REVIEW OF IMPROVEMENT OF ENERGY LOSSES IN METAPHENOXY BENZALDEHYDE PROCESS PLANT

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ABSTRACT : *In today's economy, chemical and process engineering must respond to the changing needs of the chemical processes and related industries in order to satisfy both the increasing market requirements for specific end-use properties of the product required by the customer, and the social, and the raw material and energy savings, and environmental constraints of the industrial-scale process. In such a context of globalization and sustainability and amongst several tracks, it is shown that process intensification is a path for the future of chemical and process engineering demands. Process intensification concerns the design of novel equipment based on scientific principles and new production methods and is obtained in using either multifunctional reactors, or new operating modes, or microengineering and microtechnology for both high throughput and formulation screening, and for chemical production. Thus process intensification leads to more or less complex technologies that replace large, expensive, energy-intensive equipment or processes with ones that are smaller, less costly, more efficient plants, minimizing environmental impact, increasing safety and improving remote control and automation, or that combine multiple operations into a single apparatus or into fewer devices. A successful intensification of a chemical process requires a holistic view of the process and a systematic debottlenecking, which is obtained by identifying and eliminating the main transport resistances that limit the overall process performance and thus can be considered as rate determining steps on the process level.*

KEYWORDS: Process intensification; Energy balances; Material balances; New operating modes of production; Microengineering; Microtechnologies.

1. INTRODUCTION

As with mass, energy can be considered to be separately conserved in all but nuclear processes. The conservation of energy, however, differs from that of mass in that energy can be generated (or consumed) in a chemical process. Material can change form, new molecular species can be formed by chemical reaction, but the total mass flow into a process unit must be equal to the flow out at the steady state. The same is not true of energy. The total enthalpy of the outlet streams will not equal that of the inlet streams if energy is generated or consumed in the processes; such as that due to heat of reaction. Energy can exist in several forms: heat, mechanical energy, electrical energy, and it is the total energy that is conserved. In process design, energy balances are made to determine the energy requirements of the process: the heating, cooling and power required.

Numerous conferences have been held worldwide providing international avenues for closer cooperation among researchers energy and water saving and emissions and waste reductions. The series of conferences "Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction" has been designed to play an increasingly active role in finding answers the energy supply and demand challenges, through fostering cooperation among participants that often result in international projects for

the improvements in energy and materials efficiency in industrial and other economy sectors.

Material quantities, as they pass through processing operations, can be described by material balances. Such balances are statements on the conservation of mass. Similarly, energy quantities can be described by energy balances, which are statements on the conservation of energy. If there is no accumulation, what goes into a process must come out. This is true for batch operation. It is equally true for continuous operation over any chosen time interval.

Material and energy balances are very important in an industry. Material balances are fundamental to the control of processing, particularly in the control of yields of the products. The first material balances are determined in the exploratory stages of a new process, improved during pilot plant experiments when the process is being planned and tested, checked out when the plant is commissioned and then

refined an maintained as a control instrument as production continues.

When any changes occur in the process, the material balances need to be determined again. The increasing cost of energy has caused the industries to examine means of reducing energy consumption in processing. Energy balances are used in the examination of the various stages of a process, over the whole process and even extending over the total production system from the raw material to the finished product.

Material and energy balances can be simple, at times they can be very complicated, but the basic approach is general. Experience in working with the simpler systems such as individual unit operations will develop the facility to extend the methods to the more complicated situations, which do arise. The increasing availability of computers has meant that very complex mass and energy balances can be set up and manipulated quite readily and therefore used in everyday process management to maximise product yields and minimise costs.

Basic Principles

If the unit operation, whatever its nature is seen as a whole it may be represented diagrammatically as a box, as shown in Figure. 1. The mass and energy going into the box must balance with the mass and energy coming out.
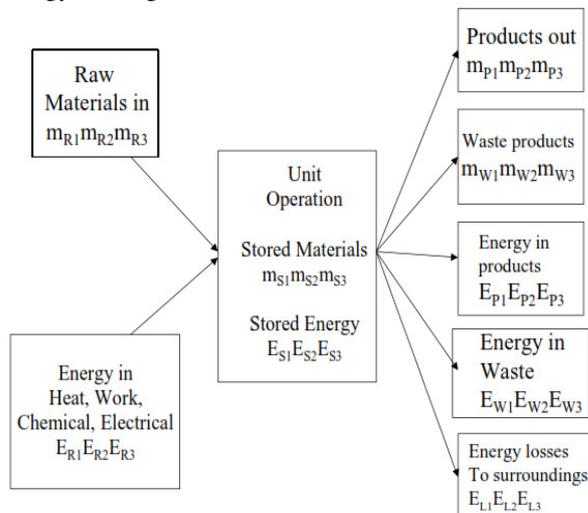

Figure 1: Mass and Energy Balance

The law of conservation of mass leads to what is called a mass or a material balance.

