UPGRADING OF HEAVY OIL USING NANOTECHNOLOGY

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Abstract - *With the increasing world energy demand, considerate attention has been centered on utilizing heavy oil, that is probably settled ultra-deep underground and can't be simply recovered. Recently, nanotechnology has appeared as a substitute for the technology for in situ heavy oil upgrading and recovery enhancement e.g., using metal-based nanoparticles. Nanocatalysts are one of the vital examples of nanotechnology applications. They portray distinctive chemical change and natural properties due to their exceptionally high surface-area-to-volume quantitative relation and active surface sites. In-situ catalytic conversion or upgrading of heavy oil with the help of multi-metallic nanocatalysts could be a promising value effective and environmentally friendly technology for the production of top quality oils that meet pipeline and refinery requirements. Further, nanoparticles can be utilized as inhibitors for preventing or delaying asphaltene precipitation and after enhance oil recovery. The "underground refinery" approach employing a nanosize ultradispersed (UD) catalyst is one amongst the alternatives to surface upgrading which will become the "next generation" of oil sands manufacturing enhancement. Water-in-vacuum gas oil micro-emulsions containing trimetallic (W, Ni, and Mo) ultradispersed mixture nanoparticles that may penetrate within the porous medium and react with the hydrocarbon. This methodology is geared towards developing a catalytic-enhanced oil recovery for hydrocarbon through the viscosity reduction mechanism with the help of trimetallic nanoparticles.*

Key Words: Nanotechnology, Nanoparticles, Heavy Oil, Upgrading Recovery, In-situ

1. INTRODUCTION

The world is facing formidable challenges in meeting energy demands, Therefore, it is necessary to look for alternative energy supplies that can be produced from natural resources. Various natural energy resources have been explored; including biomass, vegetable oils, biodiesel, etc. but they are costly and insufficient in meeting energy demands.

Further, sometimes these categories of fuels have got to be developed to satisfy the relevant properties of typical fuels. This has crystal rectifier to associate augmented demand on the upgrading and recovery of unconventional oil to satisfy current and future energy desires truly, the International Energy Agency (IEA) has foreseen that by the year 2030, regarding an hour of the whole worldwide energy growth are going to be met by fuel sources like heavy oil, coal, and fossil fuel. Nonetheless, because of its high viscosity, low hydrogen-carbon ratio, and high sulphur-nitrogen content, there are a variety of challenges related to hydrocarbon recovery and upgrading within the existing context. These challenges got to be head to create its property and economically possible various [1].

Nanotechnology is a swiftly growing technology with extensive potential applications and advantages. It provides unparalleled opportunities to develop a cost-effective and environmentally friendly heavy oil upgrading and recovery processes. within the world of engineering, a nanoparticle acts as a full unit in terms of its transport behavior and properties, and its diameter is sized between one and a hundred nanometres. Nowadays, because of such properties nanoparticles are utilized in immense areas of engineering applications, like heavy oil upgrading, fuel cell technology, compound nanocomposites, catalysis, and sewer water treatment. The potential applications for nanoparticles are in the oil and gas industry, especially upgrading and recovery improvement of heavy feedstocks by nanoparticle catalysts.

In addition to its high extent, these catalysts ought to maintain ultra-dispersion ability and high catalytic process activity. The capability to engineer desired surface functionalities of nanoparticles by calibration its characteristics furthermore because the risk of its unmoved preparation makes nanotechnology a striking distinctive choice for heavy oil upgrading and recovery [2]. Moreover, as a result of their little size and transport behavior, nanoparticles are often utilized in the reservoir surroundings wherever upgrading and recovery are required [3].

2. NANOTECHNOLOGY AND EXPLORATION

Within the near future, the industry may even be using nanoscale sensors for searching properties deep inside the reservoir, permitting us to unravel the complicated nature of the rock/fluid interactions [4].

In addition to their effects on point flow associated providing the facility to vogue acceptable exploitation plan for the quality asset. Another area of significant challenges lies inside the upgrading of hydrocarbon and heavy crude. Because of their high density and viscosity, vital resources, and intense analysis activities are dedicated to developing processes and specifically designed catalysts for on-site field upgrading combined with hydrogen/methane production [5]. These processes would encompass a reduced and controlled carbon rejection, in aggregation with a catalytically enriched hydrogen generation performed on the rejected carbon from the upgrading method. This central activity is going to be complemented with an endeavor to integrate the analysis for ultradispersed chemical process formulas for the unmoved upgrading of hydrocarbon furthermore as for element generation from coal/coke or crude pitch.

The latter needs an intensive analysis of each active phase and process setup furthermore as adopting different catalytic process forms for effective contact with the gasifying materials. This has the potential to get vital technology to convert hydrocarbon and heavy-oil reserves into yields cost-effectively.

