April 2023

FLUID MECHANICS & APPLICATIONS

EDITED BY
Dr. Saurav Mukherjee

CIIR Scientific Publications

Fluid Mechanics & Applications

EDITED BY

Dr. Saurav Mukherjee

CIIR Scientific Publications
Noida, India.

CIIR Scientific Publications

Fluid Mechanics & Applications

First published April 2023 by CIIR Scientific Publications, Noida, India.

April 30, 2023

ISBN 978-81-962237-8-6

Edited and Compiled by
Dr. Saurav Mukherjee

Publisher Address
Council for Industrial Innovation and Research
B-17, Sector-6, Noida,
Uttar Pradesh, India.
201301
Email: info@ciir.in
www.ciir.in

Contents

Preface

A crucial component of the understanding of petroleum engineers is fluid mechanics. Almost every aspect of petroleum engineering, including drilling, well completion, production technology, transportation, and refining, uses it in some way. These specialized fields use their own application-oriented hydraulics in both their design processes and day-to-day operations. These separately created subfields of applied fluid mechanics frequently lack strong integration. Within the broad context of continuum mechanics, it appears necessary to treat these different portions collectively. The elegance and logical organization of this theory may also have an impact on petroleum engineers' style of thinking.

This book's major goal is to give petroleum engineers a methodical analytical approach to solving fluid flow issues. The foundation is set by a few fundamental rules concerning the conservation or balance of mass, momentum, energy, and entropy. In areas where flow variables are continuous, it is discovered that these fundamental ideas, which are expressed in integral form, are analogous to differential field equations. These conservation and balancing equations, however, create an indeterminate system that cannot produce precise solutions without the addition of additional equations. It is necessary to define ideal materials by additional requirements known as constitutive relations within the encompassing concept of conservation laws and balancing equations. Boundary conditions, balance equations, constitutive relations, and constitutive relationships can all be used to represent a phenomenon mathematically and find a solution to a specific issue. Experimental research may be used to confirm the thus-obtained solution.

A fluid is regarded as an isotropic substance that constantly deforms in response to an applied external force. The mathematical representation of flow, the most prevalent type of fluid motion, is a continuous transformation of three-dimensional Euclidean space into itself. No matter how viscous a fluid is, it will flow even in the presence of tangential tension. Tangential stresses—which cannot exist in fluids—between neighbouring fluid particles are inversely proportional to the rate of deformation and vanish when the flow stops. A fluid might be a gas or a liquid. While gases are very compressible, liquids are relatively incompressible. While gases have a propensity to expand indefinitely, liquids have a constant density and volume (very minimally affected by temperature). The pressure at a liquid's free surface can be constant and equal to the pressure of the surrounding gas or vapour. It is common knowledge that all matter can exist in either a liquid or solid state. The physical conditions of hydrocarbon production and technology likewise invariably apply to this. Different macroscopic qualities result from the molecular differences between fluids and solids. Only those characteristics that relate to fluid motion or the factors influencing this motion are interesting from the perspective of this book.

Chapters in this book cover fluid characteristics, kinematics fundamentals, balancing equations for mass, momentum, and angular momentum, kinetic, internal, and total energy, and entropy. This content was created in part for a two-semester graduate fluid mechanics course for petroleum engineering students. Other components were created for graduate-level courses.

Dr. Saurav Mukherjee
Editor

CHAPTER - 1
INTRODUCTION TO BLENDED FUELS

Dr. Suman Paul
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- sumanpaul@presidencyuniversity.in

The economics of petroleum development provide an intriguing situation with heavy crude oils. More heavy oil is available than traditional light crude oil does worldwide. One of the biggest recoverable oil resources in the world, the Orinoco deposits (Venezuela) are estimated by the United States Geological Survey (USGS) to be worth 513 billion barrels if extracted. However, approximately 5 to 30% of the oil in situ can be recovered when it comes to this heavy oil. The chemical composition often makes a difference in recovery rates. On the one hand, heavy crudes are frequently offered at a lower price than lighter crudes owing to high sulphur content in certain oils and excessive refining expenses. Additionally, the increased density and viscosity make transportation more challenging. On the other hand, significant quantities of heavy crude have indeed been found in the Americas, which include Canada, Venezuela, and California, at shallow depths of heavy oil fields not yet deeper than 3000 feet. While this can result in lower production costs, it is counterbalanced by the challenges of transportation, which show the inefficiency of traditional production methods. To move heavy crude oil, specialized transportation techniques are being developed [1]–[3].

It is acknowledged that civilization requires a sufficient quantity of energy, which might be provided by mixing this heavy crude oil in the proper proportion with lighter petroleum products (petrol and diesel) to address issues with transportation and processing of the these crudes. A fundamental physical characteristic of liquids is their viscosity, which has a direct impact on unit activities including pumping, flow capacity, filtration, filling, distillation, extraction, as well as evaporation in addition to heat and mass transfer. The viscosity of heavy grade oils is indeed a crucial characteristic. According to Newton's law of viscosity, the shear stress is inversely proportional to the viscosity at a set speed of fluid deformation. The majority of fluids, including water and oil, adhere to the law and are referred to as Newtonian. The unit of kinematic viscosity, which measures a fluid's internal resistance to movement when subjected to gravitational forces, is m2/s. Kinematic viscosity may be measured using a wide variety of devices and is quite easy to determine. The density fluctuation is not taken into account while measuring kinematic viscosity. Kinematic viscosity is influenced by factors like temperature and pressure. The effects of temperature are quite diverse, and several studies have looked at how viscosity changes with temperature (3 – 7). In these investigations, the viscosity change with respect to temperature was determined using the Arrhenius type equation, and the constants were obtained using non-linear regression analysis [2], [4], [5].

Therefore, determining the viscosities of the chosen liquids at different temperatures is crucial. Numerous techniques exist for measuring viscosity, and they may be divided into two categories: laminar flow viscometers and rotating cylinder viscometers. Liquid is poured via a capillary and flow is monitored against time using laminar flow viscometers. This category includes viscometers such the Redwood 1, Redwood 2, Saybolt, Ostwald, Cannon-Frske, Capillary tube, and variable area. The twisting motion used to spin a cylinder within a liquid is associated to the liquid's viscosity in a rotating cylinder viscometer. The latter category includes the spinning concentric cylinder viscometer as well as the Brookfield viscometer. Many of the currently available viscosity measuring tools are expensive and intricately made.

ISBN 978-81-962237-8-6 April 2023

In the work described here, a straightforward method of kinematic viscosity calculation for Newtonian liquids was studied utilising comparisons with viscosity values and conventional Redwood 1 and Redwood 2 viscometers. Our results make it abundantly evident that temperature has an impact on density as well as viscosity. It means that the molecules in any particular fluid start to separate as the temperature rises, lowering the fluid density, and that viscosity reduces as the temperature rises. The density fluctuation is omitted in kinematic viscosity measurements, however.

The difference “between” an oil's flash point versus fire point is crucial because it indicates how much heat may be applied to the oil without causing excessive breakdown. The usage of volatile compounds affects both the temperature range in which they may be utilised efficiently and the warning that they provide a fire risk. Flash point measurements are necessary primarily to assess the safety risks in light of the material's volatility. The danger increases as the flash and fire sites decrease. Products having a flash point below 38 degrees Celsius often need to be handled with extra care. It is necessary to plan the movement of crude from storage towards the crude oil distillation units as well as the movement of crude from marine vessels into storage tanks within crude oil refineries (CDUs). It involves crude oils with various qualities, and the goals are to either increase gross margin throughout the CDUs by appropriately blending the various crude oil products somewhere at tanks to produce the best blends, or to lower operating costs.

Improved crude blend scheduling may provide operational and financial advantages of millions of dollars annually. Every refinery that feeds a mixture of crude oils to the vacuum and atmospheric distillation units does have a chance to improve. The quicker a refinery can determine if a given crude oil acquisition will result in a viable operation, the better it's going to be able to take advantage of short-term market possibilities. From an operational standpoint, variations in the quality of the crude oil mix and the flow rate charged towards the distillation column have an impact on the downstream production units and constitute the refinery's most significant disturbance. Overall, scheduling and optimizing crude oil blends is a rather quick and economical technique to boost performance.

Fuel properties

Because other types of ethanol are neither soluble or have extremely limited solubility in the overwhelming majority of diesel fuels, the ethanol used throughout the testing was basically anhydrous. The hydrocarbon makeup, wax concentration, but also ambient temperature of both the diesel fuel all affect how soluble ethanol is in that fuel. The mix fuels' water content affects this solubility as well. A solubilize is necessary in ethanol-diesel mixed fuel to solve this issue. In this test, analysis-grade anhydrous ethanol (99.7% purity) and commercial diesel fuel have been employed. Solubilize dose, ethanol, and diesel fuel are the components of ethanol-diesel mixes. The recommended blending procedure called for combining the solubilizer with ethanol first (1.5% v/v for all ethanol-diesel blends other from pure diesel fuel), and then blending this mixture through into diesel fuel. For instance, 15% ethanol-diesel mix (E15-D) contains 83.5% diesel, 1.5% solubilizer, and 15% ethanol. Different physico-chemical changes are brought about by the addition of ethanol in diesel fuel, most notably decreases in cetane number, low heat content, viscosity, flashpoint, ET pour point. The spray properties, combustion efficiency, and engine emissions are altered by these changes.

Cetane number

For diesel engines, the Cetane number is indeed a crucial fuel characteristic. It affects the ease with which an engine may be started, emissions, peak cylinder pressure, and combustion noise. Long engine life, minimal noise, and excellent cold starting are all guaranteed by a high Cetane

ISBN 978-81-962237-8-6 April 2023

number. The quantity and kind of additives used in the mixes determine the fuel's Cetane number.

Bibliography

[1] O. M. Ali, R. Mamat, N. R. Abdullah, and A. A. Abdullah, "Analysis of blended fuel properties and engine performance with palm biodiesel-diesel blended fuel," *Renew. Energy*, 2015, doi: 10.1016/j.renene.2015.07.103.

[2] S. Lee, S. H. Woo, Y. Kim, Y. Choi, and K. Kang, "Combustion and emission characteristics of a diesel-powered generator running with N-butanol/coffee ground pyrolysis oil/diesel blended fuel," *Energy*, 2020, doi: 10.1016/j.energy.2020.118201.

[3] G. Hippargi, S. Anjankar, R. J. Krupadam, and S. S. Rayalu, "Simultaneous wastewater treatment and generation of blended fuel methane and hydrogen using Au-Pt/TiO2 photo-reforming catalytic material," *Fuel*, 2021, doi: 10.1016/j.fuel.2020.120113.

[4] L. Liu and Q. Zhang, "Comparison of detonation characteristics for typical binary blended fuel," *Fuel*, 2020, doi: 10.1016/j.fuel.2020.117351.

[5] S. Meziane and A. Bentebbiche, "Numerical study of blended fuel natural gas-hydrogen combustion in rich/quench/lean combustor of a micro gas turbine," *Int. J. Hydrogen Energy*, 2019, doi: 10.1016/j.ijhydene.2019.04.128.

