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Application of Evolutionary Multi-objective Optimization in designing Fluidised Catalytic Cracking Unit and Chemical Engineering systems-a scientific perspective and a critical overview

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Abstract:

Petroleum refining industry is moving in the direction of visionary challenges and drastic future. Energy sustainability and depletion of fossil fuel sources has urged human scientific progress to evolve new directions. Sustainability is at a disastrous stake at this crucial juncture of history and time. Evolution of newer scientific techniques in the design of petroleum refining units is the vision for the future. In the present day human civilization, design of petroleum refinery involves optimization and rationalization of chemical processes. Chemical engineering and revolutionary techniques in petroleum engineering today stands in the midst of immense rationalization and deep comprehension. Fluidised catalytic cracking is an important and challenging procedure in the future of petroleum refining. Genetic algorithm and evolutionary multi-objective optimization is the next generation science and technology. Progress of science, the world of challenges and the visionary future will go a long way in evolving new emancipation of science and engineering. Advancement of science and technology, the vision ahead and the domain of scientific cognizance are the torchbearers of new scientific vision and comprehensive scientific understanding. Multi-objective optimization involves optimizing a number of objectives simultaneously. The problem becomes challenging when the objectives are of conflict to each other , that is, the optimal solution of an objective function is different from that of the other. In solving such problems, with or without the presence of constraints, these problems give rise to a set of trade-off optimal solutions , popularly known as Pareto-optimal solutions. In this paper, the author reviews

with cogent insight the world of challenges in the application of Evolutionary Multi-objective optimization in design of Fluidised Catalytic Cracking Unit and other Chemical Engineering systems. Forays into science and technology, innovative vision and the scientific progress ahead are the pall-bearers of a new scientific generation and the wide and vast world of intense scientific understanding in the domain of application of multi-objective optimization.

Keywords: chemical engineering, energy, petroleum refining, optimization, multi-objective.

1. 0 Introduction:

The world of challenges in petroleum refining industry is moving from one paradigm to another. Energy sustainability is at a disastrous stake in our present day human civilization. Advancements in science and technology, human progress and the world of difficulties ahead are the primordial issues of today's achievements of science. Fluidised catalytic cracking unit and its design is moving towards a visionary era. [1] Man's progress and civilisation's prowess is ushering in a new age of energy and environmental self-reliance. Application of non-traditional optimization techniques is the coinword of tomorrow. Advances in science and technology, the road towards progress and the immense world of challenges are the torchbearers of the visionary tomorrow. Optimization techniques is ushering in a new dawn and a new dimension of mathematical science. Applied mathematics, the vision to move forward and technological advancements are all the forerunners to a new generation of optimization techniques. Multi-objective optimization and genetic algorithms are creating one visionary dimension over another. Application of Genetic Algorithm and Evolutionary Multi-objective optimization is surpassing one visionary frontier over another. The vision of science, the scientific rigour of technology and the urge towards scientific sagacity will all go a long way in opening new doors of innovation and deep introspection in years to come. The vision of science and technology is at its highest ebb with the drastic progress of human civilization. Applied mathematics and genetic algorithm are restructuring the vision of evolutionary multiobjective optimization. The pursuit of science and engineering, the scientific rigour and the progress ahead will all lead a long way in the true emancipation of application of genetic algorithm. [1], [3], [4], [5]

2. 0 Purpose and aim of the study:

Petroleum refining units and application of multi-objective optimization in today's scientific generation stands in the midst of immense scientific vision and scientific understanding. The path of challenges and the scientific progress ahead will inevitably open up new doors of innovation. The main purpose and vision of the study is to unravel the intricacies of the hidden world of evolutionary multi-objective optimization(EMO) and its vast and varied future. The path towards progress in science and technology will veritably usher in new future dimensions and future

directions in the application of EMO in designing chemical engineering systems. Vision and utmost mission behind the study is to open a new chapter in the field of scientific instinct and scientific innovation. The author delineates the vast importance of Evolutionary Multiobjective optimization and its immense application in designing petroleum refining units. Fluidised catalytic cracker is a pillar in petroleum refining. Vision of design, the challenge of efficiency of the process and the economics of the process are the forerunners of scientific rigour behind petroleum refining. Petroleum industry and refining technologies are moving fast towards a new scientific generation and scientific truth and vision. [1]

3. 0 The Scope of the study:

Advancement of science, technology and engineering is moving vehemently and drastically towards a new visionary phase. The scope and the vision of the study is immense and versatile. Definition of science, the urge of scientific rigour and the vision to excel are the forerunners towards a new vision. The scope of the study delineates the immense importance of application of genetic algorithm in the vast future of design of Fluidised Catalytic Cracking Unit. [1] FCC unit is a revolutionary area of scientific petroleum engineering vision. Scientific forbearance and immense scientific vision are the visionary vistas of present global scientific pursuit. The immense and different parameters of the design of a FCC unit needs to be re-envisioned and rejustified. Modelling, simulation and optimization of industrial fixed bed catalytic reactors are the forerunners to the greater scientific understanding and scientific vision of the design and simulation of fluidized catalytic crackers. Scope of the study envisions the concept, the application domain and the path towards progress in the future direction of multi-objective optimization. [1], [3], [4], [5]

