Energy Based Efficient Resources for Real Time Manufacturing Systems

Usman Ghani, Radmehr Monfared, Robert Harrison

***Abstract*— Manufacturing companies need greater capabilities to respond quicker to market dynamics and varying demands. New paradigms such as mass customization, global manufacturing operations and competition provide this platform to meet these needs. Therefore manufacturing enterprises have a continuous effort to restructure and re-engineer their business in a response to meet the 21st century challenges. To face these challenges management decisions about the production operations need to facilitate the products life cycle dynamics and variances, including the product cycle times, resource allocation, supply pace and production cost in term of resources and energy utilization. Every related aspect of the production operations needs a careful concentration. However one of the important focused areas for almost all of the industries is the energy usage and its control. Therefore this paper proposes a conceptual approach to minimize the energy consumption during production with an integrated monitoring system. The paper also supports the strategy in the early validation of the processes for the flexible, reconfigurable production environment, which is necessary to analyze energy consumption. Utilizing less energy in production helps society to have low cost products as well as to maintain the sustainable resources over a long period of time.**

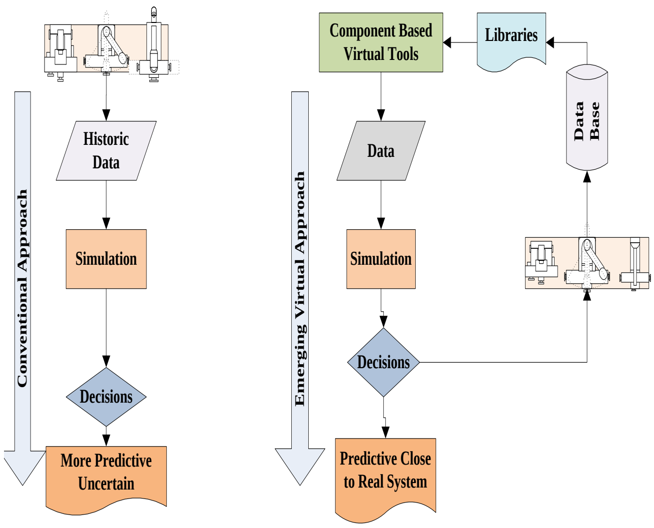
***Index Terms*— Virtual, Energy Efficient, Reconfiguration, Agile Manufacturing, Simulation**

I. Introduction

Manufacturing business success lies in better faster and cheaper product introduction in market to fulfill the customer demands. To achieve this continuous analysis of production system is required to control the non value adding factors such as resource energy consumptions when they are idle and reworks these are the additions to increase the product price. This will make an enterprise to be competitive in its perspective market. The other main competition is to shrink the time from conception to reality for launching the new product in the market. For a successful business market potential, proper enterprise models, resource allocations (Techno-Ware and Human-Ware) and the control over cycle times should be clearly addressed [1] . But one of the main issues is to validate the operational setups and resources utilization well before its installation in an environment as like as in actual conditions. This could benefit the future vision of production line having the approach of real time optimum production operations in term of resources, throughputs and energy consumptions.

This paper proposes an approach as a concept that how at the design stage prior to machine build its mechanisms could be controlled for the energy usage. This paper aims to focus the approach for an automotive industry but in a generic form it is also valid for many of the manufacturing machining and assembly operations. The concept is a guiding track to be followed for the early validation of the processes using real time data captured with the help of virtual engineering technology. Figure1 represent the utilization of this emerging technology. The virtual analysis driven simulation helps production planners in the very early stage of the business start.

Also virtual environment facilitates the real time validation of the processes and machines well before its actual installation. It is possible to drive the analysis and system design from the conventional side, for example from the machine/assembly line and then use this historic data and design for the future system as shown in figure1(a). While using the virtual engineering concept for the system design there should be a set of libraries devised on the based of machine modules, which represent the individual process in the assembly line. In this way the new setups and reconfiguration of modules combines to build the whole manufacturing/assembly line.



(a) (b)

Figure 1 Conventional vs. Emerging Approach for Manufacturing System Design

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This not only helps to analyse the cost associated with each modules, but also provides an opportunity to monitor and analyse the energy consumption associated with each module. Typically it is the facilitation to check the energy consumptions at very early stage during the machine build while using different simulation scenarios. This early validation and analysis approach not only benefit in terms of energy analysis but also in the analysis of line setups and throughputs.