ISBN 978-81-962237-8-6 April 2023

CHAPTER - 2
CRUDE OIL

Mr. Bhairab Jyoti Gogoi
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- sidharth.g@presidencyuniversity.in

Crude oil is a naturally present liquid petroleum substance made up of hydrocarbon deposits as well as other organic elements that were created from the leftovers of ancient animals and plants. After being exposed to heat, pressure, and layers of sand, silt, and rock, these creatures finally evolved into a kind of fossil fuel that's also refined into useable goods like gasoline, diesel, liquefied petroleum gases, including feedstock for both the petrochemical industry. Crude oil is a finite resource since it is a nonrenewable resource that cannot be replenished naturally there at rate people use it. The raw natural resource known as crude oil is taken from the ground and processed into goods like jet fuel, gasoline, as well as other petroleum products. Hydrocarbon deposits as well as other organic compounds that were created from the remnants of extinct creatures and plants that existed millions of years ago make up its composition. Crude oil, the unrefined oil that is taken from the ground, as well as other goods made from refined crude oil are together referred to as petroleum [1]–[3].

A commodity that is traded on markets all around the globe, as both the spot oil and via derivatives contracts, is crude oil. Considering that crude oil is presently the main source of energy production, several economists consider it to be the most significant commodity in the whole globe. The most common method of obtaining crude oil is drilling, where it is often discovered with other resources like salty water and natural gas (which would be lighter and so rests above the crude oil) (which is denser and sinks below). After being extracted, crude oil is refined and transformed into a range of products for sale to customers, including gasoline, kerosene, and asphalt. One of the most essential commodities in the world was crude oil, and fluctuations in its price may have an impact on the whole economy. Rising oil prices result in higher petrol price at the pump, greater transportation expenses, and higher producer input costs. Supply and demand dynamics are the key factors that influence the price of crude oil. Prices are lowered by excess supply and declining demand, while prices are raised by growing demand and limited supply. Geopolitical events and natural catastrophes that impact countries that produce oil might influence perceived changes in demand and supply [4], [5].

Historical View

While crude oil was originally found and exploited during the Industrial Revolution, and its industrial applications were established in the 19th century, fossil fuels like coal had been collected for generations. These materials were necessary for the operation of newly developed machines that transformed the way people do our jobs. The desire for fossil fuels, such as crude oil, sometimes causes political conflict since a few number of nations have the greatest deposits. As a result, the world's economy is heavily reliant on these resources today. Supply and demand have a significant impact on crude oil pricing and profitability, just as in any other business. The top three oil-producing countries worldwide are the United States, Saudi Arabia, and Russia. The United States was a major oil producer throughout the late 19th and early 20th centuries, and American businesses created the technology to transform oil into usable goods like gasoline. The United States became an energy importer throughout the middle and latter decades of the 20th century due to a sharp decline in domestic oil output, yet in 2021 crude oil net imports were at their second-lowest yearly level since 1985. The Organization of the Petroleum Exporting Countries (OPEC), which was established in 1960 and is made up of the

ISBN 978-81-962237-8-6 April 2023

nations with the highest quantities of crude oil and natural gas reserves, served as its main supplier. As a result, throughout the latter half of the 20th century, the OPEC members had considerable economic sway over the supply of oil and, therefore, its price. Early in the twenty-first century, a second energy boom in the United States was brought about by the advancement of new technologies, especially hydro-fracturing, or "fracking," which greatly diminished the significance and influence of OPEC. One of the primary reasons of global warming, which has received attention in recent decades, is said to be a heavy dependence on fossil fuels. Drilling for oil poses risks to the ecology, such as oil spills and ocean acidification. A lot of manufacturers have started making goods that depend on alternative energy sources throughout the 21st century as well, including electric automobiles, solar-powered houses, and wind-powered villages.

Forecasting Oil Prices

It is difficult for economists and other professionals to forecast the future of crude oil prices since they are unstable and dependent on a variety of factors. They rely on time to validate or refute their forecasts and employ a variety of forecasting technologies. The top five models employed are:

Oil futures prices

The International Monetary Fund (IMF) and central banks mostly utilise oil futures contract pricing as a benchmark. Prices for crude oil are determined by two factors: market sentiment as well as supply and demand. However, since futures prices sometimes add too much variety to the price of oil today, they may be a poor prediction.

Regression-based structural models

The likelihood of certain actions affecting the price of oil is calculated through statistical computer programming. Mathematicians may take into account factors like OPEC member country events, inventory levels, production prices, or consumption levels, for example. Although regression-based models have a high degree of predictability, it is possible for them to fail because their designers overlooked one or more important components or because unanticipated variables entered the picture.

Time-series analysis

To account for the constraints of oil futures prices, some economists employ time-series models, including such exponential smoothing models as well as autoregressive models, which encompass the subcategories of ARIMA and the ARCH/GARCH. These models use historical data on oil at different times to derive useful statistics and forecast future values based on observed values. Even while time-series analysis sometimes makes mistakes, it often yields more accurate conclusions when applied to shorter time periods by economists.

Bayesian autoregressive models

Calculations to estimate the likelihood of the effect of certain anticipated events on oil are one method to enhance the conventional regression-based model. The Bayesian vector autoregressive (BVAR) model is a popular choice among modern economists for forecasting oil prices.

Dynamic stochastic general equilibrium graphs

In this scenario, oil prices, which are a complicated economic phenomenon, are explained using macroeconomic principles via dynamic stochastic general equilibrium (DSGE) models. Because DSGE estimates are based on past data, they sometimes work but only if events and policies don't change. Every mathematical model was time-dependent, and different models

ISBN 978-81-962237-8-6 April 2023

perform better at different times. Economists often utilise a weighted mixture of all the models since none of them can successfully forecast the future on its own. For instance, in order to provide a more precise projection in 2014, the European Central Bank (ECB) combined four models to anticipate the future of oil prices. The ECB has sometimes utilised fewer or more models, depending on the best outcomes, however. Nevertheless, even the most meticulous forecasts may be thrown off course by unanticipated occurrences like natural catastrophes, political developments, or societal upheavals.

Bibliography

[1] F. Souas, A. Safri, and A. Benmounah, "A review on the rheology of heavy crude oil for pipeline transportation," Petroleum Research. 2021. doi: 10.1016/j.ptlrs.2020.11.001.

[2] M. A. Saad, M. Kamil, N. H. Abdurahman, R. M. Yunus, and O. I. Awad, "An overview of recent advances in state-of-the-art techniques in the demulsification of crude oil emulsions," Processes. 2019. doi: 10.3390/pr7070470.

[3] J. Wang, W. Shao, and J. Kim, "Analysis of the impact of COVID-19 on the correlations between crude oil and agricultural futures," Chaos, Solitons and Fractals, 2020, doi: 10.1016/j.chaos.2020.109896.

[4] L. T. Popoola, A. S. Yusuff, A. A. Adeyi, and O. O. Omotara, "Bioaugmentation and biostimulation of crude oil contaminated soil: Process parameters influence," South African J. Chem. Eng., 2022, doi: 10.1016/j.sajce.2021.10.003.

[5] I. Shaikh, "On the relation between the crude oil market and pandemic Covid-19," Eur. J. Manag. Bus. Econ., 2021, doi: 10.1108/EJMBE-08-2020-0223.

ISBN 978-81-962237-8-6 April 2023

CHAPTER - 3
OIL INDUSTRY INFORMATION

Dr. Kalpajit Hazarika
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- kalpajithazarika@presidencyuniversity.in

Successful investors and traders must have reliable information sources that cover the many variables that might affect oil prices since crude oil prices are continually fluctuating and generally more volatile that stock or currency prices. There are several websites that cover news related to crude oil, but very few of them broadcast breaking news and real-time pricing. The following three provide up-to-date details [1]–[3].

Market Watch

Market Watch offers a vast selection of business news, information on personal finances, comments in real-time, financial tools, and statistics. Despite covering all facets of financial markets, it often publishes headlines as soon as news breaks, making it one of the first to break stories. On its main page, these headlines may be seen in the upper right corner under the heading "Latest." When appropriate, Market Watch also offers more information by releasing pieces often only a paragraph or two long—to expand on its headlines. These stories are updated throughout the day. The website offers stories outlining the price trajectory of oil, as well as feature pieces, pre-market analysis, and closing bell commentary. On the website's landing page, there is a live link that displays the WTI oil price. Whenever you read an article, the price quotation is up to date since Market Watch often contains an active connection to the price of oil. Furthermore, Market Watch provides a more thorough study of the economic news that influences oil prices [3]–[5].

Reuters Commodities Page

A section of the Reuters news service's website dedicated to commodities publishes breaking news, background information, and current oil prices. It also provides more current in-depth coverage and analysis of the industry as a whole, as well as price-driving sector updates. It also does a fantastic job of breaking any important news as soon as it becomes known. Additionally, Reuters often publishes articles describing changes in the price of oil and the circumstances that caused such changes.

CNBC

It contains a page devoted to news about oil. It releases pertinent oil-related articles throughout U.S. market hours. When you glance at its home page, this equals around once each hour. When there is a change in the price of oil, CNBC routinely updates its stories, but that does not offer a live feed of oil prices as Market Watch does. However, it makes up for this by offering a wide range of news on the oil business, including all significant price movers and price-driving occurrences.

Chemical and physical properties

In addition to some nitrogen, sulphur, and oxygen, crude oil is a combination of very flammable liquid hydrocarbons (compounds mostly made of hydrogen and carbon). These substances combine to generate a wide range of intricate molecular structures, a few of which are difficult to distinguish. Almost all crude oil, notwithstanding variances, contains between 12 and 15 percent hydrogen and 82 and 87 percent carbon by weight. Paraffins, naphthenes, and aromatic hydrocarbons are the three types of hydrocarbon compounds that are often used to describe

ISBN 978-81-962237-8-6 April 2023

crude oils. The most prevalent hydrocarbons in crude oil are paraffins; certain liquid paraffins constitute essential components of gasoline (petrol) and thus are consequently highly prized. All liquid refinery byproducts include naphthenes, which also contribute to some of the heavy, asphalt-like byproducts of the process. Typically, aromatics make up a very minor portion of most crudes. The most prevalent aromatic in crude oil is benzene, a well-liked component of petrochemicals. Although crude oil is a combination with such a broad range of elements and ratios, it also has a large range of physical characteristics. For instance, it might be anything from colourless to black in appearance. Specific gravity is maybe the most significant physical characteristic (i.e., the ratio of the weight of equal volumes of a crude oil and pure water at standard conditions). Pure water is often given a specific gravity number of 1, whereas things lighter that water, such crude oil, would be given a measurement less than 1. The American Petroleum Institute (API) gravity scale is used by the petroleum industry, and pure water has been arbitrarily given an API gravity of 10. Oil and other liquids that are lighter than water have API gravities that are more than 10. Crude oils may be divided into three categories based on their API gravity: heavy, medium, and light. Depending on the concentration of sulphur, which may be found either as elemental sulphur or in compounds like hydrogen sulphide, crude oil is also classed as "sweet" or "sour." Sulfur concentration in sweet crudes ranges from 0.5 percent to 1 percent by weight, although it is higher in sour crudes. In general, the sulphur content of crude oil increases with its weight. Because sulphur oxides emitted into the environment during the burning of oil are a significant pollutant, excess sulphur is eliminated from crude oil throughout refining.

