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# Heavy Refinery Schemes based on New Nano Catalytic HRH Technology

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**Abstract.** Heavy Residue Hydroconversion (HRH) technology as a new nano-catalytic based process has applied for a commercial scale refinery scheme in Iran. HRH is supported by different patents (like US7585406 B2, Sep.2009) and its very active nano-structure catalyst make the operating condition mild (70 bars and 440-460 °C) and the catalyst recovery plant in the HRH unit makes it very independent to chemical inventory. The volume yield of conversion is as high as 110%, 60-80% of feed sulfur removes and all heavy metals convert to metal oxides as by product. The products are bottomless (the end point of heavier product is close to 520 °C) therefore upon requirement, the refinery products would be residue free. A complete refinery capacity 180'000 bbl/d for heavy crude (18 API) designed and studied based on HRH as upgrading unit. The economic figures indicate strong economy of this new scheme comparing other processes. This scheme is not very dependent on natural gas price. The self sufficient nature of HRH and its flexibility to feed composition as well as its sound economic features make HRH a unique alternative for developing new heavy crude refinery schemes.

## 1. Introduction

New explored oil reservoirs are mostly heavy and known light and intermediate oil reservoirs are declining. The first consequence is moving from convectional refineries with intermediate crude to heavy crude refineries.

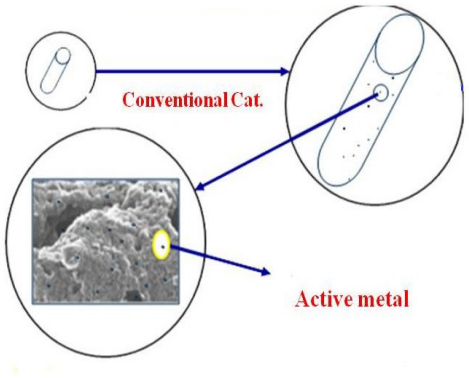
Obviously the main challenge with heavy crude refinery is bottom of the barrel upgrading. There are many upgrading processes but most of them face with problems related to asphaltene, sulfur and heavy metal of the residual oil in the feed stock. In the catalytic processes catalyst life time reduces due to contamination with mentioned materials. The non catalytic processes which are mostly in carbon rejection category , waste 15-25% of carbon atoms as low price coke or burn it in the regeneration chambers.

These traditional problems proof a serious need to new upgrading processes to convert most of the bottom of the barrel to lighter products.

Heavy Residue Hydroconversion (HRH) Process is an innovative approach to fulfill this requirement and convert any kind of heavy hydrocarbons to lighter products. The nature of this process make it a unique alternative to convert even very high sulfur, high asphaltene with high heavy metal content residues to lighter products.

## 2. HRH Technology

HRH is a new nano catalytic technology for upgrading heavy and extra heavy crude oil and residues. Before explaining this technology that is a catalytic hydrocracking we start with fundamental problems connected to conventional hydrocraking processes.



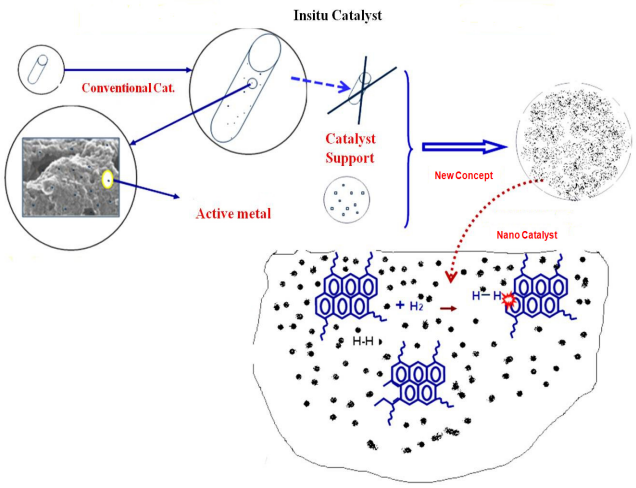




Fig. 1: conventional hydrocraking catalyst particle Fig. 2: Insitu catalyst production concept

As it is indicated in fig. 1, in conventional processes (fixed bed or ebulated bed) the catalyst active metals are located on the surface of catalyst support. The supports fundamentally have micro and macro pores. Heavy hydrocarbon molecules and asphaltene can easily block the pores and reduce the catalyst activity. The other basic problem with mentioned catalysts is heteroatoms like sulfur. These compounds deactivate the active metals and reduce the catalyst life time.

Another basic problem is due to heavy metals. Heavy metals like nickel and vanadium deactivate the catalyst sites. All above mentioned effects reduce the catalyst life time and from process point of view, the incapability of fixed bed processes for severe cracking of high metal high asphaltene heavy residues, and high amount of spend catalyst in ebulated bed processes for such heavy residues are mostly have the same reason.