Mass In = Mass Out + Mass Stored

Raw Materials = Products + Wastes + Stored Materials.

$\Sigma m_R = \Sigma m_P + \Sigma m_W + \Sigma m_S$

{where Σ (sigma) denotes sum of all terms}.

$\Sigma m_R = \Sigma m_{R1} + \Sigma m_{R2} + \Sigma m_{R3}$ = Total raw materials

$\Sigma m_P = \Sigma m_{P1} + \Sigma m_{P2} + \Sigma m_{P3}$ = Total products

$\Sigma m_W = \Sigma m_{W1} + \Sigma m_{W2} + \Sigma m_{W3}$ = Total waste products

If there are no chemical changes occurring in the plant, the law of conservation of mass will apply also to each component, so that for component A:

m_A in entering materials = m_A in the exit materials + m_A stored in plant.

For example, in a plant that is producing sugar, if the total quantity of sugar going into the plant is not equaled by the total of the purified sugar and the sugar in the waste liquors, then there is something wrong. Sugar is either being burned (chemically changed) or accumulating in the plant or else it is going unnoticed down the drain somewhere. In this case:

$M_A = (m_{AP} + m_{AW} + m_{AU})$

Where m_{AU} is the unknown loss and needs to be identified. So the material balance is now :

Raw Materials = Products + Waste Products + Stored Products + Losses

where losses are the unidentified materials.

Just as mass is conserved, so is energy conserved in food-processing operations. The energy coming into a unit operation can be balanced with the energy coming out and the energy stored.

Energy In = Energy Out + Energy Stored

$\Sigma E_R = \Sigma E_P + \Sigma E_W + \Sigma E_L + \Sigma E_S$

Where,

$\Sigma E_R = \Sigma E_{R1} + \Sigma E_{R2} + \Sigma E_{R3} + ... =$ Total energy entering

$\Sigma E_P = \Sigma E_{P1} + \Sigma E_{P2} + \Sigma E_{P3} + ... =$ Total energy leaving with product

$\Sigma E_W = \Sigma E_{W1} + \Sigma E_{W2} + \Sigma E_{W3} + ... =$ Total energy leaving with waste materials

$\Sigma E_L = \Sigma E_{L1} + \Sigma E_{L2} + \Sigma E_{L3} + ... =$ Total energy lost to surroudings

$\Sigma E_S = \Sigma E_{S1} + \Sigma E_{S2} + \Sigma E_{S3} + ... =$ Total energy stored

Energy balances are often complicated because forms of energy can be interconverted, for example mechanical energy to heat energy, but overall the quantities must balance.

2. LITERATURE REVIEW

Linda D. Tuma in 2002 has successfully utilized this three-tier program to identify intrinsically safe processes for over 10 years. The testing scenarios presented by him used guidelines and all processes should be evaluated on a case by case basis. A ''safe operating envelope''has been individually determined for each process and not simply assigned to a specific example category as presented in this paper [1].

A critical aspect in the development of a chemical process is the identification of energetic materials and the evaluation of the resulting potential risk of a thermal runaway. A three-tier assessment program used in Merck Research Laboratories identifies both thermal and chemical hazards and evaluates the potential risk of thermal.

Tier I testing identifies potential chemical and thermal hazards which could lead to thermal runaway [2]. The valuation begins with a specially designed operational hazards safety data sheet, filled out jointly by the chemist and chemical engineer, which is used to idenfy chemical and potential processing hazards. This data sheet provides information on the known cemetery, potential toxicity, heats of reactions, balanced equations, identification of reaction by-products, intertions with service fluids and

interactions between chemicals in the process as shown in Table 1. Once this data sheet is evaluated the second part of the tier I evaluation, the identification and quantification of exothermic activity for both process samples and heats of reaction, is started.