This study aims at the immense potential and vision of application of genetic algorithm in multi-objective optimization. Petroleum engineering science is moving towards a newer future dimension with the grave concern for depletion of fossil fuel resources. Technological innovations needs to be re-envisioned and revisited at each step of scientific progress in years to come. [1]

4. 0 Future vision of the study:

Increase and augmentation in the demand for gasoline, LPG and diesel over the last several decades led to the improvement of refinery operation and its dynamics. The fluidized bed catalytic cracking (FCC)is an important conversion process in most refineries. The scope of this study involves and delineates modeling as a primary tool towards refinery optimization. The world of challenges needs to be rebuilt and reshaped as there is an ushering in of multi-objective optimization and genetic algorithm in FCC design. The challenging thoughts of tomorrow's petroleum engineering science has garnered in new innovations. [1] Petroleum engineering science is slowly and drastically moving towards a newer scientific era of newer innovations. The futuristic vision of petroleum engineering science is wide and far-reaching. The depletion of fossil fuel resources has urged the scientific community to

gear towards greater and innovative petroleum refining technologies. FCC cracker design is in the midst of immense scientific vision. [1] Future perspectives in the field of petroleum refining are moving towards a new era of scientific vision and scientific cognizance. [1]

5. 0 Fluid Catalytic Cracking Process:

Due to the ever-decreasing supply of crude oil and the exponential increase in the demand for petroleum products , the petroleum refining industry is looking and increasingly searching for possible alternatives. Petroleum refining industry and its paradigm is moving towards one visionary era over another. [1] The vision of science and engineering, the advancements and the path towards future progress are the pallbearers towards a newer future direction. It is a pillar of petroleum refining procedure. The future development of science is in the process of new regeneration. The world of barriers, the difficulties in the road forward and instinctive scientific understanding will go a long way in the future emancipation of mathematical techniques. [1] RFCC is a new visionary domain of science. The paradigmatic changes and drastic challenges are the forerunners and torch bearers to the glorious future. Fluid catalytic cracking process is the heart of petroleum refining procedure. The vision, the world of challenges and the wide road to progress will all lead a long way in the true emancipation of human endeavour and human research pursuit. The difficulties, the unsurpassed barriers and the road towards immense progress are the forerunners of a new scientific generation. Fluid catalytic cracking process today stands in the midst of immense introspection and deep comprehension. The intricacies of design, the efficiency of the process and the future road to excel are the forerunners to a new future direction and the new future dimensions of design of a FCC unit. [1]
Design of a FCC unit is a challenge to scientific endeavour and scientific vision. The road to progress is arduous. [1] Such a critical juncture ushers in a new vision and a new technological boundary of genetic algorithm. Application of EMO (Evolutionary Multi-objective Optimization) is opening up new windows of innovation and new world of technological and mathematical challenges. The success, the challenges and the world of scientific instinct and scientific innovation will surely pave the way of advancement of science and engineering. [1]

6. 0 Problems associated with RFCC(Resid Fluidised Catalytic Cracking) operation:

RFCC is in the process of newer future thought and new future generation. The main problems associated with processing of FCC units are the higher boiling ranges of the resid feed, the thermolysis of the larger molecules leading to the coke formation and the large molecular size of resid components due to which these cannot diffuse into the zeolite cavity. [1] The resid generally has a boiling range of approximately 540 deg Centigrade to 759 deg Centigrade , and in addition to the hydrocarbons , contains undesirable contaminants such as sulphur and nitrogen compounds , as well as metals such as nickel, vanadium and iron. The vision of RFCC operation needs to be

restructured and rebuilt. In order to meet the strict environmental regulations , for processing resid in FCC units , the catalyst design , process parameters and the hardware have to be modified. During FCC operation , the partially vaporized feed comes in contact with the hot regenerated catalyst. At these conditions the feed is not only vaporized but can also undergo thermal cracking (thermolysis). This thermolysis of the liquid components results in increased coke yields and formation of a coke layer on the catalyst surface. This leads to rapid catalyst deactivation, degradation in the product yields , higher reactor outlet temperature as well as higher regenerator temperature. [1], [7]

7. 0 Literature review and catalyst model:

Extensive visionary research pursuit marks the road to success in catalyst model and FCC modeling. The catalyst design plays a very important and pragmatic role in the function of RFCCs. The usual FCC catalyst is a complex composite of zeolite crystallite dispersed on silica-alumina support(matrix), binders and other additives. The activity of the catalyst depends on the pore size and distribution of matrix and zeolite. The pore distribution of such a catalyst pellet is a major factor affecting the relative rates of diffusion in the macro porous and micro porous regions. For passive matrix zeolite catalysts , researchers showed that the rate of reaction is limited by the diffusion of the feed molecules into the zeolite pores. Karger and Ruthven(1992)[1] showed that the most of the active sites are located in the zeolites but the resid molecules cannot easily diffuse into the zeolites. Several studies have been carried out on the diffusion, adsorption and reaction phenomena in FCC catalysts. The diffusion phenomenon and the kinetic effects inside different catalysts have been analyzed to predict the mass transfer effects. The vision of science and engineering is emboldened with every step of scientific rigour and scientific endeavour. Elnashaie and Elshishini(1993)[1] in a lucid treatise elucidated on the modeling, simulation and optimization of industrial fixed bed catalytic reactor. This domain of mathematical modeling stands as a major component in the scientific progress of process design of FCC unit. [1] The ammonia production line consisting of 7 fixed bed gas-solid catalytic reactors is elucidated in details in this treatise. The list of fixed bed catalytic reactors used in these industries is endless, and despite some of their disadvantages and the common and theoretically justified criticisms directed toward these types of contacting equipments in favour of other more sophisticated configurations such as bubbling fluidized beds, circulating fluidized beds etc, they remain by far the most dominant configuration in petrochemical and petroleum refining industries. It will not to be an over-estimation to say that more than 90-95% of gas-solid catalytic reactors operating industrially are of the fixed bed type. Despite the relatively simple and passive external appearance of fixed bed catalytic reactors, the processes taking place within the boundaries of the system and their interactions are quite complex and can give rise to rather complicated problems in design, safe operation and optimization. [1], [7] Science and technology of fluidized bed catalytic cracking is moving towards a visionary horizon. Scientific research pursuit, scientific validation and the barriers of application of multi-objective optimization are transforming the optimization

scenario. Research endeavour in today's world needs to be re-envisioned with the scientific forays into the unknown world of process optimization. The petroleum engineering and the process engineering paradigm are opening up new chapters in the domain of science and vision. Varshney et al(2010)[4] elucidated and devised a multigrain catalyst model for unifunctional multicomponent catalysts. The research pinpoints and develops a multigrain catalyst model to describe and envision the simultaneous diffusion – cum-reaction taking place in a unifunctional multicomponent catalyst. In this, particles of the more active component are randomly dispersed in a less active near-spherical porous matrix. Cracking of a model compound , 1, 3, 5 –triisopropylbenzene (1, 3, 5-TIPB), in this catalyst particle is selected as a simple test problem. Catalyst design and process modeling stands as a major pillar and a primordial issue in this research area. The concentration profiles of the reactant and the products within the catalyst macro-particle are computed and the effect of important parameters are investigated in details. [4] Kasat et al(2002)[6] brought a new dimension to the research area of optimization of industrial FCC units. They propounded a multiobjective optimization model of industrial FCC units using Elitist Nondominated Sorting Genetic Algorithm. A five lump model is used to characterize the feed and the products. The model was tuned using industrial data. The elitist nondominated sorting genetic algorithm (NSGA-II) is used to solve a three-objective function optimization problem. [6] Kasat et al(2003)[5] dealt with deep and cogent insight on multi-objective optimization of an industrial fluidized-bed catalytic cracking unit(FCCU) using genetic algorithm (GA) with jumping genes operator. The multiobjective optimization of industrial operations using genetic algorithm and its variants, often requires inordinately large amount of computational time(CPU). An adaptation is developed in this study that is inspired from natural genetics. [5] Scientific vision and scientific rigour are challenging chemical engineering and petroleum engineering systems. Human vision and scientific progress are in the path of a new era. Multiobjective optimization is surely and veritably ushering in a new visionary frontier. Technological vision and application of process engineering and process modeling is witnessing new changes. Multiobjective optimization and genetic algorithm are ushering a new eon in designing petroleum engineering systems. The world of challenges, the future trends and the definitive futuristic vision are opening up new vistas of science and engineering.

8. 0 Modelling , simulation and optimization of industrial fixed bed reactors:

Mathematical modeling of industrial fixed bed reactors are of utmost importance in petrochemical and petroleum refining reactors. The vision of science and engineering , the world of difficulties and the fetters of scientific challenges are the torchbearers to a new scientific generation, scientific hope and immense scientific fortitude. [1] The list of fixed bed catalytic reactors used in these industries is endless and despite some of their disadvantages and the common and theoretically justified criticisms directed toward these types of contacting equipment in favour of other more sophisticated configurations such as bubbling fluidized beds, circulating fluidized beds , etc, they

remain by far the most dominant configuration in petrochemical and petroleum refining industries. [1]

Modeling of catalytic processes combines knowledge from many disciplines of applied chemistry and chemical engineering. The vision of application of genetic algorithm and other optimization techniques are the key difficulties and utmost visionary areas in the scientific road towards progress and the world of scientific rigour. Modeling involves the following aspects:[1]

a) Surface phenomena responsible for the catalytic activity itself.
b) Modeling of intrinsic catalytic reaction rates, i. e. , reaction rates in the absence of diffusional resistances.
c) Thermodynamic equilibrium of the reaction mixture for reversible reactions.
d) External mass and heat transfer resistances between the bulk gas phase and the surface of the catalyst pellets which are functions of the fluid flow conditions around the pellets.
e) Intraparticle mass diffusion and heat conduction for porous catalyst pellets.
f) Pressure drop associated with the flow of gas mixture through the packed bed. [1], [7]
g) Heat evolution(for exothermic reactions) or heat absorption (for endothermic reactions) associated with the reaction.
h) Integration of the above steps into the formulation of the overall reactor model and the inclusion of heat transfer between the catalyst bed and external cooling or heating media.