Extraction and processing

Depending on the depth, crude oil is found underground at a variety of pressures. It may include a significant amount of natural gas that the pressure keeps in solution. In addition, water often enters an oil well together with gas and liquid crude. Surface machinery collects each of these fluids and separates them. Clean crude oil is stored aboveground inside cylindrical steel tanks that may be up to 30 metres (100 feet) throughout diameter and 10 metres (33 feet) tall at a pressure close to atmospheric pressure. Transporting crude oil from widely dispersed production locations to treatment facilities and refineries is a common need. Most overland transportation uses pipes. Tank trucks are used to collect crude from more remote wells and deliver it to pipeline terminals. Specially designed train waggons are also sometimes used for transportation. Tanker tankers with specialised designs are used for international transportation. Less than 100,000 barrels to even more than 3,000,000 barrels are the range of tanker capacity. A refinery is where most crude oil is sent after extraction. Any combination of the following three basic tasks is performed there: the various types of hydrocarbons contained in crude oils are divided into fractions with more closely related properties, these same separated hydrocarbons are chemically transformed into more desirable reactive species, and the products are purified of undesirable elements and compounds. Fractional distillation is the primary method for isolating the hydrocarbon parts of crude oil. The distillation-separated crude oil fractions are then processed into a variety of goods, such as heating oil, asphalt, gasoline, and diesel fuel. The picture illustrates the ratios of products that could be created by distillation of five common crude oils, ranging from either the heavy Boscan oil from Venezuela to the light Bass Strait oil production in Australia. The market value of a crude oil often increases with rising yields of light products, in accordance with the pattern of current demand (that tends to be higher for transportation fuels like gasoline). Crude oil is often measured in metric tonnes outside of the United States since most other regions of the globe define capacity even by weight of materials produced and record measurements using metric units. About 139 kg would be the weight of a barrel of API 30° light oil (306 pounds). On the

ISBN 978-81-962237-8-6 April 2023

other hand, a metric tonne of API 30° light oil is equivalent to around 252 imperial gallons, or roughly 7.2 U.S. barrels.

Bibliography

[1] J. Khan, M. Jaafar, B. Javed, N. Mubarak, and T. Saudagar, "Does inclusive leadership affect project success? The mediating role of perceived psychological empowerment and psychological safety," *Int. J. Manag. Proj. Bus.*, 2020, doi: 10.1108/IJMPB-10-2019-0267.

[2] M. Zane and V. K. Tucci, "Exploring the Information Literacy Needs and Values of High School Chemistry Teachers," *J. Chem. Educ.*, 2016, doi: 10.1021/acs.jchemed.5b00450.

[3] A. Amarasinghe *et al.*, "Induction of innate host responses characterized by production of interleukin (IL)-1β and recruitment of macrophages to the respiratory tract of chickens following infection with infectious bronchitis virus (IBV)," *Vet. Microbiol.*, 2018, doi: 10.1016/j.vetmic.2018.01.001.

[4] Y. Chen *et al.*, "Latilactobacillus curvatus: A candidate probiotic with excellent fermentation properties and health benefits," *Foods*. 2020. doi: 10.3390/foods9101366.

[5] S. Lucht *et al.*, "All-source and source-specific air pollution and 10-year diabetes Incidence: Total effect and mediation analyses in the Heinz Nixdorf recall study," *Environ. Int.*, 2020, doi: 10.1016/j.envint.2020.105493.

ISBN 978-81-962237-8-6 April 2023

CHAPTER - 4
BASICS OF LUBRICITY

Dr. Sidharth Gautam
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- sidharth.g@presidencyuniversity.in

The capacity of a lubricant in this example, diesel fuel to reduce friction between and damage damage surfaces in relative motion under pressure is a common definition of lubricity. Typically, boundary lubrication conditions are attempted to be created during experiments to determine the lubricity of diesel fuel. In further detail, test findings that quantify a fuel's lubricity are an assessment of the fuel's capacity to reduce wear on surfaces that are moving relative to one another under boundary lubrication circumstances. To test fuel lubricity, many techniques have been devised:

Vehicle tests

In a vehicle test, the vehicle is driven for a certain amount of time or over a predetermined distance on the fuel. The parts of the fuel system may then be dismantled and wornness assessed. The benefit of this test is that it is the most accurate representation of actual operating circumstances and that it measures all wear-related failures, not only those related to boundary lubrication. However, tests of this kind are highly costly and time-consuming, and they do not lend themselves to evaluating a lot of fuel mixtures [1]–[3].

Pump rig tests

A pump rig test is an alternative towards the vehicle test. A fuel injection pump is installed on a test stand and therefore is powered by an electric motor during a pump rig test. For a certain amount of time, fuel is cycled through the pump. The pump and any connected equipment may then be taken apart and checked for wear as well as other negative consequences. The benefit of this test is that it is less expensive than a complete vehicle test and can still test for various wear-related issues in addition to those connected to boundary lubrication. It still takes a lot of time and money to run. A single exam may take 500–1000 hours to complete. Pump rig tests are often required to assess the efficacy of much easier bench testing.

Bench tests

To enable quick and reasonably priced assessments of fuel lubricity, a variety of bench experiments that attempt to replicate boundary lubrication conditions comparable to those seen in fuel injection equipment have indeed been developed:

It is possible to develop innovative biofuels using the fuel made from lignocellulosic feedstock, which would be regarded as 2nd generation biofuel [4], [5]. 2nd generation biofuel production does have the potential to help by eating waste leftovers and using vacant area, depending on the feedstock choice and growing methods. In light of the strategy, the new fuels might provide a big opportunity to promote rural advancement and development in developing economic circumstances and growing regions. Motorized vehicles run on ethanol as fuel. It may also be utilised alone in a specially constructed engine or combined with gasoline without requiring any engine modifications. It's interesting to note that these improved fuels have shown promise for many engine types to reduce emissions without sacrificing performance. Furthermore, fuel's low freezing point is advantageous for other low-temperature applications, including such antifreeze in car radiators. Raw resources for first-generation ethanol include corn, sugarcane, maize, etc. The issue of these feedstocks influencing the food price structure arises. Rice

ISBN 978-81-962237-8-6 April 2023

straws, maize stover, sugarcane debris, and other non-edible plant parts make up the majority of the raw materials used to make second generation ethanol. Lignocellulose, a fundamental substance that makes up a significant portion of plant mass, is the principal raw material used to make second generation ethanol. The two primary issues with the first generation of ethanol feedstocks—contradictory impacts on food prices and lack of scalability—are resolved by the second generation of ethanol feedstocks. The created mix of second generation ethanol-blended diesel is an oxygenate fuel, which is a benefit of its usage as fuel. By increasing the amount of oxygen in the fuel mixture, it makes the fuel burn completely with less emissions of pollutants. The selection of the 2nd generation ethanol-blended diesel fuel source rests mostly on compliance with the fundamental fuel standards necessary for diesel engine operation. According to this viewpoint, the advancement of knowledge regarding the physical chemical characteristics of the second generation ethanol-blended diesel fuel is a crucial issue to consider when making decisions regarding speculative plans for the expansion of the second generation ethanol production, quality control, processing, but instead engine tolerability.

Viscosity

The propensity of a fluid to resist any change in its structure or motion is known as viscosity. It is a measurement of a fluid's internal forces. When a fluid layer is forced to travel across another layer, internal forces, or friction, come into play. More friction means that more force must be used to move the layers, which is shearing. Whenever a fluid moves or is disseminated, such as when it is poured, sprayed, spread, mixed, etc., shearing happens. This explains why fluids with a high viscosity require more effort to move than those with a low viscosity. Viscosity Measurement. Viscosity may be measured using a variety of techniques, depending on the materials being utilised and the situation. It might be challenging to choose a viscometer that is appropriate for your investigation. Viscosity measurements come in a variety of forms; the simplest count the number of seconds a liquid drops off a stick while the most advanced use sophisticated automated recorders. Because of this, choosing an instrument type when experimenting with precise measurement might be challenging a liquid within which the fluid particles flow in a straight, parallel path.

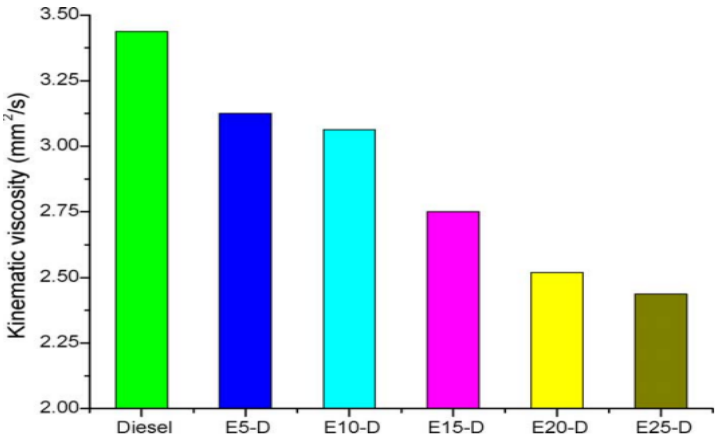

Figure 1: Illustrates the Kinematic viscosities of blend fuels and diesel fuel.

The Fluid Viscosity has been the subject of various hypotheses put out by Sir Isaac Newton. The flow velocity in fluids varies linearly at various places, with a velocity of 0 at the bottom and a velocity of 'u' at the top. The area 'A' of the layer, the fluid velocity 'u,' and the force F acting mostly on fluid particles are all directly proportional to each other, but the distance 'y' between the two is inversely proportional. Kinematic viscosity is the primary factor that controls lubricity. It is simple to gauge kinematic viscosity. The testing results for mix fuels

ISBN 978-81-962237-8-6

are shown in Figure 1. The viscosity of diesel fuel is reduced by ethanol addition. The viscosity does not meet the minimal standards for diesel fuels with an ethanol level of 10–20% [6].

Bibliography

[1] M. Sejkorová, I. Hurtová, P. Jilek, M. Novák, and O. Voltr, "Study of the effect of physicochemical degradation and contamination of motor oils on their lubricity," *Coatings*, 2021, doi: 10.3390/coatings11010060.

[2] F. T. Hong, E. Singh, and S. M. Sarathy, "On the origins of lubricity and surface cleanliness in ethanol-diesel fuel blends," *Fuel*, 2021, doi: 10.1016/j.fuel.2021.121135.

[3] F. T. Hong, N. M. Alghamdi, A. S. Bailey, A. Khawajah, and S. M. Sarathy, "Chemical and kinetic insights into fuel lubricity loss of low-sulfur diesel upon the addition of multiple oxygenated compounds," *Tribol. Int.*, 2020, doi: 10.1016/j.triboint.2020.106559.

[4] L. Boggero, S. Corpino, A. De Martin, G. Evangelista, M. Fioriti, and M. Sorli, "A virtual test bench of a parallel hybrid propulsion system for UAVs," *Aerospace*, 2019, doi: 10.3390/AEROSPACE6070077.

[5] M. Steimle, N. Weber, and M. Maurer, "Toward Generating Sufficiently Valid Test Case Results: A Method for Systematically Assigning Test Cases to Test Bench Configurations in a Scenario-Based Test Approach for Automated Vehicles," *IEEE Access*, 2022, doi: 10.1109/ACCESS.2022.3141198.