Table 1
Potentially hazardous structures
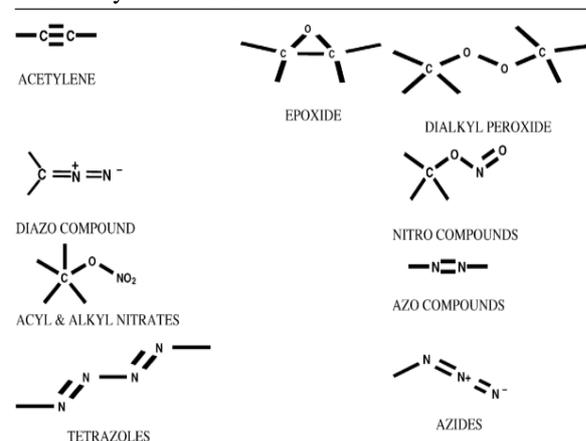
Tier II evaluates the risk of potential thermal runaway which could arise from the exothermic decompositions, heats of reactions and the heat releases associated with water/jacket service intrusions which were identified in tier I testing. Various test methods are used to identify exothermic onset temperatures, determine rates of temperature and pressure releases associated with the decomposition and identify potential shock sensitivity. Initiation temperatures are determined using isothermal age techniques.

Tier III identifies an intrinsically safe process through several steps. In the first step, potential chemical and thermal hazards are identified and reviewed in conjunction with the factors involved in thermal runaways and the causes of thermal runaways. Hence they has determined if operating restrictions can provide for a safe operating envelope or if alternate chemistry must be developed to provide for an intrinsically safe process.
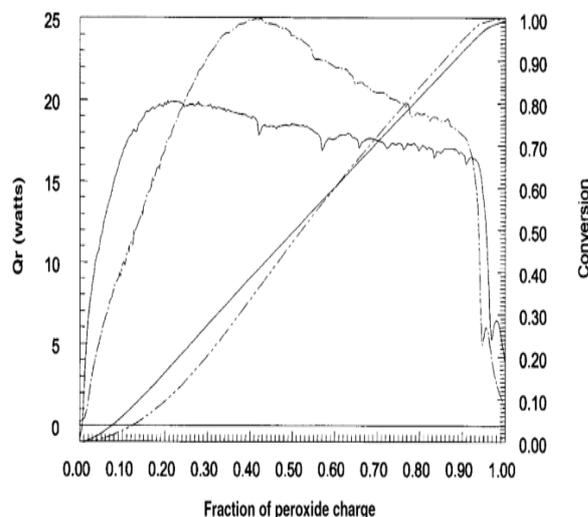

Fig. 2 Hydrogen peroxide addition.

This presented the possibilities of a sudden release of excess energy and/or a rapid release of oxygen from the decomposition of peroxide which could result in a flammable vapour phase. The revised procedure called for an increase in the reaction temperature to 40 ºC, which resulted in a reduction in the maximum heat flow and results in a more uniform heat flow as shown in Fig. 2

Jean-Claude Charpentier in 2007 shows that process intensification involving both microtechnology and unit operation hybridization is proposed and compared to a conventional plant in his paper [3]. These improvements in the design of modern petrochemical plants are actually already obtained to day in certain cases. Hence today's microreaction technology contributes substantially to the fields of chemistry, chemical engineering and energy generation. This technology him developed by him, the reaction level shows a broad variety of facets concerning different applications, has now reached the field of downstream processing to influence industrial pilot and also production processing.

Process intensification concerns the design of novel equipment based on scientific principles and new production methods and is obtained in using either multifunctional reactors, or new operating modes, or microengineering and microtechnology for both high throughput and formulation screening, and for chemical production. Thus process intensification leads to more or less complex technologies that replace large, expensive, energy-intensive equipment or processes with ones that are smaller, less costly, more efficient plants, minimizing environmental impact, increasing safety and improving remote control and automation, or that combine multiple operations into a single apparatus or into fewer devices. With the help of the multidisciplinary and multiscale approach of the chemical engineering applied from the scale of the microreaction technology up to the scale of multifunctional macroreactors or equipment, process intensification offers new opportunities for chemical engineering, e.g., in concurrent product/process or microprocess engineering which can offer strategic competitive advantage in speed to market, cost, and also production innovation. It is thus involved in the trend "molecules into money" which is based on the premise that chemical engineering drives today economy development and is fundamental to wealth creation.

Process intensification using unit operation Hybridisation

The "multifunctional" equipment that couples or uncouples elementary processes (transfer reaction–separation) to increase productivity and/or selectivity with respect to the desired product and to facilitate the separation of undesired by-products. The concept of reactive or catalytic distillation has been

successfully commercialized, both in petroleum processing, where packed bed catalytic distillation columns are used, and in the manufacture of chemicals where reactive distillation is often employed [4-6].

Process intensification using microengineering and Microtechnology

Current production modes facing the challenged by decentralization, modularization and miniaturization. Miniaturization of chemical analytic devices in micrototal-analysis-system (µTAS) represents a natural extension of microfabrication technology to biology and chemistry, with clear applications in combinatorial chemistry, high throughput screening, and portable analytical measurement devices. Also, the merging of µTAS techniques with microreaction technology promises to yield a wide range of novel devices for reaction kinetic and micromechanism studies, as well as on-line monitoring of production systems [9].