2.1 In-Situ Prepared Ultradispersed Nanoparticles

Supported catalysts may well be placed solely within the assembly to perform unmoved upgrading. Due to coke accumulation and metal poisoning occurring in three segments, supported catalysts system deactivates. The three segments are in constant deactivation rate of the catalyst caused by metal deposition and block active catalysts sites, coke deposition on the contemporary catalyst network and fast deactivation of the catalyst caused by metal deposition which ends up in constriction of pore mouth and sensible chemical process properties, like high consistency and resistance to pore plugging are favorable properties for the process of heavy feedstocks. To overcome the pore plugging downside ultra-dispersed nanocatalysts were developed for industrial applications [6].

There exist many benefits with the usage of nanocatalysts including:

- The small size of nanocatalysts deal large surface area to volume relation which ends up in improved catalytic process performance for process functions.
- The likelihood of contacts between reactants is augmented because of nanocatalysts mobilization within the reactor that ultimately will increase the economics of the upgrading method. ·
- Absence of any fixed bed catalysts because of nanocatalysts implementation within the medium modify longer run times for conversion as there's no necessity of catalyst replacement.
- Transmission of nanocatalysts within the porous media and reacting in-situ cause hydrocarbon dissolution as well as viscosity reduction of produced liquid, and successful in-situ process reduces the operational prices, as well as environmental issues related to hydrocarbon production.

Nanocatalysts were initiated into the porous media to perform upgrading within the reservoir and convert hydrocarbon to lighter products. Since SAGD is the major recovery method for hydrocarbon production, the ultimate goal for nanocatalysts usage is to adjoin each of the advantages of nanocatalysts presence within the porous media as well as thermal drive mechanism at the same time. This could be expressed as a function of the initial absolute porosity and a flow potency issue of the cross-sectional space receptive flow. Besides, the retention method conjointly modifies the phases' relative porosity, a product of the wettability alteration. The latter involves a limit once all the surfaces of the rock are coated by the nanoparticles reaching the utmost wettability alteration within the porous media. From that moment on, more retention of nanoparticles can affect the consistency and absolute porosity. Related to this development, there is an accumulation of larger clusters with similar nanoparticles (i.e., homo-aggregation) or alternative colloidal/suspended particles (i.e., hetero-aggregation) [7].

This increment in the size, and therefore in its crucial velocity, can lead to deposit in the channels or throats. Moreover, these clusters will subsequently capture free nanoparticles, resulting in a secondary aggregation method, increasing their size till a crucial “diameter” is reached, and therefore the cluster collapses and is split into many smaller items.

2.2 Process Pressure for in Situ Upgrading

Hydrocarbon and additional heavy oils are generally present in comparatively shallow reservoirs. Therefore, in-situ upgrading of these oils needs a relatively low process pressure. Deeper bitumen or extra-heavy oil reservoirs would allow using even higher pressure, which significantly favors hydro-processing reactions. The preparation of nanocatalysts may well be obtained by the integration of two reacting systems (one containing the precursor salt and therefore the alternative a reducing agent) in a variety of microemulsions.

For heavy oil conversion, the associate emulsion was developed in presence of water claiming steam cracking of vacuum gas oil (VGO) catalyzed by catalytic process emulsion [8]. Mechanical splitting and accumulation of UD nanocatalysts supported their motion in the viscous fluid media has been investigated in exceedingly cylindrical geometry. 2D and 3D convective-dispersive models were developed that supported experimental tests.

Besides, concentration profiles for particles (ranging from micro to the nanoscale) movement through fluid media as a function of their position and time were a success-absolutely foreseen. It is significant in mentioning that the accumulation of ultra-dispersed nanoparticles in the medium plays a crucial role in the sedimentation of nanoparticles as well as the potency of produced nanoparticles from desired metal precursors.

2.3 Required Facilities for Nanocatalysts Application in Heavy Oil Upgrading and Recovery

Implementation of the new advanced technologies is directly related to the usage of modern systems for industrial developments. Due to the nature of ultra-dispersed nanocatalysts upgrading complications, it's essential to acquire management systems to avoid any allied threats. Several strategies are planned to upgrade unconventional oils directly in reservoirs. Injecting propane as a solvent produces both precipitations of asphaltenes and reduce the viscosity of the unconventional oil since essentially the maltene fraction of it would be produced mixed with the solvent. Radiation methods such as ultrasound and microwave have also been suggested along with in situ bio-upgrading.

Thermal strategies have the most intrinsic disadvantage of generating more and denser asphaltenes and manufacturing olefins, which makes the requirement for hydro-treating of the produced crude on the surface before pipelining. The incorporation of a catalytic perimeter around the production wells has already been projected and combined with air injection strategies to produce heat and produce upgrading reactions [9]. The price of nanocatalysts depends totally on the native availableness of their precursors, types, preparation techniques, and methodology of application. Because the nanocatalysts might be prepared in-situ, inside the reservoir surroundings, the prices of the materials may well be reduced.