[6] D. Li, H. Zhen, L. Xingcai, Z. Wu-gao, and Y. Jian-guang, "Physico-chemical properties of ethanol–diesel blend fuel and its effect on performance and emissions of diesel engines," *Renew. Energy*, vol. 30, no. 6, pp. 967–976, May 2005, doi: 10.1016/j.renene.2004.07.010.

CHAPTER - 5
ENERGY DENSITY

Dr. Saurav Mukherjee
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- sourav.mukherjee@presidencyuniversity.in

Calculating the amount of energy that may be held in a given mass of a material or system is known as energy density. Therefore, the quantity of energy contained in a system or substance will increase as its energy density increases. Numerous different types of materials and systems can store energy. Four different kinds of reactions may release energy from any substance. Which include electrical, chemical, electrochemical, and radioactive. Most often, only usable or extractable energy is assessed when estimating the total quantity of energy in a system. We often calculate energy density in scientific equations. The total quantity of energy in a system per unit volume is known as energy density. For instance, the quantity of calories present per gramme of food weight. Foods have a low energy density, meaning that each gramme of food contains less energy [1]–[3]. It implies that because they have less calories, we can consume more of them. As a result, we may define energy density as the quantity of stored energy per unit of system volume. Its symbol is the letter U. The major sources of energy storage are magnetic and electric fields. The energy density formula for an electromagnetic current or capacitor is written as:

$$Electrical\ energy\ density = \frac{permittivity * electric\ field\ squared}{2}$$

$$U_E = \frac{1}{2}\varepsilon_0 E^2$$

The magnetic field or inductor's power density formula:

$$Magnetic\ energy\ density = \frac{magnetic\ field\ squared}{2 * magnetic\ permeability}$$

In the form of an equation,

$$U_B = \frac{1}{2\mu_0} B^2$$

The general energy us:

$U = U_E + U_B$

Where,

U=Energy density

UE=Electrical energy density

UB=Magnetic energy density

ε0=Permittivity

E=Electric field

B=Magnetic field

μ=magnetic permeability

ISBN 978-81-962237-8-6

The engine's power output is directly impacted by a fuel's low heat value. On a bulk basis, ethanol has around 33% less energy than diesel fuel [4]. When ethanol and diesel are blended, the fuel's volumetric energy density decreases according to the ethanol concentration.

Flash point

The lowest temperature at which a liquid (often a petroleum product) can produce a vapour in the atmosphere at its surface that will "flash," or momentarily ignite, when in contact with an open flame. The flash point is a broad indicator of a liquid's combustibility or flammability. There is not enough vapour available underneath the flash point to enable combustion. The liquid will create enough vapour to enable combustion at a temperature above the flash point. This degree is referred as the fire point. The flash point has been used as a gauge of a liquid's danger since the 19th century [1], [2], [5]. Kerosene, which is primarily used as fuel for burners and lamps, was the primary petroleum product before gasoline became popularity. Petroleum distillers had a propensity to leave as much of the economically useless gasoline throughout the kerosene as possible in order to distribute more product. This kerosene adulteration with extremely flammable gasoline resulted in several fires and explosions in oil lamps and storage tanks. To reduce the risk, laws were passed, test procedures were outlined, and minimum flash points were established. By heating a liquid to predetermined temperatures under controlled circumstances and then applying a flame, flash points may be calculated.

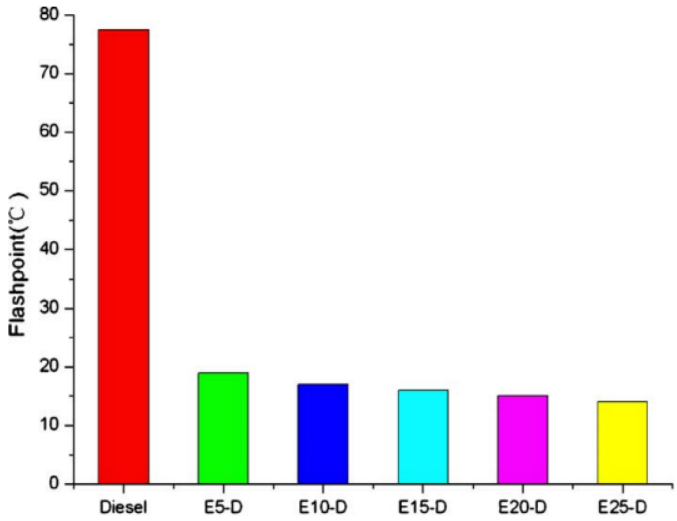

Figure 1: Illustrates the Flash points of blend fuels and diesel fuel.

To simulate the circumstances of storage and the workplace, the test is conducted in either a "open cup" or a "closed cup" device, or in both. The flash point refers to the lowest temperature at which the fuel will ignite whenever exposed to that of an ignition source. Representative liquids including their approximations are shown below. The fuel's flashpoint has an impact on the categorization of fuels for transportation and storage as well as the safety measures that need to be taken while handling and transporting the fuel. The fuel component in a mix with both the lowest flash point often dominates flash point readings. This is corroborated in Figure 1. Ethanol predominates in ethanol-diesel mix fuel flashpoints.

Bibliography

[1] A. Drewnowski and S. E. Specter, “Poverty and obesity: The role of energy density and energy costs,” *American Journal of Clinical Nutrition*. 2004. doi: 10.1093/ajcn/79.1.6.

[2] W. Cao, J. Zhang, and H. Li, “Batteries with high theoretical energy densities,” *Energy Storage Mater.*, 2020, doi: 10.1016/j.ensm.2019.12.024.

[3] S. Gupta, T. Hawk, A. Aggarwal, and A. Drewnowski, "Characterizing ultra-processed foods by energy density, nutrient density, and cost," *Front. Nutr.*, 2019, doi: 10.3389/fnut.2019.00070.

[4] S. Patel, A. Chauhan, and R. Vaish, "Enhanced Electrical Energy Storage Density in Mechanical Confined Antiferroelectric Ceramic," *Ferroelectrics*, 2015, doi: 10.1080/00150193.2015.1100469.

[5] L. Wang *et al.*, "Li-free Cathode Materials for High Energy Density Lithium Batteries," *Joule*. 2019. doi: 10.1016/j.joule.2019.07.011.

ISBN 978-81-962237-8-6 April 2023

CHAPTER - 6
SURFACE TENSION

Dr. Saurav Mukherjee
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- sourav.mukherjee@presidencyuniversity.in

A liquid surface's ability to operate like a stretched elastic membrane was known as surface tension. Small liquid droplets and soap bubbles have almost spherical shapes, which are indicators of this phenomena. Some insects can stand upon that surface of water due to this characteristic. The surface tension of the water may also sustain a razor blade. When pushed through the water's surface, the razor blade sinks rather than floats. The fundamental factors affecting surface tension are the forces of attraction between the molecules in the supplied liquid and the gas, solids, or liquid in contact with it. For instance, the water molecules in some kind of a drop of water have a slight attraction to one another. The surrounding molecules may be thought of as equally attracting the water molecules in all directions inside the drop. However, when surface molecules were to move just a little bit away from the surface, these would be drawn back by the molecules in the area. The effort or energy required for removing the surface layer of molecules in some kind of a unit area may be conceived of as being roughly equal to the energy necessary for the phenomena of surface tension [1]–[3].

As a result, surface tension may be described in terms of energy (joules) per unit area (square metres). At 20 °C (68 °F), water does have a surface tension of 0.07275 joule per sq meter. Mercury has a greater surface tension than organic liquids like benzene and alcohols, which have lower surface tensions. Surface tension falls when temperature rises because it reduces the net force of attraction between molecules. Another way to think about surface tension is as the consequence of forces operating in the surface's plane and tending to reduce its area. The amount of force applied to a surface that is perpendicular to something like a line of a certain length is a common way to describe surface tension based on this theory. The measurement is then in newton's per metre, or joules every square metre. The spray properties and atomization and fuel droplets are influenced by surface tensions; this has a substantial impact on combustion efficiency. In Figure 1, surface tensions were determined using both an experimental technique and an automated stabilizer tension-meter [4], [5].

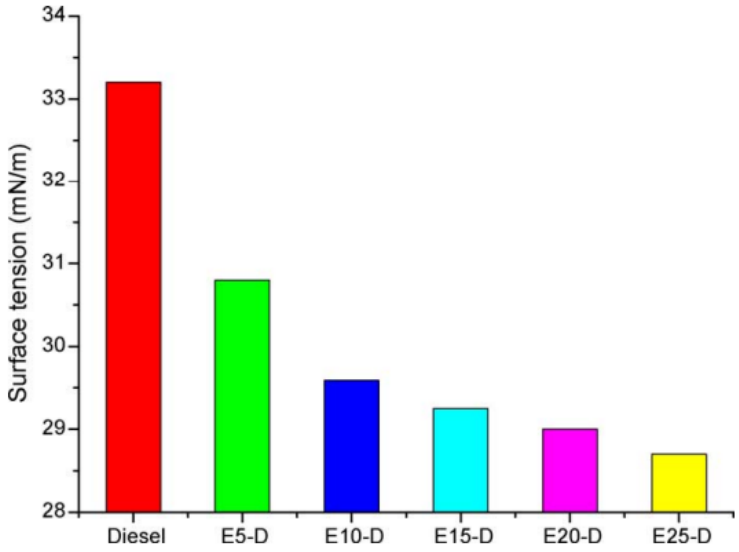

Figure 1: Illustrates the Surface tensions of blend fuels and diesel fuel.

ISBN 978-81-962237-8-6

Boiling point

Boiling point, the temperature that occurs when the pressure that a liquid is subjected to from its environment equals the pressure that the liquid's vapour is subjected to; in this situation, the addition of heat causes the liquid to turn itself into the vapour without raising the temperature. A liquid partially vaporizes into the space above it at virtually any temperature up to the vapour pressure of the liquid at around that temperature, which is a characteristic value. The vapour pressure rises as the temperature rises, and when the liquid reaches the boiling point, vapour bubbles develop within the liquid and ascend to the surface. A liquid's boiling point changes depending on the pressure being applied; the normal boiling temperature is the temperature that occurs when the vapor pressure of the liquid is equivalent to the average atmospheric sea level pressure. (760 mm [29.92 inches] of mercury). Water boils at sea level at 100° C (212° F). Lower boiling point temperatures are seen at greater elevations. Ethanol has a boiling point that is lower than the conventional diesel propellant lowest boiling fraction. At temperatures below 200°C, ethanol addition changes the distillation curve's form.

Stability and phase separation

A well-known issue with ethanol-diesel mix fuel is phase separation and water tolerance. Fuel instability is indeed a clear issue after complete phase separation. By adding more water to samples of the mixes, the water tolerance of the ethanol/diesel blends was thus assessed. It seems sense that samples of ethanol-diesel mix fuel at higher temperatures would be better able to withstand larger levels of water contamination. Phase separation and fuel instability are more likely to begin earlier in environments with low temperatures and substantial water contamination. Ethanol and gasoline mix well with each other in most situations. Contrary to gasoline, diesel fuel isn't always a simple combination with ethanol. Low temperature and/or contaminated water conditions might be particularly problematic. Phase separation may cause fuel instability in both cases.