Small reactors are already used for testing process chemistries, like catalyst testing. Chemical detection is the rate-limiting step in most techniques since detailed product information must be obtained using sequential screening. However, with the continual advances in µTAS and microfabrication techniques, these macroscopic test systems could be replaced by PC-card-sized microchemical systems consisting of integrated microfluidic, sensor, control, and reaction components requiring less space and utilities, and producing less waste. Moreover, the small dimensions imply laminar flow, making it feasible to fully characterize heat and mass transfer and extract chemical kinetic parameters from sensor data. Fig. 3 indicates process intensification.

Fig. 3 process intensification may look

It was proposed a new concept for high throughput screening (HTS) experiments for rapid catalyst screening based on dynamic sequential operations with a combination of pulse injections and micromachined elements Several important barriers must be overcome before going for the process intensification is widely adapted, such as the maturity and economic competitiveness of the new technologies compared to the conventional technologies. The conservatism of plant owners using batch processes means will not easily accept continuous processing solutions.

It is seen that this technology, which on the reaction level already shows a broad variety of facets concerning different applications, has now reached the field of downstream processing to influence industrial pilot and also production processing. Indeed one of the main advantages of microstructured reactor technology is that a lot of industrial batch processes can be run continuously by using this new technology which provides more flexibility compared to traditional plants. The integration of microstructures reactors within existing plants is thus facilitated by him.

Hannsjörg Freund and Kai Sundmacher [9] in 2008 he break the tradition of thinking in terms of "unit apparatuses" and suggest a new, more rigorous function-based approach that focuses on the underlying fundamental physical and chemical processes and fluxes. For this purpose, he decomposes the chemical process into so-called functional modules that fulfill specific tasks in the course of the process. The functional modules itself can be further decomposed and represented by a linear combination of elementary process functions. These are basis vectors in thermodynamic state space. Within this theoretical framework we can individually examine possible process routes and identify resistances in individual process steps. This allows us to analyze and propose. possible options for the intensification of the considered chemical process.
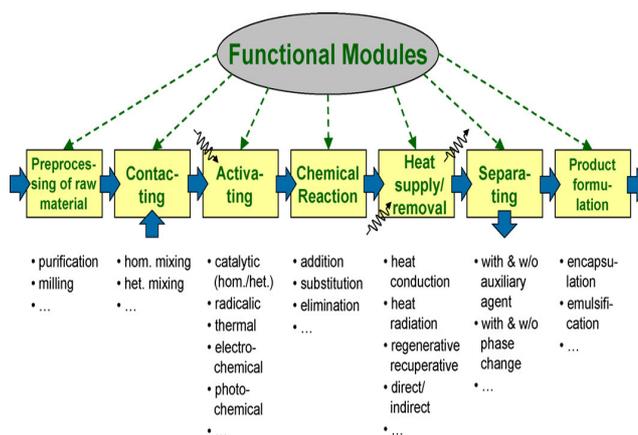

Fig. 4 Representation of a chemical process in term of a potential sequence of functional modules.

Process intensification at the plant level

He examine the interconnection between individual apparatuses (process units) and thus analyze the overall process flow sheet at the superordinated plant level. A great deal of process intensification possibilities at the plant level is linked with the

sequence of the process operations and the potential integration of unit operations into multifunctional process units, respectively. In this regard integrate reaction and separation into a single apparatus (reactive separation processes) as in the case of reactive distillation, reactive pervaporation, reactive Extraction, reactive chromatography, reactive crystallization, adsorptive reactors and membrane reactors has been established sequence of the process operations and the potential integration of unit operations into multifunctional process units, respectively [10-13].

Hence he contributed important aspects of the history of chemical engineering as given in Section 1 clearly illustrates that the concept of unit operations can be regarded as a key paradigm in the development of chemical engineering as an independent discipline. Nearly 100 years after its introduction, the unit operation concept is still the dominant approach in the chemical and process engineering community. It provides the problem with the unit operation concept is that it is strongly linked with the idea of thinking in terms of apparatuses. It provides us with "ready solutions" (e.g. mixers, reactors, distillation columns, etc.) using technology off the shelf. However, this is often a severe constraint for breakthroughs in productivity and/or selectivity since it inherently narrows the solution space for process design and optimization. Here The elementary process function concept proposed here, in contrast, allows for thinking in terms of functions that have to be fulfilled in the course of a chemical process. The functions are represented by functional modules, which in turn are characterized by specific generalized flux vectors and elementary process functions (basis vectors in thermodynamic state space). This new approach presented allows for a detailed analysis and design of chemical processes, which helps to systematically identify and investigate suitable measures for process intensification.