HRH technology is established based on a new concept. In HRH instead of putting the active metals on the surface of the catalyst support, that is the main root of all mentioned problems, the active metals are distributed in the bulk of the heavy residue. The reactions take place on the surface of the heavy molecules due to nano structure of new catalyst. In conventional processes, reactions occur in the macro pores of the catalyst support. Fig. 2 indicates this new concept

The HRH catalyst precursors are produced in the bulk of the feed, therefore insitu production of catalyst in the bulk of the feed makes it very active and very well dispersed.

## 3. Process description

HRH Process is indicted in fig.3 .Heavy feed introduces to a separator to separate the lighter parts. Heavier portion (API <10) introduces to the reactor. This stream mixes with hydrogen and catalyst precursors. The catalyst precursors reacts insitu with H2S in the reactor and produces the nano catalyst. The reacted feed goes to the distillation unit and un-reacted portion recycles to the beginning of the process. A defined portion of this residue goes to catalyst regeneration unit. The nature of process is such that it can tolerate any amount of heavy metals, asphaltene and sulfur. Therefore there is no limitation for recycle stream and the overall conversion is %95 or more

The main advantages of HRH process are as follow:

- High conversion up to 95% or more
- High product volume yield, up to 110%
-60-80% sulfur removal
- Catalyst regenerates in the HRH unit.
- Heavy metal converts to metal oxides as a by product.

These advantages make HRH and excellent alternative for converting any kind of heavy residue to lighter products.

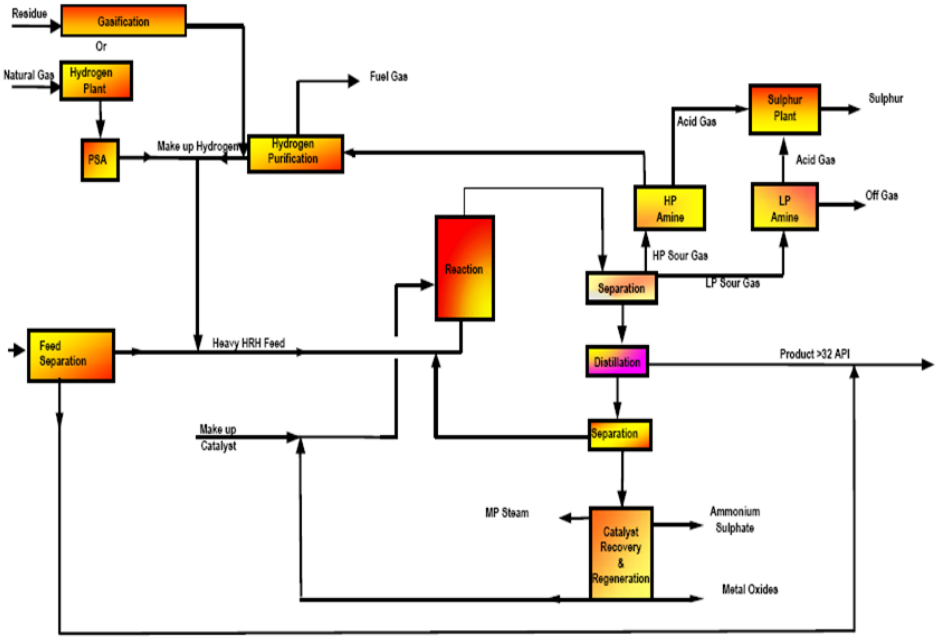



Fig. 3: HRH simplified process flow diagram for heavy crude oil

## 4. HRH Application

HRH process has different applications. It is applicable for converting heavy crude to light crude in the oil field. By utilizing this process heavy crude with l0 API or less is converted to low sulfur and residue free light syrcrude with 30-34 API , with more than 100% (up to 110% )volume yield.

Retrofitting existing refineries is the other application of HRH

The third application that is the subject of this paper is new heavy crude refinery schemes.

## 5. New heavy crude refinery scheme with HRH

In this paper a complete heavy crude refinery based on HRH as upgrading unit is studied. The scheme includes all downstream processes such that the products meet Euro-5 standard. The feed specification is indicated in table -1

This refinery is designed to maximize diesel fuel production .The heavy residue of this refinery goes to the HRH unit and all residue converts to light ends, naphtha, middle distillates and vacuum gas oils up to 520 °C as cut point of heavier product. The overall scheme of this refinery is indicated in fig.-4.