Fluid catalytic cracking process is ushering in a new generation of scientific vision and scientific fortitude. The immense scientific understanding , the world of introspection and the futuristic vision will all lead a long way in opening a new world of scientific emancipation and innovation. [3], [4], [5], [7]

9. 0 Non-traditional Optimization Algorithms:

This section describes two non-traditional search and optimization methods which are becoming popular in engineering optimization problems in the recent past. These algorithms are included not because they are new but because they are found to be potential search and optimization algorithms for complex engineering optimization problems. Genetic algorithms(GA's) mimic the principles of natural genetics and natural selection to constitute search and optimization procedures. Simulated annealing mimics the cooling phenomenon of molten metals to constitute a search procedure. [1]

Multiple, often conflicting objectives arise naturally in most real-world optimization scenario. As evolutionary algorithms possess several characteristics that are desirable for this type of problem, this class of search strategies has been used for multiobjective optimization for more than a decade. Meanwhile evolutionary multiobjective optimization has become established as a separate subdiscipline combining the fields of evolutionary computation and classical multiple criteria decision making.

The term evolutionary algorithm (EA) stands for a class of stochastic optimization methods that simulate the process of natural evolution.

10. 0 Genetic algorithms:

Genetic algorithms are computerized search and optimization algorithms based on the mechanics of natural genetics and natural selection. Professor John Holland of the University of Michigan, Ann Arbor, USA envisaged the concept of these algorithms in the mid-sixties and published his seminal work. Thereafter , a number of his students and other researchers have contributed to developing this field. An extensive list of GA-related papers is referenced elsewhere. GA's are revolutionizing the multi-objective optimization scenario. The vision of science, the definitive vision of optimization and the visionary world of challenges are the forerunners towards a deeper scientific understanding and scientific fortitude.

11. 0 Multi-objective optimization and application of genetic algorithm:

The vision of the application of multi-objective optimization to the future of petroleum refining is far-reaching. Vision, purpose and the world of challenges is opening up a new era of intense and immense scientific advancement. Man's vision, scientific cognizance and the immense world of scientific validation is reshaping and redefining the world of petroleum refining. Foray of science to human society, the deep retrospection of technology and the vision ahead will inevitably re-envision the true concept of EMO and genetic algorithm. [1]

Since the pioneering work of Rosenberg in the late 1960s regarding the possibility of using genetic-based search to deal with multiple objectives , this new area of research (now called Evolutionary Multi-Objective Optimization, or EMOO for short) has grown considerably as indicated by the notable increment (mainly in the last 15 years) of technical papers in international conferences and peer-reviewed journals, special sessions in international conferences and interest groups in the Internet. [1]

Multiobjective optimization is with no doubt a very interesting and challenging topic both for scientists and engineers , not only because of the multiobjective nature of most real-world problems , but also because there are wide and vast open questions in this domain. [1] Evolutionary algorithms seem particularly suitable to solve multiobjective optimization problems because they deal simultaneously with a set of possible solutions(the so called population) which allows to find an entire set of Pareto optimal solutions in a single run of the algorithm , instead of having to perform a series of separate runs as in the case of the traditional mathematical programming techniques. In addition to that, evolutionary algorithms are less susceptible to the shape or continuity of the Pareto front , whereas these two issues are a real concern for mathematical programming techniques. [1]

12. 0 Evolutionary multi-objective optimization and its tremendous potential and vision:

In the past 15 years, evolutionary multi-objective optimization(EMO) has become a popular and of utmost importance in the field of research and application. Evolutionary optimization (EO) algorithms use a population based approach in which more than one solution participates in an iteration and evolves a new population of solutions in each iteration. The reasons for their popularity are wide and many: i) EO s do not require any derivative information, ii) EO s are relatively simple to implement , iii) EO s are flexible and have a wide-spread applicability. For solving single-objective optimization problems , particularly in finding a single optimal solution , the use of population of solutions may sound redundant , in solving multi-objective optimization problems an EO procedure is the utmost choice. The multi-objective optimization problems , by nature, give rise to a set of Pareto-optimal solutions which need a further processing to arrive at a single preferred solution. Vision of science and technology, application of optimization techniques and the future vision and road towards progress all will lead a long way in the ultimate culmination and emancipation of applied mathematics. [1], [7]

13. 0 Multi-objective optimization and its scientific doctrine:

As the name suggests , multi-objective optimization involves optimizing a number of objectives simultaneously. The problem becomes challenging when the objectives are of conflict to each other, that is, the optimal solution of an objective function is different to each other. In solving such problems, with or without the presence of constraints , these problems give rise to a set of trade-off optimal solutions , popularly known as Pareto-optimal solutions.