The usage of bioenergy produced biofuels has emerged as an appropriate substitute as a result of depleting fossil resources, growing reliance on imported crude oil, and worsening environmental balance. The development of alternative fuel sources has received significant attention in a number of nations, with a focus on biofuels that have the extra benefit of being renewable. As agricultural products used to make biofuels are naturally oxygenated, they provide advantages in terms of lower emissions. The next generation of fuels among these bio-derivatives include bio alcohols like ethanol and butanol. Because it has a high octane rating, ethanol has been used as a blending ingredient in gasoline-powered spark ignition engines for a few decades now. However, alcohols, particularly ethanol and also to a much lesser degree methanol, may also be used as alternative fuel for internal combustion engines. Anhydrous ethanol is solubility in gasoline, but it needs additives to be soluble in diesel fuel in a variety of situations, notably at low temperatures whenever the miscibility is restricted. To increase the solubility of ethanol in diesel, a number of methods have been devised, one of which is the creation of emulsion blends by adding an emulsifier to avoid phase separation. It has been claimed in the past to add various emulsifying agents, such as biodiesel and spans 80, to a blend between ethanol and diesel to improve blend stability. The research also shown that mixing biodiesel with diesel fuel may alleviate wear issues in sensitive fuel pump systems and lower lubricity, viscosity, and calorific value of the fuel, which are all effects of adding just ethanol to diesel fuel.

Bibliography

[1] B. R. Bzdek, J. P. Reid, J. Malila, and N. L. Prisle, “The surface tension of surfactant-containing, finite volume droplets,” *Proc. Natl. Acad. Sci. U. S. A.*, 2020, doi:

10.1073/pnas.1915660117.

[2] L. Ruan, J. Liu, B. Zhu, S. Sueda, B. Wang, and B. Chen, "Solid-fluid interaction with surface-tension-dominant contact," *ACM Trans. Graph.*, 2021, doi: 10.1145/3450626.3459862.

[3] N. B. Vargaftik, B. N. Volkov, and L. D. Voljak, "International Tables of the Surface Tension of Water," *J. Phys. Chem. Ref. Data*, 1983, doi: 10.1063/1.555688.

[4] H. Wang and P. R. Brito-Parada, "The role of microparticles on the shape and surface tension of static bubbles," *J. Colloid Interface Sci.*, 2021, doi: 10.1016/j.jcis.2020.11.094.

[5] K. Hadler and J. J. Cilliers, "The Effect of Particles on Surface Tension and Flotation Froth Stability," *Mining, Metall. Explor.*, 2019, doi: 10.1007/s42461-018-0020-z.

ISBN 978-81-962237-8-6

CHAPTER - 7

INTRODUCTION TO VISCOSITY MODELLING

Dr. Suman Paul
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- sumanpaul@presidencyuniversity.in

A thorough grasp of fluid characteristics like viscosity is necessary for many engineering disciplines including design choices. Viscosity is a crucial factor in the design of crude oil transportation machinery, the costly cleanup after oil spills, and the estimation of oil production rates, because directly affect reservoir profitability. To account voor phase separations and variations in pressure, temperature, but also composition as the fluid flows through reservoirs and pipelines, reliable and precise viscosity information must be provided throughout a broad range of external variables. Viscosity is one of the PVT qualities that plays a significant role in controlling fluid flow through porous media and should be carefully measured. The viscosity of the crude oil must thus be precisely evaluated at several points throughout oil exploration and production. The evaluation of porous fluid flow, well efficiency, well modelling, well testing, and flow in pipelines for the manufacture and design of pipelines, transport machinery, and the design of operations and advances in the field all depend on this parameter. Predictive models based on theoretical, experimental, or semi-theoretical foundations are often used to estimate viscosity since empirically measuring viscosity under a broad variety of circumstances is costly and time-consuming [1]–[3].

In Figure 1, the domains of time series prediction, prediction, and classification all heavily rely on artificial neural networks (ANNs). The input parameters, such as the number of neurons within each layer and the ideal weights and biases given to each neuron, have a significant impact on how well an ANN performs. A computational tool evolved from artificial intelligence, a field of computer science concerned with the building of intelligent computer systems that act like intelligent humans, are artificial neural networks. Since 1988, chemical engineering has used neural networks much more often. Process control, system troubleshooting, dynamic process modelling, and process prediction as well as estimate make up the four primary areas of application thus far in chemical engineering. For the advancement and operation of manufacturing applications including crystallization, food processing, and fertilizer manufacturing, thermal-physical characteristics of electrolyte solutions, including such dynamic viscosity, are required (Figure 1).

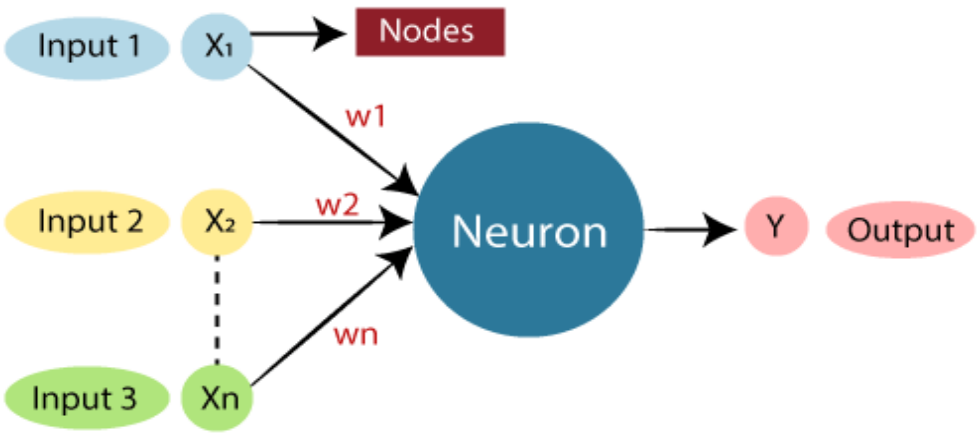

Figure 1: Illustrates the schematic diagram of artificial neural network.

ISBN 978-81-962237-8-6

It is costly and time-consuming to measure an aqueous solution's density and viscosity, particularly when many electrolytes are present. For engineering design applications, dimensionless groups must be calculated using density and viscosity data. As a result, viscosity and density have a strong relationship and are crucial for predicting pumping costs, measuring pipelines, and designing evaporators and crystallizers throughout the saline recovery process. The physiological neural networks that shape the structure of the human brain are where the phrase "artificial neural network" originates. The artificial neural networks also feature neurons that are linked to one another in different levels of the networks, much like the human brain, which has neurons that were already interconnected to one another. Nodes are the name for these neurons. Artificial neural networks are used in artificial intelligence to simulate the network of neurons that make up the human brain, giving computers the ability to comprehend information and make choices in a way similar to that of a person. Computers are programmed to function exactly like a network of linked brain cells to create an artificial neural network. The human brain has around 1000 billion neurons. Between 1,000 to 100,000 association points are present in each neuron. Data is distributed stored inside the human brain, allowing us to access many pieces of information from our parallel memories as needed. The human brain is said to have a staggering number of incredible parallel processors. Consider the example of a digital logic gates that accepts input and outputs so that we may better grasp the artificial neural network. Two inputs are required for the "OR" gate. If either one or both of the inputs are "On," the output will also be "On." If both inputs are "Off," the output will also be "Off." In this case, output is dependent on input. Our brains do not carry out the same function. Because our brain's neurons are always "learning," the connection between outputs and inputs is constantly changing [4], [5].

Oil may be primarily generated throughout the primary recovery stage utilizing renewable energy sources, including such reservoir pressure. As oil production increases, reservoir pressure falls, making it impossible to produce oil profitably. Water flooding (secondary recovery), which is the technique of injecting water through into reservoir, has been widely used in most oil fields to decrease the drop of reservoir pressure as well as push the oil in the reservoir toward the production well. Only 10% to 40% of the original oil in situ is generally extracted using the main and water flooding processes. The great mobility of the injected water caused by its low viscosity is one of the primary causes of oil remaining after water flooding. Mobility is calculated by dividing the reservoir's effective permeability by the phase's viscosity, in this example, water. Low volumetric sweep efficiency as well as a lot of leftover oil come from the increased mobility of injected water relative to oil. The amount of oil in contact with both the displacing agent multiplied by the volume of a original oil in situ is known as the volumetric sweep efficiency. The injection of viscous fluids is one of the efficient ways to raise volumetric sweep efficiency overall oil output. A viscous polymer solution is injected into the reservoir as part of the enhanced oil recovery (EOR) technology known as polymer flooding. Since its extensive use in the Daqing oil field in northeast China, having produced around 300,000 more barrels of oil per day, polymer flooding is currently regarded as a scientifically and economically proven EOR technique. The essential element for the effective use of polymer flooding is the viscosity of a polymer solution. Calculations can be made using the reservoir's water saturation, the relative permeability of each phase (oil and water), as well as the viscosity of the oil to determine the necessary viscosity of the polymer solution to successfully push viscous oil from the pore spaces of the rock formation to the manufacturing well. The apparent viscosity, also referred as in situ viscosity, is the viscosity of the precursor solution in some kind of a porous media, such as the reservoir, and has to be calculated in order to determine if it can attain the needed viscosity given the injecting and reservoir circumstances. It is impossible to directly quantify apparent viscosity.

ISBN 978-81-962237-8-6 April 2023

Bibliography

[1] I. Konstantinov, C. Villa, R. Cong, and T. Karjala, "Viscosity Modeling of Polymer Solutions," *Macromol. Symp.*, 2018, doi: 10.1002/masy.201600179.

[2] J. P. Schupsky, T. Netter, G. Wu, H. Spliethoff, and M. Müller, "Crystal morphology data for viscosity modelling of fuel slags – Supplementation of spinel phase and validation by crystallisation in entrained flow gasifiers," *Fuel*, 2021, doi: 10.1016/j.fuel.2021.121114.

[3] W. Gąsior, "Viscosity modeling of binary alloys: Comparative studies," *Calphad Comput. Coupling Phase Diagrams Thermochem.*, 2014, doi: 10.1016/j.calphad.2013.10.007.

[4] S. E. Quiñones-Cisneros, C. K. Zéberg-Mikkelsen, and E. H. Stenby, "The friction theory for viscosity modeling: Extension to crude oil systems," *Chem. Eng. Sci.*, 2001, doi: 10.1016/S0009-2509(01)00335-9.

[5] V. A. Torrealba, H. Hoteit, and R. T. Johns, "Description of Micellar Radii for Phase Behavior and Viscosity Modeling of Aqueous Surfactant Solutions and Microemulsions," *Langmuir*, 2018, doi: 10.1021/acs.langmuir.8b02828.