II. STATE OF THE ART RESEARCH

It is understood that energy is a cost adding factor and has great impact on the productivity. The impact of energy cost over total production may vary from one industry to another. For instance it may have more significance impact on welding and forging in companies with metal cutting or assembly. An effective controlling mechanism for the energy usage could cause a business to be competitive in the market. This energy control is not only beneficial for the producer but also equally beneficial for the customers to enjoy the cheap products while not compromising on the quality and reliability of the product. New lines working procedure in production industry now a day’s focused on the knowledge intensiveness. This caused to change the whole pace of validation and planning. Looking in the history of manufacturing and production concepts it becomes clear that how the technology got drive to the emerging approaches for the analysis of various parameters of the production facilities. The traditional manufacturing methods were developed during the age of mass production, which focused on economy of scale and machine utilization. It created the idea that if the machine was idle, it was losing money, so it was kept running at all costs. Traditional companies achieve customer satisfaction by maintaining large inventories in anticipation of customer orders. They did this by keeping a machine running with a specific setup for as long as possible to reduce the unit cost [2]. Over the period it emerged to control these waste and increase productivity leads research and thinking. Therefore today’s modern manufacturing includes all intermediate processes required for the production and integration of a product's components. The manufacturing sector is closely connected with engineering and industrial design. So today’s state of the art production and manufacturing is basically has been passed from many evaluations, starting from the handicraft to the machine and then from the machine to the automation and robots not only in the actual production but also in the early validation and planning levels.

One of the first approach which has been developed was Lean manufacturing [3] which is an attractive concept of bringing efficiency and minimizing the process cost for many manufacturing enterprises because it provides remarkable results without needing complex additional system and equipments [3]. This is basically a management philosophy which is leading to have certain rules and then provides a base for its implementation.

Lean system concentrates on keeping the producer competitive in the market. While the customer side still needs more attentions for coping their demands and thinking in the production. No doubt that the customer is the sole driver of the whole business activity and if the customer satisfaction is not included in the product then it is pointless to produce anything. Therefore the concept of the Agile system has been developed which provides integration between all of the stack holders having involvement in the production. Basically “*Agile manufacturing can be defined as the capability to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-designed products and services”*[4]. The integration of all factors are shown in figure 2, which shows that if system is closely driven according to the market trends then it will respond according to the customer wishes. Having such type of system in the production then it is continuously required to have the flexibility for the technology, resources (human and technical) and management decisions to accommodate the responsiveness according to the market trends.

As the industry expands the requirements of the customers also increased and their demands started in the form of diversity in functionalities of products as well as in the product cost. They also start demanding to have more quickly their products in hand, and thus the concept of better, faster and cheaper emerged. This concept then drives the technology towards the reconfigurable systems. This reconfigurable approach facilitates the agile concept to provide a base for the cheaper options in term of the working procedures and resources selection. The reconfigurable systems can be defined as the “manufacturing system/assembly line having the ability to achieve the cost effectiveness while incorporating the ability to use manufacturing production combinations for the different types of the products via adopting modularity, integrability, flexibility, scalability and convertibility”[5].

The reconfiguration required at both levels as shown in figure3. The physical reconfiguration is basically the machine oriented dimensional setups while the logical reconfiguration is the devised rules designed for the people and software used while executing the validation and planning and running the machines according to the new setups.

As this paper proposes the concept of energy consumption analysis and control method therefore it is recommended to be focused on the machine stations. A “station” is referring to a combination of machine and facilities within a line that fulfill one complete set of operations on a part. These

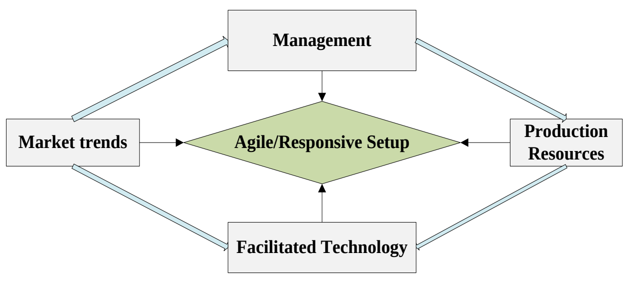

Figure 2 Responsive Agile System [5]