Multiobjective optimization (also called multicriteria optimization , multiperformance or vector optimization) can be defined as the problem of finding : “a vector of decision variables which satisfies constraints and optimizes a vector function whose elements represent the objective functions. These functions form a mathematical description of performance criteria which are usually in conflict with each other. Hence, the term “ optimize” means finding such a solution which would give the values of all the objective functions acceptable to the designer. ”[7]

In the past 15 years, evolutionary multi-objective optimization (EMO) has become a popular and useful field of research, application and vision. Evolutionary optimization(EO) algorithms use a population based approach in which more than one solution participates in an iteration and evolves a new population of solutions in each iteration. The reasons for their popularity are many and varied: (i) EO’s do not require any derivative information, (ii) EO’s are relatively simple to implement, and (iii) EO’s are flexible and have a wide spread applicability. [7]

14. 0 Nontraditional optimization algorithms and its visionary approach:

The non-traditional optimization algorithms are found to be potential search and optimization algorithms for complex engineering optimization problems. Genetic

algorithms(GA s) mimic the principles of natural genetics and natural selection to constitute search and optimization procedures. Simulated annealing mimics the cooling phenomenon of molten metals to constitute a search procedure. Non-traditional optimization is today revolutionizing the entire applied mathematics scenario. Biological adaption of optimization algorithm is surpassing visionary frontiers. The challenges, human scientific endeavour and the human history of scientific rigour will open up new frontiers of science and technology in years to come. Scientific history and immense vision of science are surpassing wide and versatile frontiers. [1], [6], [7], [8]

14. 1 Genetic algorithms:

Genetic algorithms are computerized search and optimization algorithms based on the mechanics of natural genetics and natural selection. Professor John Holland of the University of Michigan, Ann Arbor, USA envisaged the concept of these algorithms in the mid-sixties and published his seminal work(Holland, 1975). The vision of the science of genetic algorithm is expanded and emboldened by his students and colleagues till date. Genetic algorithms is surpassing wide and visionary frontiers. To illustrate the working principles of Gas , we first consider an unconstrained optimization problem. Later we will delve deep into how Genetic Algorithm can be used to solve a constrained optimization problem. Let us consider the following maximization problem:

Maximize f(x), $x_i^{(L)} \leq x_i \leq x_i^{(U)}$, i=1, 2, …, N.

Although a maximization problem is considered here, a minimization problem can also be handled using GA s. The working of GA is accomplished by performing the following tasks:

14. 2 Coding:

In order to use GA s to solve the above problem , variables x_i's are first coded in some string structures. It is important to note and mention here that the coding of the variables is not absolutely necessary. There exist some studies where GA s are directly used on the variables themselves , but here we shall ignore the exceptions and discuss the working principle of a simple genetic algorithm. Coding is the main pillar of the application domain of multi-objective optimization. Design of a FCC Unit involves veritable and drastic challenges. [3], [4], [5]

15. 0 Evolutionary optimization (EO) for Single-Objective Optimization:

Evolutionary optimization principles are different from classical optimization methodologies in the following main ways:

- An EO procedure does not usually use gradient information in its search process. Thus, EO methodologies are direct search procedures , allowing them to be applied to a wide variety of optimization problems.
- An EO procedure uses more than one solution (a population approach) in an iteration, unlike in most classical optimization algorithms which updates one solution in each iteration(a point approach).

- An EO procedure uses stochastic operators, unlike deterministic operators used in most classical optimization methods. The operators tend to achieve a desired effect by using higher probabilities towards desirable outcomes, as opposed to using predetermined and fixed transition rules. This allows an EO algorithm to negotiate multiple optima and other complexities better and provide them with a global perspective in their search.

An EO begins its search with a population of solutions usually created at random within a specified lower and upper bound on each variable. Thereafter, the EO procedure enters into an iterative operation of updating the current population to create a new population by the use of four main operators: selection, crossover, mutation and elite-preservation. The operation stops when one or more pre-specified termination criteria are met.

16. 0 Petroleum refining and the vision for tomorrow:

Petroleum refining needs to be redefined and re-envisioned. The vision for tomorrow is widely inspiring and newer concepts are transforming visionary frontiers. Challenges, difficulties and future vision all are leading a long way in the emancipation of science. The vision for the future and the scientific barriers of tomorrow are opening up a new era of petroleum refining. Depletion of fossil fuel resources are the torchbearers to the visionary future in petroleum refining. Scientific barriers are surpassed and wide scientific frontiers overwhelmed. Man's vision, human civilisation's prowess and the utmost scientific challenges are ushering a new era of intense scientific instinct. The vision for tomorrow is wide, effective and far-reaching. Future path towards progress needs to be re-envisioned and restructured.