ISBN 978-81-962237-8-6

CHAPTER - 8

DEVELOPMENT OF ANN MODELS

Dr. Sidharth Gautam
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- sidharth.g@presidencyuniversity.in

Input, hidden, and output layers are the standard structure of ANNs. Neurons are coupled within each layer. The neuron inside the layer above sums up all of the signals coming from all of the neurons in that layer. The training process then applies bias and weights, which also are changed, to this total value. The activation function computes each signal from each neuron. According on their structure, training technique, or way of processing input via the network, ANN models may be divided into many categories. The most prevalent kind of ANN is a feed-forward neural network, typically consists of input layer neurons coupled to only one subsequent layer. A feed-forward neural network containing two hidden layers is useful for estimating the viscosity of pH-sensitive polymers for increased oil recovery, according to prior studies. Polymer physics and oil field circumstances should be taken into account when choosing neurons for the input layer because these factors must be taken into account since they have an impact just on viscosity of the polymer solution [1]–[3]. A non-Newtonian fluid, a polymer solution for better oil recovery, was used, and the input layer contained the shear rate. A polymer solution becomes more viscous as even the polymer concentration rises. The more interactions between polymerization and the greater frictional effects that come from the more polymer molecules present, the higher the viscosity will be. The reservoir contains a variety of convocations including divalent cations that may balance the charge throughout the side chains of polymers. When a cation is introduced, a polymer solution's viscosity reduces. Injection water and formation water which come into direct contact with the polymer often include Na+, one of the most prevalent cations. According to earlier research, Ca2+ reduces viscosity more effectively than other common divalent cations like Mg2+. As a consequence of improved polymer molecule activity and decreased molecular friction as a temperature rises, viscosity reduces. Five neurons, shear rate, polymer concentration, NaCl concentration, Ca2+ concentration, and temperature, make up the input layer in this investigation. Three ANN models are suggested in this work, one for each of the Flopaam TM 3330S, Flopaam TM 3630S, and AN-125. As a result, the input layer did not include the molecular mass and amount of hydrolysis, which seem to be polymer attributes. Artificial neural networks kind [4]–[6].

Feedforward Neural Network

One of the most fundamental artificial neural networks is the feedforward neural network. The data or input used in this ANN only moves in one direction. Although hidden layers might or might not exist, it enters the ANN via the input layer and departs through the output layer. Consequently, the neural network's feedforward function only experiences front propagation and often does not experience back propagation.

Recurrent Neural Network

The Recurrent Neural Network stores a layer's output and feeds it back into the input to improve layer prediction. The first layer of the RNN is roughly comparable to the feed-forward neural network, and after the output of the first layer is calculated, the recurrent neural network begins. Following this layer, each units will retain some data from the preceding phase so that it may function as a memory cell for calculations.

ISBN 978-81-962237-8-6 April 2023

Convolutional Neural Network

The feed-forward neural network, in which the connections between units contain weights that indicate the impact of one unit on another unit, and the convolutional neural network have certain characteristics. However, a CNN contains one or more convolution layer that operate on the input by convolution and then send the output to the following layer. CNN offers voice and image application services that are very beneficial for computer vision.

Modular Neural Network

A modular neural network is made up of a variety of discrete neural networks that each function separately to produce the desired output without communicating with one another. By acquiring distinct inputs from other networks, each of the several neural networks executes a separate sub-task. This modular neural network's benefit is that it divides an extensive and complicated computational process into more manageable components, reducing its complexity while still producing the desired result.

Radial basis function Neural Network

The distance between a point and its center is taken into account by radial basis functions. Functions using RBF have two levels. The input is translated into each of the hidden layer's radial foundation functions within the first layer, and the output layer then calculates the result in the next step. Typically, data that indicates any underlying trend or functionality is modelled using radial basis function nets.

Applications of Artificial Neural Networks

Social Media

Social media makes extensive use of artificial neural networks. Take Facebook's "People you may know" tool, for instance, which advises users to send friend requests to base on potential familiarity. The individuals you could know are determined by employing Artificial Neural Networks, which examine your profile, hobbies, existing friends, their friends, and several other characteristics to determine whom you might know. Facial recognition is a typical use of machine learning within social media. Convolutional neural networks are used to locate around 100 points of reference on the subject's face and then compare them to those in the database.

Healthcare

Oncology use artificial neural networks to develop algorithms that can recognize malignant cells at the microscopic level with the same accuracy as skilled medical professionals. Using facial analysis on the images of the patients, certain uncommon illnesses that might appear physically can be detected in their early stages. Therefore, the widespread use of artificial neural networks in the healthcare industry can only increase the diagnostic skills of medical professionals and eventually result in an improvement in the standard of medical treatment provided globally.

Personal Assistants

Almost all have probably heard of Siri, Alexa, Cortana, and other virtual assistants thanks to your smartphones. These are personal assistants that employ voice recognition and Natural Language Processing to converse with their users and provide responses in line with their needs. Artificial neural networks are used in natural language processing to manage many of these personal assistants' functions, including managing language grammar, semantics, accurate pronunciation, the dialogue that is now taking place, etc.

Bibliography

ISBN 978-81-962237-8-6 April 2023

[1] W. Wu, G. C. Dandy, and H. R. Maier, "Protocol for developing ANN models and its application to the assessment of the quality of the ANN model development process in drinking water quality modelling," *Environmental Modelling and Software*. 2014. doi: 10.1016/j.envsoft.2013.12.016.

[2] I. Marović, I. Sušanj, and N. Ožanić, "Development of ANN model for wind speed prediction as a support for early warning system," *Complexity*, 2017, doi: 10.1155/2017/3418145.

[3] S. Chen, J. Mao, F. Chen, P. Hou, and Y. Li, "Development of ANN model for depth prediction of vertical ground heat exchanger," *Int. J. Heat Mass Transf.*, 2018, doi: 10.1016/j.ijheatmasstransfer.2017.10.006.

[4] Y. I. Alatoom and T. I. Al-Suleiman, "Development of pavement roughness models using Artificial Neural Network (ANN)," *Int. J. Pavement Eng.*, 2022, doi: 10.1080/10298436.2021.1968396.

[5] J. Jawad, A. H. Hawari, and S. Javaid Zaidi, "Artificial neural network modeling of wastewater treatment and desalination using membrane processes: A review," *Chemical Engineering Journal*. 2021. doi: 10.1016/j.cej.2021.129540.

[6] S. M. Cabaneros, J. K. Calautit, and B. R. Hughes, "A review of artificial neural network models for ambient air pollution prediction," *Environmental Modelling and Software*. 2019. doi: 10.1016/j.envsoft.2019.06.014.

CHAPTER - 9

ARCHITECTURE OF AN ARTIFICIAL NEURAL NETWORK

Mr. Gaurav Kundu
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- gaurav.kundu@presidencyuniversity.in

Knowing the components of a neural network is necessary to comprehend the idea of the architecture of the artificial neural network [1]–[3]. A vast number of artificial neurons, also known as units, are placed in a hierarchy of layers to form what is known as a neural network. In Figure 1, an artificial neural network typically consists of three layers:

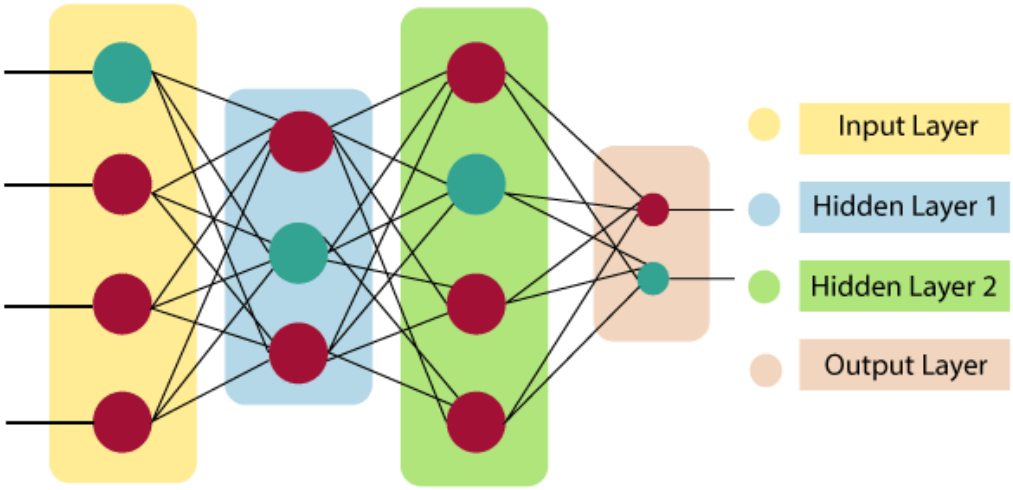

Figure 1: Illustrates the Architecture of an artificial neural network [4]**.**

Input Layer

It takes inputs in a variety of forms that the programmer provides, as the name implies.

Hidden Layer

Between the input and output layers is the hidden layer. It does all computations to look for patterns and hidden characteristics.

Output Layer

The hidden layer is used to turn the input into a variety of outputs, which are then communicated through this layer. When given input, the artificial neural network computes average weighted total of the inputs and incorporates a bias. A transfer function is used to visualise this calculation.

$$\sum_{i=1}^{n} Wi * Xi + b$$

In order to create the output, it passes the weighted total as an input to a convolution operation. A node's activation functions determine whether or not it should fire. The output layer is only accessible to individuals who are fired. Depending on the kind of work it is conducting, several activation functions are available.

ISBN 978-81-962237-8-6

Artificial neural networks working

The ideal way to visualise an artificial neural network is as a weighted directed graph, where another nodes are the artificial neurons. The directed edges having weights represent the relationship between the neuron inputs and outputs. As shown in Figure 2, the Artificial Neural Network takes in the input signal from the outside source as a pattern and a picture as a vector. Then, for each and every n inputs, they are mathematically allocated using the notations x(n).

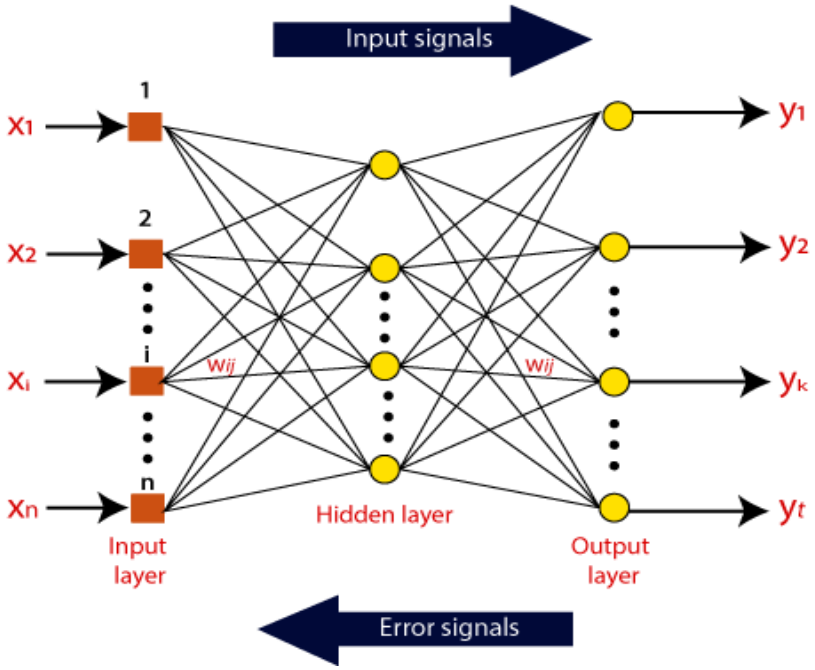

Figure 2: Illustrates the working process of artificial neural intelligence.