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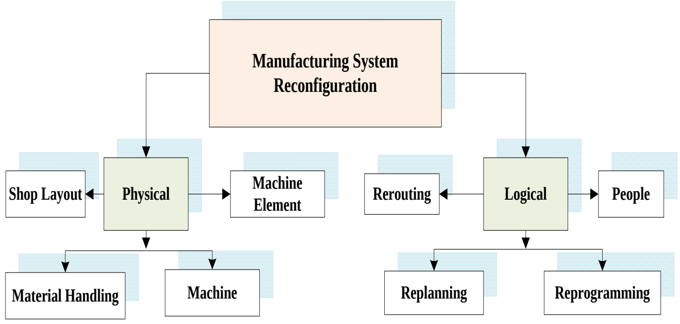

Figure 3 Reconfiguration of Manufacturing System

machine stations need to be worked in the reconfigurable environment. Virtual system analysis approaches provides a solid base to validate this reconfigurabity. In this way it can be very easily analyzed for the different machine elements, build setups in the reconfigurable scenario.

A. *Virtual environment and Production Analysis*

Focusing the emerging technology this paper provides a platform to minimise the production cost and also to minimise the time to market. This is possible only to have the arrangement of validating and analysing the aspects need at the system design stage. This setup could also be used to control the energy usage in the production line. Therefore the best suitable way is to have the virtual setups for the machine prior to build it. This could help in two ways before production it could produce the most accurate analysis and can reduce the time to market for the products and after starting production in case of the existing system analysis could help to reduce production energy cost. All this analysis could be done through the simulation modelling. The advantage of virtual analysis before the production and after the production is elaborated in figure 4. If all the associated data for machine build stored with each module (sub division of machine components) in the

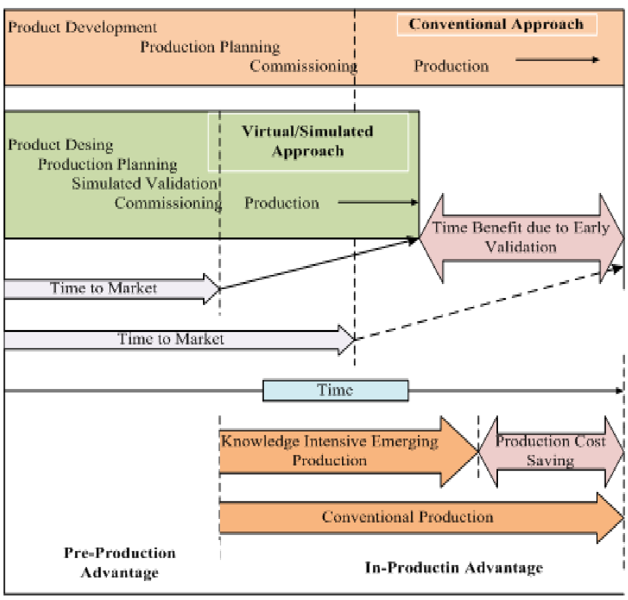

Figure 4 Virtual Driven Manufacturing System Advantage

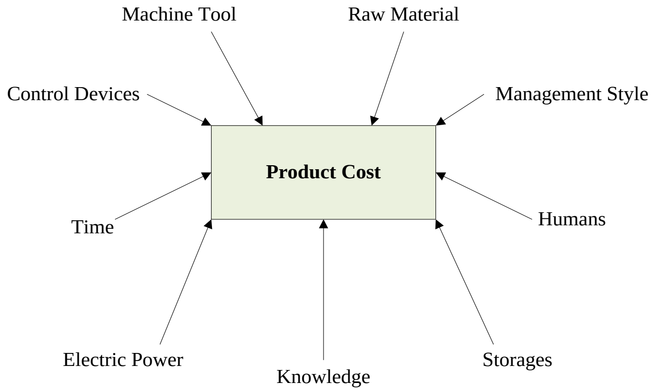

Figure 5 Product Cost Adding Factors

libraries, then it could be used in the development stage. So in this way it is easier to analyze the system at early design stage and gets the advantage of early production over the conventional approaches. This technology also facilitates to analyse the various cost adding factors which are going to add price to the product. The various cost adding factors are in figure 5. These can be controlled at both stages once during the system analysis at the early validation and design phase, and second during the production.