3. FUNDAMENTAL CHEMICAL AND ENGINEERING CHALLENGES FOR NANO CATALYTIC IN SITU UPGRADING

A non-exhaustive list of elementary aspects on the technical challenges for bringing this concept to technology includes these items: ·

- Planning setups for reproducible, steady and consistent UD- catalysts synthesis/delivery for industrial application.
- Building a nanocatalysts reactivity database to secure the flexibility required to regulate the levels of chemical upgrading conveniently.
- Reliable synthesis of the catalyst active species and even critical for a process, granting the effective size of it to secure ease penetration within the permeable media.
- Dynamics of nanocatalysts agglomeration with temperature up to reaction conditions and control of permeability with time.
- Management of the fluid dynamics of nanocatalysts concerning undesirable agglomeration, reliable separation, and reprocessing is required.
- Sufficiently determining these aspects would contribute to an effective cost estimate of the catalyst and process.

3.1 Nanocatalysts Transport Behaviour Inside the Porous Media

After the preparation and synthesis of nanocatalysts in a microemulsion system, a crucial issue concerning the usage of nanocatalysts for hydrocarbon upgrading is that the practicability of nanocatalysts transport within the porous media.

To conduct the effective upgrading process underground, the placement of nanocatalysts in an acceptable zone within the oil sand medium is essential. Recently, a bunch of consultants described the transport behavior of gold and multi-metallic ultra-dispersed nanocatalysts, suspended in VGO, within oil sand absorbant media at totally different experimental and operative conditions [10].

Results validated that the procreation of ultra-dispersed nanocatalysts in associate oil sands packed bed column at typical pressure and temperature of the SAGD recovery method is achievable, as neither key absorbency reduction nor pore corking was witnessed. The try-outs conducted by Zamani et al. were implemented at low temperatures and in the absence of cracking reaction that showed nanocatalysts were able to circulate through the sand medium, however larger agglomerative particles were clarified out.

This indicated that the accumulation affinity of nanocatalysts is intensely affected by the form of metal, temperature, and sand porosity. Rising the temperature favored the bunch, this was accredited to the rise in frequency of particle collision due to the heavy oil viscosity reduction and consequently, higher aggregation rate.

One of the necessary aspects of nanocatalysts passage in the permeable media is that the control over the particle size during the injection and reaction times. Additionally, to various experimental studies, robust mathematical modeling of nanocatalysts transport behavior within the permeable media would offer valuable information on the conception of particle mass transfer.

4. UPGRADING AND RECOVERY ENHANCEMENT

41. Quality Enhancement

Analysis of product quality is necessary for any upgrading processes to work out the extent of the augmented value of heavy feedstocks. Therefore, the standard of produced liquid streams produced from upgrading and recovery ought to be characterized on the premise of hydrogen to carbon ratio (H/C), micro carbon residue (MCR) content, viscosity, API gravity, sulphur, and nitrogen content.

4.2 H/C Atomic Ratio

One amongst the most distinctive properties of heavy oil and hydrocarbon is the low value for hydrogen to carbon ratio. Any enhancement to H/C ratio may be used as a sign for the extent of heavy feedstock upgrading. Any thermal upgrading method involves synchronized cracking and hydrogenation of heavy molecules to generate lighter constituents with smaller molecules as well as greater hydrogen to carbon ratios. Experiments are successfully carried out to check the catalytic hydro process reactions of hydrocarbon in a batch mode.

Experimental outcomes indicated that nanocatalysts enriched the upgrading of hydrocarbon by considerably increasing the hydrogen to carbon atomic ratio and reducing viscosity and coke formation. Additionally, a major reduction of sulphur and MCR may be ascertained. Supported by the observed results, nanocatalysts will enhance the hydrogen to carbon ratio via cracking followed by the hydrogenation process. Besides, higher hydrogen to carbon ratio appears in complex conversion values.

4.3 Viscosity Reduction and API Augmentation

Viscosity is taken into account as a vital factor for hydrocarbon transportation via pipelines. For viable transportation, hydrocarbon API gravity is enhanced to approx 19-21° API, and the viscosity of hydrocarbon is reduced to roughly (250 cP at 10 °C). In the existing context, most of the attribute development is accomplished on the surface through surface upgrading facilities, or acceptable diluent is considered to meet plant feedstock specifications. Ultra-dispersed nanocatalysts experiments are implemented in batch and packed bed reactors exhibited in- situ upgrading and recovery methods that may be enforced to raise the standard of hydrocarbon which could meet the pipeline transportation conditions exclusive of diluent addition. In processes (i.e. batch and initial experiments), the viscosity of the yield is reduced against the time of the reaction. Additionally, higher viscosity reduction occurred at increasing temperatures. In each of the experimental series, vacuum gas oil was used as nanocatalysts carrier into the medium, and positively by using the lighter carrier, higher viscosity reduction may be witnessed since dilution was co-joined with the thermal catalytic action throughout upgrading testes. Add on to viscosity reduction and the API gravity of yield may be used as a symbol of quality enrichment.