Fine-Tuning of the ANN Model

Although the majority of ANN models were trained on big datasets, it is not always feasible to do so in practice since it may be costly and difficult to acquire the necessary data. We only employed 125 experimentally collected data points in this study, and the ANN model were adjusted by changing its hyperparameters, such as expanding the number of hidden layer nodes and epochs in the code. Due of its increased complexity, the multilayer perceptron network construction featured two hidden layers (few data points were used). The experimental dataset's R2 rose from 0.8793 to 0.9995 after the nodes again for two hidden layers were changed from (10, 10) to (100, 100). Additionally, it was crucial to choose those characteristics. Along with early halting, we employed the optimizer "Adam" as well as the activation function "ReLU". This division will contribute to a reduction in connections and will prevent these networks from interacting with one another, which will speed up processing. However, the amount of neurons and their role in calculating the outcomes will affect processing time [5]–[7].

Bibliography

[1] N. Rankovic, D. Rankovic, M. Ivanovic, and L. Lazic, “A New Approach to Software Effort Estimation Using Different Artificial Neural Network Architectures and Taguchi Orthogonal Arrays,” *IEEE Access*, 2021, doi: 10.1109/ACCESS.2021.3057807.

[2] I. N. da Silva, D. Hernane Spatti, R. Andrade Flauzino, L. H. B. Liboni, and S. F. dos Reis Alves, “Artificial Neural Network Architectures and Training Processes,” in *Artificial Neural Networks*, 2017. doi: 10.1007/978-3-319-43162-8_2.

[3] T. Zhou *et al.*, "Large-scale neuromorphic optoelectronic computing with a reconfigurable diffractive processing unit," *Nat. Photonics*, 2021, doi: 10.1038/s41566-021-00796-w.

[4] J. Point, "Artificial Neural Network," 2020.

[5] J. Kalliola, J. Kapočiūte-Dzikiene, and R. Damaševičius, "Neural network hyperparameter optimization for prediction of real estate prices in Helsinki," *PeerJ Comput. Sci.*, 2021, doi: 10.7717/peerj-cs.444.

[6] J. C. Pyo *et al.*, "An integrative remote sensing application of stacked autoencoder for atmospheric correction and cyanobacteria estimation using hyperspectral imagery," *Remote Sens.*, 2020, doi: 10.3390/rs12071073.

[7] C. Li, C. Yin, and X. Xu, "Hybrid optimization assisted deep convolutional neural network for hardening prediction in steel," *J. King Saud Univ. - Sci.*, 2021, doi: 10.1016/j.jksus.2021. 101453.

‘

ISBN 978-81-962237-8-6

CHAPTER - 10

ERROR ANALYSIS AND STATISTICAL METHODS

Dr. Sidharth Gautam
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- sidharth.g@presidencyuniversity.in

The maximum level of accuracy is sought for determining physical quantities such as the gravitational constant, elementary charge, and speed of light, among others. In other words, the aim of the experiment is to establish certain parameters. The purpose of the second kind of experiment is to determine if a certain theory or theoretical model coincides with the results of the experiment. These kinds of studies test a theory. These two different sorts of experiments often overlap greatly. The majority of experiments performed in intermediate labs fall under the first category, which requires that a physical quantity be determined with the greatest degree of accuracy and precision. A number of other directly measured values, including such voltages, currents, lengths, etc., are used to calculate this amount, such as Planck's constant. You may calculate an average value by repeating the same measurement and seeing that each time you receive somewhat different results. We make the assumption that the experimental circumstances are perfectly repeatable in the sense that the real value may be determined with infinite precision and accuracy by doing the same measurement an endless number of times. In practise, this is not achievable, thus you must estimate the actual value using the measurements that are available together with a reliable estimation of the range of values that you anticipate the genuine value to fall within. Visitors might refer to this final amount as the experimental uncertainty, error, or precision [1]–[3].

Accuracy vs Precision

There is a distinction between what one intends precisely and accurately. How closely the experimental value matches the actual value is determined by the accuracy. The accuracy determines how repeatable the results of your experiment are. When your result's uncertainty is given as a percentage of its value, it is often helpful to calculate the relative accuracy. Accuracy and precision must be taken into account concurrently in a successful experiment. Even the most exacting experiment might provide erroneous results if, for instance, the equipment calibration is off. Even if an inaccurate experiment may be correct, but won't get any new knowledge from it. In the explanation of the findings, students should evaluate the accuracy of your result (how much more it deviates from the generally recognised, much more exact number) to the precision of given result if they already have an experimental result where you have, for example, calculated Planck's constant. One may be pleased knowing that their experiment agrees within its accuracy if the reported result is within the range of your estimated uncertainty [3]–[5].

Types of Errors/Uncertainties

There are two primary types of mistakes, each of which may occur for different reasons:

Random mistakes are caused by variations in the data, which provide different outcomes every time the experiment is run. In order to reach a precision that satisfies the necessary experiment accuracy, they need repeated measurements. Only by strengthening the experimental design and enhancing the methodologies used in the experiment can random mistakes be decreased. Random mistakes may be caused by measuring method limits or by intrinsic equipment limitations, which may be addressed by employing better instruments. For instance, even if you

ISBN 978-81-962237-8-6 April 2023

use the best instrument available, overall relative accuracy will be restricted if simply count the number of random processes that take place during a certain period of time and the overall number of counts is too small.

Systematic Errors

Even the most exact measurement will deviate from the true value due to this kind of mistake. The reduction and identification of an experiment's systematic error takes up a significant portion of its design and analysis since these flaws may be exceedingly challenging to identify.

Estimating Measurement Errors

The maximum error and the standard error are two significant measures of the uncertainty in some kind of a measured quantity (note these names can be different in different books). Optimal error: This is meant to show the range in which the real value unquestionably falls. It is actually the only kind of mistake that can be calculated from a single measurement.

Standard error

A "normal" or "Gaussian" distribution curve will be produced if you have a lot of measurements of the single quantity, as seen below. The equation for the curve is shown in Figure 1 and the ordinate seems to be the number of observations per unit's range of values that fall between:

$$n(t) = \frac{N}{\sigma\sqrt{2\pi}} e^{\frac{-(t-t)^2}{2a^2}}$$

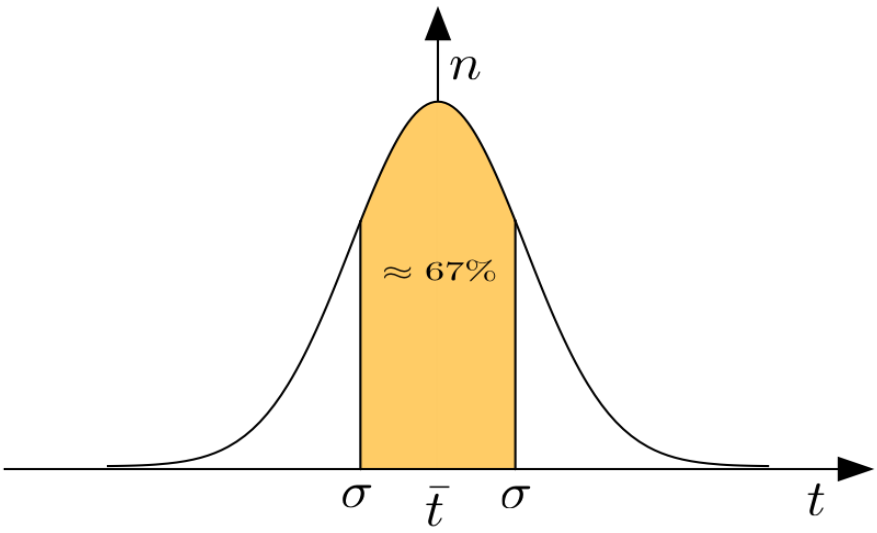

Figure 1: Illustrates the Gaussian distribution curve.

Standard deviation, also known as standard error, is a measurement of the breadth of the curve and therefore is symmetrical around the mean value, which is the complete number of observations made. The RMS value of the individual measurements' deviations from the mean for with this distribution, as well as the squared of the RMS value, is referred to as the variance of:

$$\sigma_t^2 = \frac{1}{N}\sum_i (t_i - t)^2$$

Viewers can demonstrate that 67 percent of all t measurements fall within t, 95 percent within t2, and 99.7 percent within t3. In reality, t and must be inferred from the data since they are

unknown. The estimation of the uncertainty of a counting experiment, in which the quantity of randomly occurring events is tallied over a specified time period, is a crucial application (e.g. particle emitted by a radioactive source).

Bibliography

[1] K. H. Yim, F. S. Nahm, K. A. Han, and S. Y. Park, " Analysis of Statistical Methods and Errors in the Articles Published in the Korean Journal of Pain ," *Korean J. Pain*, 2010, doi: 10.3344/kjp.2010.23.1.35.

[2] "Error in the Statistical Analysis Subsection of the Methods Section," *JAMA Cardiol.*, 2020, doi: 10.1001/jamacardio.2020.0720.

[3] F. Zhu and G. Hummer, "Convergence and error estimation in free energy calculations using the weighted histogram analysis method," *J. Comput. Chem.*, 2012, doi: 10.1002/jcc.21989.

[4] C. Fruciano, "Measurement error in geometric morphometrics," *Development Genes and Evolution*. 2016. doi: 10.1007/s00427-016-0537-4.

[5] A. D. Willis, "Rarefaction, alpha diversity, and statistics," *Front. Microbiol.*, 2019, doi: 10.3389/fmicb.2019.02407.

ISBN 978-81-962237-8-6

CHAPTER - 11

CLASSIFICATION OF DENSE-FLUID VISCOSITY MODELS AS SEMI-THEORETICAL

Dr. Sidharth Gautam
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- sidharth.g@presidencyuniversity.in

Many petroleum and analytical chemistry disciplines, such as the estimation of recoverable petroleum within such a reservoir, the computation of flow rates in porous materials or wellbores, the forecast of manufacturing profiles of petroleum reservoirs, as well as the design of transport machinery and pipelines, all call for an understanding of viscosity over broadening ranges of temperature, pressure, and composition. This crucial quality may be obtained, for example, by experimental measurements. Direct viscosity measurements, however, are not just costly and time-consuming, but also very challenging and sometimes impossible to acquire, particularly under high-temperature, high-pressure (HTHP) conditions [1]–[3]. When investigations are challenging, a different method of producing fictitious experimental viscosity data to augment actual experimental data is provided by molecular dynamics simulations. The molecular description is often reduced when doing molecular dynamic simulations in order to shorten the computing time, and as a result, the predicted viscosities were typically only within about an order of magnitude of experimental values. Industry does not yet generally embrace this strategy. However, the molecular dynamic simulations may provide light on the behaviour of viscosity. Additionally, given the fast advancements in computer technology, industrial adoption of the use of simulations using molecular dynamics for engineering reasons is predicted to increase in Figure 1.