17. 0 The scientific doctrine of Fluidised Catalytic Cracking Unit:

Fluidised catalytic cracking unit is moving towards an inspiring and a visionary era. Scientific truth and scientific justification are the order of the day. The scientific doctrine behind the design of Fluidised Catalytic Cracking Unit is veritably posing difficult challenges and immense scientific vision. Scientific cognizance , the greatness of process design and the difficult road ahead is unquestionably re-envisioned. [1]

As a critical process in petroleum refineries, fluid catalytic cracking(FCC) produces liquefied petroleum gas, gasoline, diesel and propylene from heavy distillates such as vacuum gas oils or even residues. One notable researcher [1] reported that about 75% gasoline, 30% diesel and 40% propylene in China were produced by FCC up to 2007. It is of great significance to optimize the design and operation of industrial FCC units for their huge throughputs. Therefore, modeling and simulation of FCC processes have been being an important topic of research since about 1940's. Notably early work on this topic includes the correlations for the feed stock conversion and coke formation as well as a hypothetical mechanism for carbon formation [1] and the catalytic cracking equations . [1], [2], [3], [4], [5].

18. 0 Modeling and simulation of Fluidised Catalytic Cracking Units:

Vision , aim and target of scientific endeavour of fluidized catalytic cracking units should be towards greater efficiency and effectivity of the reaction processes in the riser unit and the overall emancipation of science and engineering in the design of FCC unit. Despite the relatively simple and passive external appearance of fixed bed catalytic reactors, the processes taking place within the boundaries of the system and their interactions are quite complex and can give rise to rather complicated problems in design, safe operation and optimization. Consequently, mathematical models for these fixed bed catalytic reactors can be a very strong tool in their design, optimization and operation. However, to achieve this, the models have to be rigorous and reliable in describing accurately the processes taking place inside the system and their interaction.

Modeling of catalytic processes combines knowledge and visionary areas from many disciplines of chemistry and chemical engineering. It envisions the following aspects:

- Surface phenomena responsible for the catalytic activity itself.
- Modeling of the intrinsic catalytic reaction rates, i. e. : reaction rates in the absence of diffusional resistances.
- Thermodynamic equilibrium of the reaction mixture for reversible reactions.
- External mass and heat transfer resistances between the bulk gas phase and the surface of the catalyst pellets which are functions of the fluid flow conditions around the pellets.
- Intraparticle mass diffusion and heat conduction for porous catalyst pellets.
- Pressure drop associated with the flow of the gas mixture through the packed bed.
- Heat evolution(for exothermic reactions) or heat absorption (for endothermic reactions)associated with the reaction.
- Integration of the above steps into the formulation of the overall reactor model and the inclusion of heat transfer between the catalyst bed and external cooling or heating media. [1], [2], [3], [4], [5]

Mathematical modeling of diffusion and reaction in petrochemical and petroleum refining systems is a very strong tool for design and research endeavour. Emancipation of science, technological advancements and the vision to excel will all lead a long way in the realization of the greatness of process modeling and veritably the mathematical modeling of a petroleum refining system. It leads to a more rational approach for the design of these chemical engineering systems in addition to elucidating many important phenomena associated with the coupling between diffusion and reaction. An important point to be noticed with regard to the state of the art in these fields , is that steady state modeling is more advanced than unsteady state modeling due to the additional complexities associated with unsteady state behavior and the additional physico-chemical information necessary. Evolutionary multi-objective optimization is the next generation technology in the design of petroleum refinery. Vision of Science, the unimaginable scientific challenges ahead and the great vision of technology will all go a long way in the clear and distinct emancipation of petroleum engineering science.

19. 0 Challenging problems in modeling a fluid catalytic cracking unit(FCCU):
One of the visionary and challenging problems in modeling a fluid catalytic cracking unit(FCCU) is to describe the chemical reactions of feed and product oils which are complicated mixtures of numerous hydrocarbons and non-hydrocarbons. Some researchers ([1][3], [4], [5]) proposed a kinetic model of three lumps, stock oil, gasoline(C_5-410 Deg F), and C_3 + C_4+ dry gas + coke, to account for stock oil (gas oil) conversion and gasoline yield in isothermal fixed, moving and fluid bed reactors. This model, for its extreme simplicity and strong capability to correlate production data , are still widely used in advanced models of FCC reactors. With the increasing power of computation and knowledge on the mechanism of the catalytic cracking reactions, more complex reactions have been developed in order to have a more detailed description of the compositional behavior of FCC reactors. A visionary research pursuit [1] presented a kinetic of 10 lumps which are the gasoline(C_5-430 deg F), coke, and other eight light and heavy fractions of paraffins, napthenes, aromatic rings and aromatic substituent groups. With the last eight lumps derived from assay data (narrow cuts of ASTM distillation and their molecular weights , density, molecular composition etc) of stock oils, this scheme was predictive in the sense that the kinetic equation parameters were universal for a wide variety of feedstock oils with respect to a given catalyst. [1], [2]
The challenges, the immense barriers to scientific explanation and scientific truth are far-reaching , wide and visionary. The modeling challenges are surpassing veritable scientific barriers. Process simulation and modeling are opening up new future dimensions and intense future scientific rigour. The world of scientific fortitude and scientific forbearance will surely open up new dimensions of scientific grit and scientific determination.