4.4 Coke Reduction

Micro carbon residue (MCR) content measure refers to the quantity of carbon residue that is left behind when the thermal treatment of the heavy feedstocks is done. The high value of micro carbon residue content for a model which is inferred as a low caliber product.

In a batch reactor test for hydrocarbon catalytic cracking, micro carbon residue content may be improved by involving the ultra-dispersed nanocatalysts. Executing the ultra-dispersed nanocatalysts modified the micro carbon residue from 16 wt% in the blank experiment up to approximately 11 wt% for designated experimental conditions.

It may be foreseen that, at an increased temperature and in presence of nanocatalysts, the lowest quantity of micro carbon residue may be measured that upholds the effectiveness of nanocatalysts for cracking reaction as well as quality enhancement.

4.5 Sulphur Removal

Environmental issues enforce tight rules on the sulphur content of fossil combustibles. In hydrotreating processes, hydrodesulphurization is considered as a vital reaction that involves removing the sulphur from petroleum compounds to produce hydrogen sulphide as well as desulphurized compounds. Generally, dispersed catalysts show higher percentages of sulphur removal compared with supported catalysts; owing to their effective accessibility. However, sulphur removal is associated with hydrogen sulphide production, which may cause some undesirable aspects for the nanocatalysts implementation within the permeable media.

4.6 Nanocatalysts Recycling

Existence of nanocatalysts within the medium along the side of hydrogen incorporation aims to enhance the standard of the produced liquid via catalytic cracking. Quick deactivation of conventional supported catalysts is a major disadvantage compared to ultra-dispersed nanocatalysts. Ultra-dispersed nanocatalysts might offer an appropriate level of reaction activity as well as a choice to perform within the well level. A key bottleneck to the in-situ applications will be the recyclability of the consumed nanocatalysts that may offer cost-effectiveness for the method as well as the reduction in the environmental footprints. Nanocatalysts are injected through an injector well within the permeable media and enhanced oil is manufactured via recovery well. Produced liquid from the reservoir contains some active nanocatalysts within the non-distillable residue which may be recycled and re-injected to the porous reservoir. It'll be in favor of the process economics if the ultra-dispersed nanocatalysts might be used numerous times before losing consistency and catalytic activity.

5. ENVIRONMENTAL EFFECT OF NANOPARTICLES

Over the last decade, many nanomaterials have moved into the marketplace with direct and indirect application in society. However, there are only minimal data on the nanomaterials' exposure effect on human health and the environment.

From the environmental perspective, the associated benefits of nanoparticles are combined with the potential challenges that may be difficult to predict. Additionally, there exists little data regarding the production, usage, and disposal of the nanomaterials and any correlated threats from the exposure of nanomaterials.

The development of heavy oil enhancement and recovery using nanoparticles as catalysts is a kind of new and complex method, and similarly the additional extent of nanotechnologies with the prospects and challenges. As an example, percentages of injected nanoparticles into the development are accumulated within the medium and will remain in place unaltered for several years. Furthermore, on the functional side, the probability of groundwater adulteration by the produced nanocatalysts ought to be measured as an operational failure risk. Yielded sustainable nanocatalysts intend to illustrate higher activity, higher selectivity, effective recovery, sturdiness, and recyclability in a very efficient way.

6. CONCLUSION

Transmission of nanocatalysts within the permeable media is possible and ultradispersed multi-metallic nanocatalysts might be controllably transported through oil sands permeable media into the desired heavy oil reservoir where they might work as adsorbents or catalysts for heavy oil enhancing. The existence of nanoparticles within the permeable media and stipulating acceptable reaction conditions with necessary elements involving hydrogen would result in recovery enhancement and further considerable quality improvement altogether in three phases of liquid, gas, and solid. Enhancement of viscosity, API gravity, micro carbon residue content, sulphur, and nitrogen content in the liquid phase is vital. Advanced quality of manufactured gases in terms of hydrocarbon and carbon dioxide emission in the gas phase and fewer quantity of coke content in the solid phase depicts promising prospects for the nanoparticles in-situ implementation. Furthermore, nanoparticle-based fluid might be used with success for ever-changing reservoir wettability from oil-wet to a water-wet condition.

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