Table 1: Feed specification

| Description | | Analytical Result | Method |
|---|---|---|---|
| | API | 19.82 | |
| Density (20°C) | g/cm$^3$ | 0.9318 | D4052 |
| Sulphur | wt% | 3.85 | D4294 |
| Nitrogen | wt% | 0.21 | D4629/5762 |
| Micro Carbon Residue | wt% | 12.57 | D4530 |
| Total Acid Number | mgKOH/g | 0.72 | D664 |
| Salt | mgNaCl/L | 41.0 | D3230 |
| Ash | wt% | 0.028 | D482 |
| Resins | wt% | 12.5 | |

| | | | |
|---|---|---|---|
| Asphaltene | wt% | 9.9 | IP 143 |
| Wax Content | wt% | 2.9 | UOP 46 |
| Iron, µg/g<br>Nickel, µg/g<br>Vanadium, µg/g<br>Sodium, µg/g | | 1.3<br>33.8<br>111.4<br>13.4 | D5708<br>D5708<br>D5708<br>D5863 |
| K-Factor | | 11.7 | |

Table 2: Refinery product distribution

| | |
|---|---|
| Feed | 180000 BPD |
| Product | |
| LPG | 2255 TPD |
| Gasoline | 62919 BPD |
| Diesel Pool | 104125 BPD |
| Jet Fuel | 8978 BPD |
| Fuel Oil | 8466 BPD |

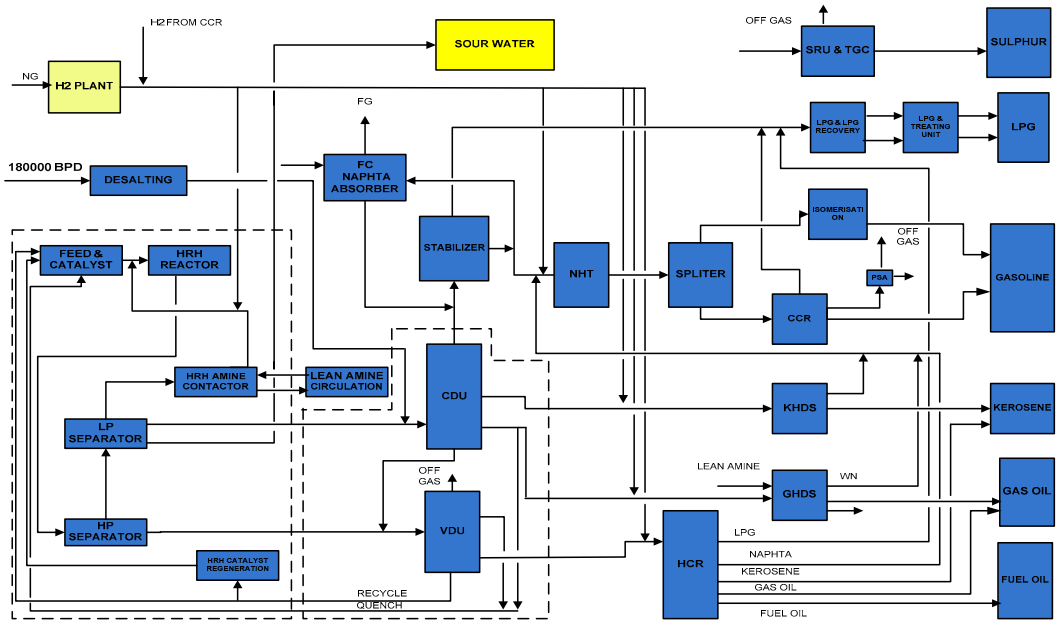



Fig. 4: Overall scheme of the refinery

Due to domestic requirements, few thousand barrels per day fuel oils is produced. If there is no demand to fuel oil, it is possible to eliminate fuel oil and converts all heavy fractions to lighter products. Table 2 indicates the product distribution of the refinery.

## 6. Economy of the refinery

The economy of this refinery and its sensitivity to escalation of different parameters has been studied. The assumptions are as follow:

- Project horizon: 4 years construction and 21 years production
- On stream factor 0.96
- Discount rate 10%

- Crude prediction price: Escalation 3% year
- Repair and maintenance: 0.1% of total fixed capital cost, Escaltion:3% year

## 7. Feasibility study results

COMFAR III software is being used for the feasibility study. The prices of key components are escalated .The results are as follow:

Internal Rate of Return (IRR) : >21%

Net Present Value (NPV) : > 6.5 million Euros

Normal Pay-back Period : 3.5 years

## 8. Conclusion

The feasibility study results are summarized as follow:

- Refinery scheme based on HRH is definitely feasible.
- Increasing crude price improves the economy of the project.
- Project isn't sensitive to natural gas price escalation

This scheme is compared with another optimized Coker based scheme for the same place and same refinery. The economic figures of Coker scheme is far from comparison with HRH and regardless of its environmental problems, the NPV is negative and such scheme is not feasible. Other hydro-upgraders have already studied for this refinery. Due to IP restriction, we do not mention the name and the figures related to those upgrading processes but general wording, it is found that HRH scheme indicates better figure comparing to all of them.

## 9. References

[1] "Process for hydroconverting of a heavy hydrocabonaceous feedstock", United State Patent No. US7585406 B2, Sep.2009