20. 0 Application of Evolutionary Multi-Objective Optimization in designing chemical engineering systems:
Chemical Engineering and Petroleum Engineering in today's world are moving towards a new dimension of intense rationalization and optimization. Evolutionary Multi-Objective optimization and its immense forays into scientific vision are the torchbearers to a new generation of scientific judgement and deep introspection. Chemical Engineering systems and fluidized catalytic cracking unit in today's world is moving towards re-envisioning and restructuring. Depletion of fossil fuel resources is in the midst of grave crisis. The question of energy sustainability is in a deep catastrophe. In the midst of immense retrospection, new technological developments are the answers and plausible solutions towards the alleviation of the inevitable disaster to energy and environment. History of engineering, the road towards progress and visionary targets are unquestionably the answers towards a new scientific thought and an intense scientific vision. Challenges, barriers and difficulties are the coinwords of a scientific development in today's world. Application of multi-objective optimization in the world of science of petroleum refining is wide, varied and versatile. The challenge lies in the application of genetic algorithm in designing FCC

unit. The author willfully discusses the visionary vistas of the domain of petroleum refining and its far-reaching vision.
Evolutionary multi-objective optimization is ushering in a new era of scientific forbearance. Scientific vision and immense scientific understanding are the goals and mission of tomorrow. Human scientific endeavour, scientific vision are opening up new paths of intense challenges in years to come. Chemical engineering systems are robust and ground-breaking. Vision of technology and engineering and the road towards scientific progress will veritably open up new doors of scientific challenges in years to come.

21. 0 Application and vision of genetic algorithm in designing FCC Unit:
As a critical process in petroleum refineries, fluid catalytic cracking (FCC) produces liquefied petroleum gas, gasoline, diesel and propylene from heavy distillates such as vacuum gas oils or even residues. Some researchers reported that about 75% gasoline, 30% diesel and 40% propylene in China were produced by FCC up to 2007. It is of great significance to optimize the design and operation of industrial FCC units for their huge throughputs. Therefore modeling and simulation of FCC processes have been being an important topic of research since about 1940s. [1], [2], [11], [12], [13], [14]
One of the challenging problems in modeling a fluid catalytic cracking unit(FCCU) is to describe the chemical reactions of feed and product oils which are complicated mixtures of numerous hydrocarbons and non-hydrocarbons.
Application of genetic algorithm is undergoing visionary challenges and drastic motives. Advancements of science and technology, the visionary path towards progress and the wide road ahead are the torchbearers to a new generation of scientific hope and determination. The challenges and difficulties are awesome. Yet technological innovations and scientific instincts are surpassing visionary frontiers. Scientific motivation, scientific truth and scientific cognizance are visibly the torchbearers of a visionary future. [1], [2], [8], [9], [10], [14]

22. 0 Scientific doctrine, scientific cognizance and progress in EMO techniques:
Scientific doctrine , scientific vision and the intense scientific cognizance of the present day human civilization will all lead a long way in greater emancipation in the domain of Evolutionary Multi-Objective Optimization. History of science and technology is ushering in a new beginning with the evolution of newer optimization techniques. The world of challenges, the path towards progress and the advancement of science are the hallmarks of the new generation of scientific realm. EMO techniques are a boon to the advancement of optimization techniques. The doctrine and cognizance of EMO is fundamentally changing the scenario of optimization procedure. Vision of science, the scientific doctrine of genetic algorithm and the immense potential of EMO has revolutionized and ushered in a new age of research and development. [14]

23. 0 Single-objective Genetic Algorithm(SGA) and optimization of Bioreactors:
Optimization of Bioreactors offers a formidable challenge to the future of evolutionary multi-objective optimization. [2]Challenges, difficulties and intense vision will all lead a long way in the true goal of application of EMO. Optimization techniques have long been applied to problems of industrial importance. Several excellent texts([1], [5], [6]) describe the various 'traditional' methods with examples. These usually involve the optimization(maximization or minimization) of a single objective function(or, fitness function), I, and bounds on the decision(design or control) variables. A unique optimal solution is obtained. An example is a problem involving two($n_{parameter}$=2) decision variables:
Opt I(x)
Subject to (s. t.):
Bounds on x: $x_i^L \leq x_i \leq x_i^U$; i=1, 2.