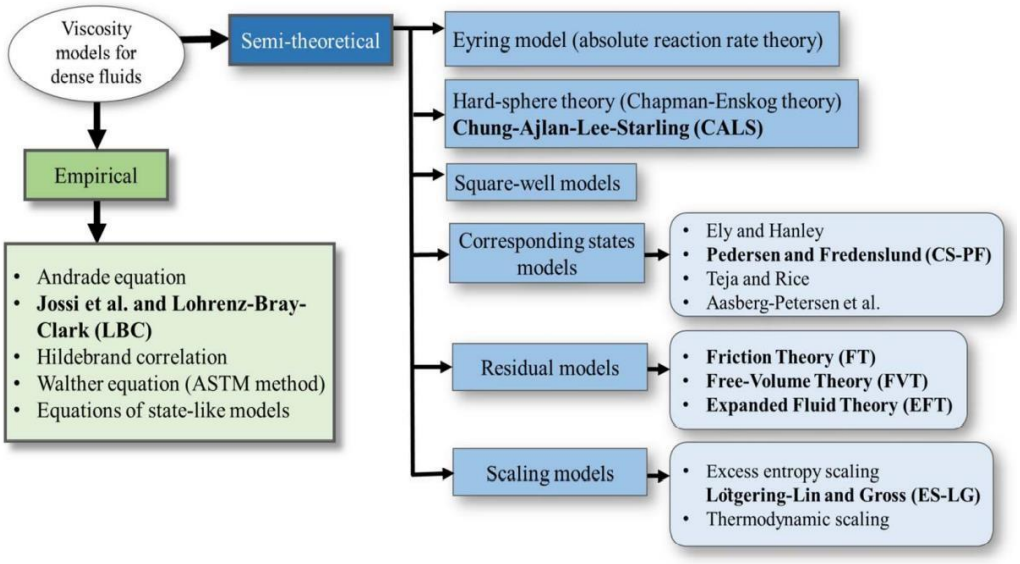

Figure 1: Illustrates the Classification of dense-fluid viscosity models as semi-theoretical and empirical.

Viscosity may be predicted and correlated using reliable viscosity models. There are several precise theoretical models with correlations for the calculation of gas viscosity since the theory of gas viscosity under low pressures is well developed with both the kinetic theory of gases. However, owing to complexities brought on by intermolecular interactions between molecules,

ISBN 978-81-962237-8-6

the viscosity concept of liquids still has to be improved. Therefore, there is no universally recognised straightforward theoretical approach for forecasting liquid viscosities, and there is no agreement on the process of momentum transmission in liquids. In actuality, the majority of viscosity calculation methods for liquids are either empirical or semi-empirical. As a result, there exist several models and relationships in the literature for estimating the viscosities of gases and liquids. Viscosity models have been categorized in a number of ways, such as theoretical, semi-theoretical, and empirical methodologies. While semi-theoretical models, that possess a basic base, have modifiable parameters established by applying the model to experimental data, theoretical models are solely predictive in nature. Correlations derived from experimental observations make up the empirical models. Additionally, viscosity models may be further divided into two categories: correlative, in which each of the adjustable parameter estimation must be determined by experimental data, and predictive, in which no experimental data is needed to establish the model parameters. Additionally, depending on the fluid's condition, viscosity models may be split into three groups: those that can forecast the viscosities of gases, liquids, or both gases and liquids.

Eyring model (absolute reaction rate theory)

Eyring created the absolute reaction rate hypothesis to explain the speeds of chemical reactions. Eyring later understood, nevertheless, that this idea might also be used to explain other rate processes [4], [5]. Viscous flow may be seen as a rate process wherein the molecules are stimulated to cross a potential energy barrier and relocate to a neighboring empty location. The following equation for the viscosity of the a Newtonian liquid was created by Eyring and colleagues.

$$\eta = \frac{hN_A}{V} \exp\left(\frac{\Delta F}{RT}\right)$$

Where h is Planck's constant, NA is Avogadro's quantity, V is the liquid's molar volume, R is the gaseous constant, while the absolute temperature T. is the liquid's dynamic viscosity. The heat of vaporization for simple liquids containing spherical components is about one-third of the molar fixed activation energies for flow, where equals the molar free energy of flow.

Thermodynamic scaling models

Two distinct thermodynamic property variables are integrated into one and connected to viscosity throughout the thermodynamic scaling technique. The thermodynamic scaling approach was first suggested. They discovered via non-equilibrium simulations using molecular dynamics that the lowered excess viscosity is a consequence of a single variable that is the sum of the temperature and density, rather than of the temperature and density individually.

By connecting the excess viscosity to something like a single generalized variable that contains, in addition to density and temperature, a third element to account for the impact of the volume expansion with said triple point as just a reference state, it created a generalized viscosity equation. When a material constant is regressed from experimental results, the scaling parameter may be used to characterize the dynamics of solvents and polymers that form glass. Data merged into a single master curve when shown as a proportion of relaxation time. Obtained the same finding in a different study done in the same year. The super placement of relaxation durations in relation to viscosity was expanded.

Bibliography

[1] A. Allal, C. Boned, and A. Baylaucq, “Free-volume viscosity model for fluids in the

dense and gaseous states," *Phys. Rev. E - Stat. Physics, Plasmas, Fluids, Relat. Interdiscip. Top.*, 2001, doi: 10.1103/PhysRevE.64.011203.

[2] M. Binti Mohd Taib and J. P. M. Trusler, "Residual entropy model for predicting the viscosities of dense fluid mixtures," *J. Chem. Phys.*, 2020, doi: 10.1063/5.0002242.

[3] C. Ganguly and J. Quintin, "Microphysical manifestations of viscosity and consequences for anisotropies in the very early universe," *Phys. Rev. D*, 2022, doi: 10.1103/PhysRevD.105.023532.

[4] R. A. H. Timmermans, H. C. Mastwijk, M. N. Nierop Groot, and M. A. J. S. Van Boekel, "Evaluation of the Gauss-Eyring model to predict thermal inactivation of micro-organisms at short holding times," *Int. J. Food Microbiol.*, 2017, doi: 10.1016/j.ijfoodmicro.2017.10.001.

[5] A. Singla, R. Bansal, V. Joshi, and A. S. Rathore, "Aggregation kinetics for IgG1-based monoclonal antibody therapeutics," *AAPS J.*, 2016, doi: 10.1208/s12248-016-9887-0.

ISBN 978-81-962237-8-6 April 2023

CHAPTER - 12

ANN PROCESS

Mr. Gaurav Kundu
Assistant Professor, Department of Petroleum Engineering,
Presidency University, Bengaluru, India
Email Id- gaurav.kundu@presidencyuniversity.in

However, ANN enhance their own rules, the more judgements they make, the better decisions they may become. Computers are adept at calculations that receive inputs, analyses them, and then offer the outcome depending on calculations done at certain Algorithms that are coded in software's. ANN models are often trained using several datasets, however this is not always achievable since retrieving such data is a very time-consuming procedure from both a practical and financial standpoint [1], [2]. Prior to being used, the data points must be normalized so that the output will appear in a form that is compatible (0 or 1) and allows the result to be read. The distribution of the input-output dataset, the input-output dataset's distribution, and the manner in which the input-output dataset is presented to the neural network are some of the variables that affect the ANN model's capacity to generalize data. The notion of the adaptive weights is the strength of the connections between neurons that are active during both prediction and training. The synapses keep "weights," or parameters, that control how the data is handled in the computations in Figure 1.

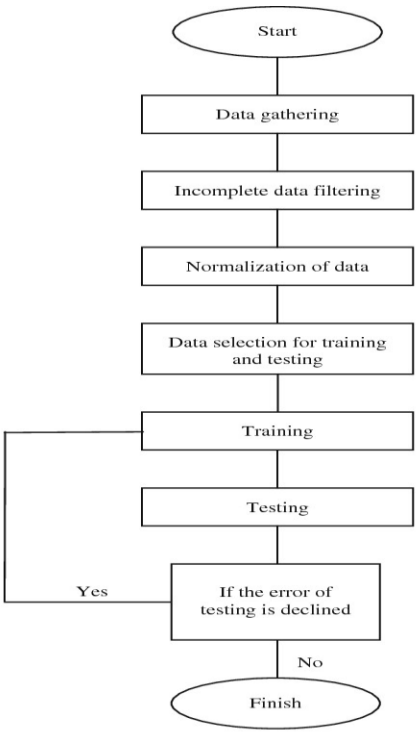

Figure 1: Illustrates the ANN process flow chart.

Activation functions are crucial because they aid in understanding and learning about complex, non-linear mappings across inputs and outputs. In artificial neural networks, activation functions are utilised specifically to convert input signals into output signals that are then sent as input to the subsequent layer in the stack. In such an artificial neural network, first add up the inputs and their appropriate weights, then apply some activation function to generate the layer's output, which we use as input for the layer after that. If an operational amplifier is not

ISBN 978-81-962237-8-6

specified, a neural network performs similarly to a linear regression model with such a constrained performance where the projected output is exactly the same as the given input. Non-linear activation functions are the most often utilised activation functions. To make the network dynamic, add the capacity to extract intricate information from data, and depict non-linear convoluted random functional mappings among input and output, one must apply the activation function [3].

A few of the Activation functions are as follows:

Sigmoid Function

Given that it is a non-linear function, it serves as the most often employed activation function [4]. The sigmoid function modifies the values between 0 and 1.

Tanh Function

A hyperbolic tangent factor represents it. The tanh function is symmetric about the origin, unlike the sigmoid function, which is not. The values range from -1 to 1. Tanh is chosen over nonlinear function because it is zero-centered and already has gradients that may change in any direction.

ReLU Function

It is a non-linear activation function that is frequently employed in neural networks and stands meaning rectified linear unit. ReLU is more effective than other functionalities because a limited number of neurons were engaged at once rather instead of all of the neurons simultaneously.

Leaky ReLU Function

It is a modified version of the ReLU function wherein, for negative values of x, the value of the ReLU function is specified as a very tiny linear component of x rather than zero. It is also a somewhat different version of the Rectified Linear Unit with higher performance. By adding a new parameter to the negative component of the algorithm, it fixes the issue where the gradient of ReLU becomes 0 for negative values of x. One may utilise the leaky ReLU function if with us defined as the sharing dead neurons. If the ReLU function does not provide sufficient results, we go on to other functions. Studies have shown that sigmoid and tanh function are inappropriate for hidden layers because the gradient of the function decreases as the input increases or decreases, slowing learning algorithm [5], [6].

Bibliography

[1] W. M. Ashraf *et al.*, “Artificial intelligence based operational strategy development and implementation for vibration reduction of a supercritical steam turbine shaft bearing,” *Alexandria Eng. J.*, 2022, doi: 10.1016/j.aej.2021.07.039.

[2] W. Wu, G. C. Dandy, and H. R. Maier, “Protocol for developing ANN models and its application to the assessment of the quality of the ANN model development process in drinking water quality modelling,” *Environmental Modelling and Software*. 2014. doi: 10.1016/j.envsoft.2013.12.016.

[3] L. De Marinis, M. Cococcioni, P. Castoldi, and N. Andriolli, “Photonic Neural Networks: A Survey,” *IEEE Access*, 2019, doi: 10.1109/ACCESS.2019.2957245.

[4] J. Dombi and T. Jónás, "Generalizing the sigmoid function using continuous-valued logic," *Fuzzy Sets Syst.*, 2022, doi: 10.1016/j.fss.2022.02.010.

[5] J. Schmidt-Hieber, "Nonparametric regression using deep neural networks with relu activation function," *Ann. Stat.*, 2020, doi: 10.1214/19-AOS1875.

[6] J. M. Klusowski and A. R. Barron, "Approximation by combinations of ReLU and squared ReLU ridge functions with ℓ1 and ℓ0 controls," *IEEE Trans. Inf. Theory*, 2018, doi: 10.1109/TIT.2018.2874447.

ISBN 978-81-962237-8-6

M/S CIIR Scientific Publications
B-17, Sector - 6, Noida,
Uttar Pradesh, India.
201301
Email: info@ciir.in

April 2023
ISBN 978-81-962237-8-6