameter = 0.4 m, Height = 0.3 m.
Operational Speed Range: 950 - 1150 rpm (low-speed centrifuge, separation factor 1000-1500).

3) Coal Mixer:

Chamber Diameter = 0.4 m, Height = 0.44 m.
Mixing Impeller: Outer diameter = 0.28 m, Speed = 10 rad/min.

B. Material Balance Analysis

The steady-state flow rates for all inputs and outputs are confirmed to validate the system's functional processing capacity as:

- *Inputs:*

Oily Sludge: 0.42 m³/h
Reagent Solution: 2.58 m³/h
Pulverized Coal: 0.045 m³/h

- *Outputs:*

Liquid Phase from Clarification Tank: 2.63 m³/h
Liquid Phase from Centrifuge: 0.312 m³/h
Final Sludge-Coal Briquette Mixture: 0.1 m³/h

This balance confirms the system's functionality in processing the specified input flow and achieving the desired separation and mixing.

IV. RESULTS AND DISCUSSION

The key findings from the engineering design process, including performance metrics and product details as shown in Figure 3.

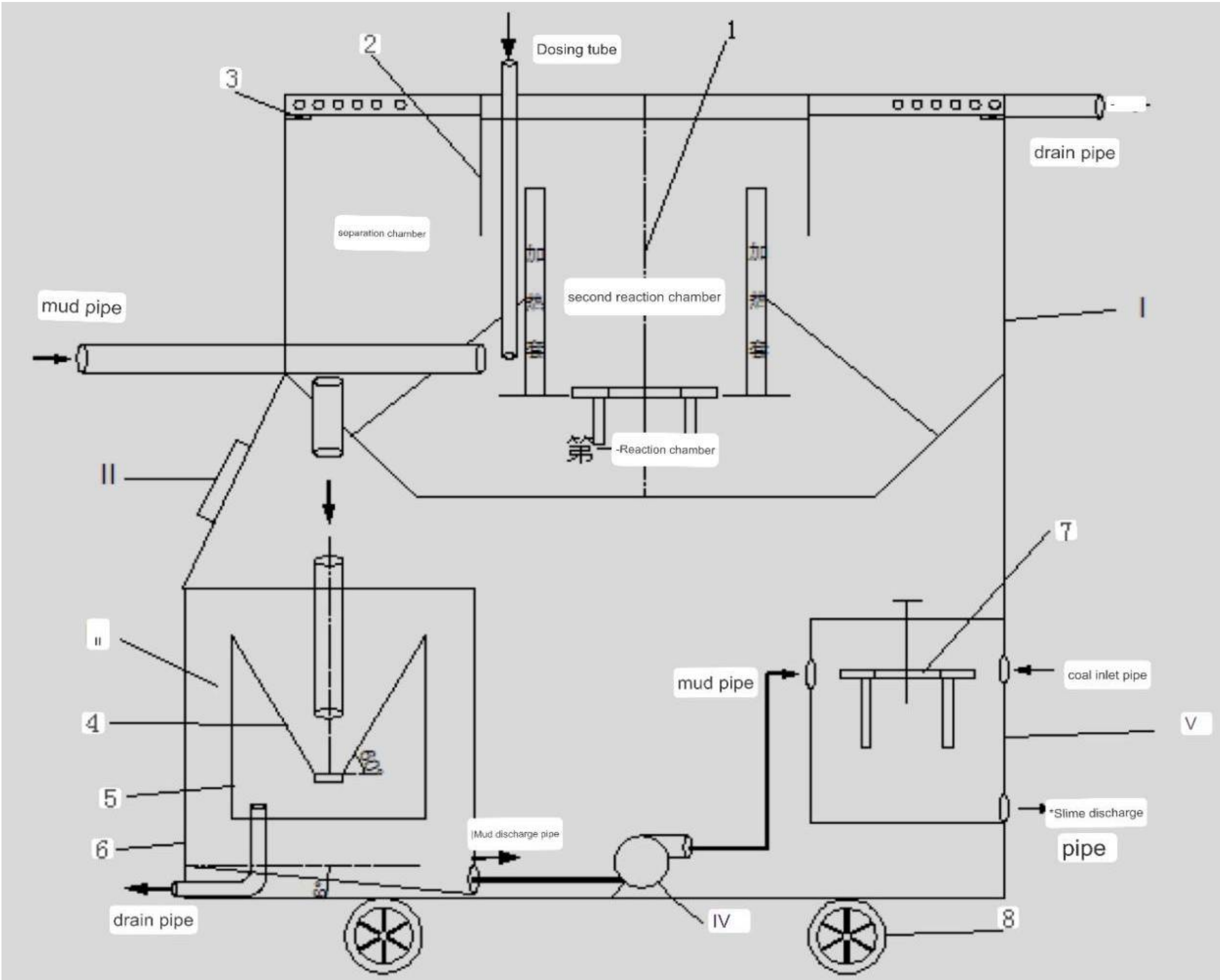

Figure 3: Movable Sludge Making Coal Machine Structure Diagram

I. Mechanical clarification pool
II. Control Panel
III. Automatic continuous discharge centrifuge
IV. Lifting pump
V. Pulverized coal mixer
1. Mechanical clarification tank stirring impeller
2. Dive board
3. Collection sink
4. Turn the drum
5. The inner shell of the unloader
6. Unloader housing
7. Pulverized coal mixer impeller
8. Wheel

A. Design Outcomes

The detailed engineering design resulted in a fully specified, movable integrated machine, as indicated in figure 1. Key performance metrics derived from the design parameters and material balance include:

- High Oil Recovery: The combined clarification and heating process achieves a 98.89% oil removal rate.
- Effective Solid Recovery: The centrifuge recovers 90% of the solids, which are then valorized.
- Product Valorization: The final output is a sludge-coal mixture suitable for use as a solid fuel, thereby achieving the goal of resource recovery.

B. Advantages of the Design

The key benefits of the machine's final design, focusing on its mobility, integration, and ease of use. The unit can be easily moved, enabling in-situ treatment and reducing transport costs and risks. The integration combines multiple treatment steps (separation, dewatering, mixing) into a single, compact system. The control panel allows for straightforward operation with minimal manual intervention.

V. CONCLUSION

This study successfully designed a removable sludge making coal machine which offers a practical and efficient solution for the resource recovery and harmless treatment of oily sludge. By integrating mechanical clarification, centrifugation, and coal mixing, the device achieves high oil recovery and produces usable coal briquettes. The design addresses the environmental challenge of oily sludge disposal while offering an economically attractive solution through resource recovery. Its mobile nature makes it particularly suitable for decentralized application in oilfields, contributing to cleaner production and circular economy principles in the petroleum industry.

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