24. 0 Multi-objective Simulated Annealing(MOSA) with the jumping gene adaptations:
Multi-objective simulated annealing has a purposeful and definitive vision. The challenge, the vision and the world of difficulties and barriers will lead a long way in the emancipation of science, engineering and technology of Multi-Objective Simulated Annealing. The target of human scientific endeavour is inspiring and immeasurable. Efficiency of a manufacturing process largely depends on engineering tools of optimization. MOSA with the jumping gene adaptation is a wide vista of science of optimization. Human scientific endeavour is opening up new avenues of mathematical applications and ushering in immense world of challenges in genetic algorithm. History of technology is in its new visionary avenue. MOSA is characterized by its immense efficiency of optimization. Multi-objective simulated annealing is a latent yet a burgeoning area of science. [2], [14]

25. 0 Application of genetic algorithm in polymer science and engineering:
Polymer science is a vast and visionary domain of scientific research pursuit. The application of genetic algorithm in polymer science is not latent yet mature. Vision of science, the scientific urge to excel and the wide pursuit of technology will lead a visionary way in the true emancipation of polymer science and related wide domains. [2], [14]
Polymer science is a burgeoning area of science and technology. In last several years , genetic algorithm has gained wide acceptance as a robust optimization algorithm in almost all areas of science and engineering. Polymer science and engineering is no exception. Researchers in this field have devoted considerable attention to the optimization of polymer production using objective functions and constraints that lead to products having desired material properties. Multiple objective functions have been optimized simultaneously. An example is the minimization of reaction time in a reactor(lower costs) while simultaneously minimizing the concentration of side products (that affect the properties of the product adversely). Vision of science of

polymers, the deep scientific understanding and intense comprehension will go a long way in the true emancipation and understanding of polymer engineering. Several end-point constraints (equality or inequality) may also be present as eg . , obtaining polymer of a desired molecular weight. Again , this requirement stems from producing polymer having desired strength. Solving such problems usually result in Pareto sets. A variety of adaptations of GA have been developed to obtain optimal solutions for such complex problems. These adaptations can be used to advantage in other fields too. The visionary applications of GA in areas of polymer science and engineering other than polymerization systems are few and far between, but this field is now maturing, and it is envisioned that the future will see several newer applications. [2], [3], [4], [5]

26. 0 Vision of science of multi-objective optimization and application of genetic algorithm:

The vision, purpose and aim of the application of genetic algorithm is surpassing visionary frontiers. Advancement of science, thrust areas of research and development and the wide road to progress are all the forerunners to a new future direction of Evolutionary Multiobjective optimization and Genetic Algorithm. Today's thrust areas are targeted towards application of EMO is solving intricate multi-objective optimization problems. Scientific vision is at its peak with human scientific progress. Application of genetic algorithm , the vision behind multi-objective optimization and the progress of science are the important and utmost parameters behind the success of design of a FCC unit.

27. 0 Future recommendations of the study:

The world of challenges , the futuristic vision and the future perspectives of application of multi-objective optimization are wide and visionary. Advancement of science and technology in today's scientific panorama is witnessing visionary and drastic challenges. Depletion of fossil fuel resources is of grave concern and of immediate comprehension. A scientist's intuitive prowess and a man's futuristic vision will go a long way in true emancipation of the application of multi-objective optimization in chemical engineering systems and petroleum engineering paradigm. The challenge, the vision and the future of petroleum refining needs to be revamped and reorganized at every step of human civilization.

Technology is moving at a rapid pace in today's scientific world. Human scientific vision needs to be reshaped with every step of civilisation's progress. Depletion of fossil fuel resources is a burning and primordial issue. Futuristic vision of genetic algorithm and the surge ahead of human mankind are the pallbearers towards a greater emancipation and true realization of holistic petroleum engineering science.

28. 0 Futuristic vision, the future paradigm of genetic algorithm and application scenario of multi-objective optimization:

Petroleum refining and chemical engineering science are ushering in a new era of scientific sagacity and immense scientific cognizance. Vision of science and technology needs to be revamped with each step of human history and time. Depletion of fossil fuel resources has urged and propelled the scientific vision to a newer world of hope and scientific alacrity. Genetic algorithm and application of multi-objective optimization are changing the scientific horizon and the wide scientific scenario. Energy and environmental sustainability are the veritable pillars of the human scientific progress today. Efficiency of a petroleum refining unit, the robustness of operation of fluidized catalytic cracking unit and the wide vision of science and technology will go a long and visionary way in the true realization of application of multi-objective optimization in process design. Future paradigm of genetic algorithm is transforming the process design scenario. Chemical process engineering and its definite vision are ushering in a new ground – breaking scenario.

29. 0 Conclusion:

Vision of science and engineering are surpassing vast frontiers. Scientific challenges, the drastic barriers to application of science and cognizant research pursuit are ushering in a new era of petroleum refining. Depletion of fossil fuel resources is a major impediment of petroleum engineering paradigm. Petroleum refining technology needs to be drastically rejuvenated. The instinct, innovation and future scientific progress will lead a long and visionary way in the true emancipation of non-renewable energy resources. Human scientific research progress and surge of petroleum engineering science are ushering in a new era of non-renewable energy. Vision of science and the eons of progress are the pallbearers of a new era of petroleum refining science and non-renewable energy science. Application of mathematical tools such as genetic algorithm are opening up a new era of petroleum refining technology.

Scientific challenges and scientific fortitude in today's world are in the midst of immense scientific thought process and deep introspection. Man's vision as well as a scientist's prowess are opening up a new visionary tomorrow. The drastic challenges needs to be envisioned at this crucial juxtaposition of human history and time. The futuristic vision needs to be challenged in the field of petroleum engineering science as human mankind transforms itself from one decade to another.

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