Kazuo Matsuda, Kenichi Kawazuishi, Yoshiichi Hirochi, Rei Sato, Yasuki Kansha, Chihiro Fushimi, Yutaka Shikatani, Hiroshi Kunikiyo and Atsushi Tsutsumi in 2010 [14]. They studied the reaction section of the naphtha hydrodesulphurization (HDS) process where the heating and cooling thermal process consisted of a feed/effluent heat exchanger and a fired heater. Energy savings in this industrial implementation are fundamentally made as a result of the maximized heat recovery in the heat exchanger and the reduced heat duty of the fired heater. For further energy saving in the process they adopted "self-heat recuperation technology" (SHRT) where they introduced compressor. The suction side of the compressor needed a lower pressure and the feed stream evaporated much easily. The discharged side of the compressor satisfied the operating conditions of both pressure and temperature at the inlet of the

reactor. And the reactor effluent stream was possible to be used completely to preheat and vaporize the feed stream. All the heat in the process stream was re-circulated without using a fired heater. They applied SHRT to the naphtha HDS process of 18,000 barrel per stream day (BPSD) in the refinery and the mass and energy balance of the process was calculated using commercially available simulation software, Invensys PROII Version 8.1. Their case study confirmed that despite there being no more energy saving potential in the conventional process that makes use of a fired heater, the advanced process with SHRT can reduce the energy consumption significantly by using the recuperated heat of the feed stream.

Graham Thomas Polley, Martin Picón-Núñez and José de Jesús López-Maciel in 2010 [15]. They describe procedures for the design of processes in which water and energy consumption form a large part of the operating cost. They stated that good process design can be characterised by a number of properties, amongst the most important are: efficient use of raw materials, low capital cost and good operability. In terms of thermodynamic analysis these processes have been characterised by the authors as being either a "pinch" problem or a "threshold" problem. They have shown that the water conservation problem and the heat recovery problems can be de-coupled and the water conservation options should be established first. The number of heaters and heat recovery units required for the system, the quantity and type of hot utility needed for the plant and the complexity of the heat recovery network can all be determined without having to design any HEN. This allowed selecting the better water conservation option before embarking on the design of the heat recovery network. For this type of problem the design of the heat recovery network itself is usually simple and straight forward.

Johanna Jönsson and Jessica Algehed in 2010 [20] they have studied the trade-off between different technology pathways for utilization of excess steam and heat at kraft pulp mills is investigated for a case depicting a typical Scandinavian mill of today. The base was annual net profit for the mill and global emissions of CO_2. A valuable point was that the trade-off was analysed for four future energy market scenarios having different levels of CO_2 charge. The target of this study was increasing electricity production in new turbines, production of district heating, increased sales of biomass in the form of bark and/or lignin, and carbon capture and storage (CCS). Their results show that the proven pathways, increased electricity production, bark export and district heating production, are economically robust, and that they are profitable for all of the studied energy market scenarios.

Martin Pavlas, Michal Tous, Ladislav Bébar and Petr Stehlík in 2010 [16]. They carried out their work based on the thermal treatment of waste with the heat recovery (Waste to Energy - WTE), which can provide us relatively clean and reliable energy in the form of heat and power. Their work contributed to primary energy saving in conventional utility systems. Impact of WTE regarding the environmental issue was quantified by authors. A novel methodology was proposed by him and an assessment of the emission rate was fully discussed. An existing modern municipal solid waste incinerator with nominal capacity 100 kt/y was studied. The benefit of its operation had been compared with some other up-to-date utility concepts. With respect to some negative attitudes to constructions of new WTE facilities, alternative plans for waste management can be developed. Hence result presented described positive evaluation important for WTE plants.

3. CONCLUSION

In this paper "Process Integration for Energy Saving and Pollution Reduction", evolved the development of priorities in the industrial production and related research commitments on environmental, social and economic challenges. The review on important aspects of the history of chemical engineering illustrates that the concept of unit operations can be regarded as a key paradigm in the development of chemical engineering as an independent discipline. We feel that the problem of the unit operation concept is that it is strongly linked with the idea of thinking in terms of apparatuses. It provides us with "ready solutions" (e.g. mixers, reactors, distillation columns, etc.). The new approach presented allows for a detailed analysis and design of chemical processes, which helps to systematically identify and investigate suitable measures for process intensification.

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