A number of cost adding factors have been identified in figure 5, but the one which is the main contributor in this research is the electrical energy consumed in the production. It is clear that the energy is in shortage over the globe and also it is an expensive resource therefore this study will help to concentrate on a concept to control the energy consumption in production system.

III. Importance of Energy Analysis

Productivity is an important indicator to measure the performance of businesses. Productivity has been defined as the number of produced products per resources used per year [6]. In today's competitive marketplace, energy efficiency can provide means to improve productivity through reducing the manufacturing energy cost. To study the opportunities for energy systems improvement, it is important to understand how energy is used in the production[6]. Especially in automotive assembly shops the electricity is used throughout the production for many different purposes, e.g. compressed air, lighting, ventilation, air conditioning, motors for the machines running, materials handling and welding. Estimates of the energy usage in vehicle assembly plants may vary among the processes used[7].

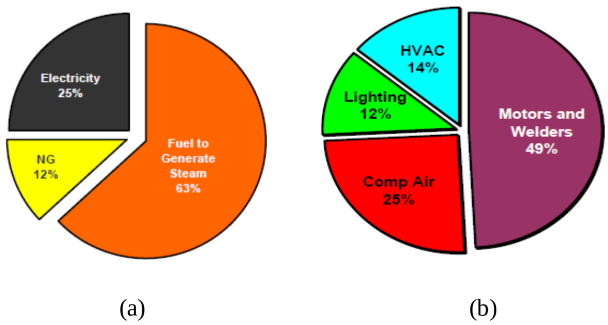

Figure 6 Energy Consumption in Automotive Industry

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Figure6 (a) shows the energy distribution in the automobile assembly plant. This is not a calculated figure for this research but has been taken as a reference to show the importance for the energy controls.

As shown in figure 6, fuels represent 75% of the energy use, while the electricity represents the remaining 25% of the total energy use in a typical auto assembly plant. About two-thirds of the energy budget in assembly plants is spent on electricity due to the difference in prices between fossil fuels and electricity. This demonstrates the importance of the electricity in the fuel mix[7]. Figure 6(b) shows that the electric motors and welding machines account for nearly 50% of all electricity used to drive the different pieces of equipment in the plant and metal welding operations. This emphasizes the importance of motor system optimization installed at the machine module levels and adopting technologies such as high efficiency operational systems including power factor improvement techniques in the energy efficiency improvement strategies. One of the possible approaches is machines mechanism control during the production processes in real times.

A. Current Approaches for the Energy Analysis

Until now the research and the devised approaches have been adopted for the energy analyses are focused on the utilities control. As one of the leading group working in the area of energy controls at the utilities level is the Energy Star [8]. This group basically helped out the rules and control techniques on the basis of some principles to reduce the utilities costs.

These are based on the approaches devised so for like one is the INSIDE-OUT approach, which emphasis on the identification of energy savings opportunities that begins at the heart of the production plant, with the equipment that actually manufactures the product, and works outward[9]. According to this approach to reduce energy costs sequentially analyze the manufacturing equipment and processes, energy distribution systems, primary energy conversion equipment, and finally the utility services. During the protocol of "the INSIDE-OUT approach", process flow diagrams are used to indicate the magnitude and location of energy-use, waste generation, and production costs of the manufacturing processes. Using these diagrams, specific systems, equipment, and processes are to be targeted for detailed analysis to identify, analyze and prioritize the most attractive energy savings opportunities.

Second approach is the KAIZEN TEIAN approach, based on the continuous improvement to aware the employees about energy importance in production processes. In few words this approach focuses workers participation for the effective utilization of machines while bearing in mind about the energy importance [10].

It is clear from the existing approaches that they have the capacity of analysis only when the system is installed and take the measures to decrease the energy consumptions. While the proposed concept is different from existing approaches to have the following

1. The analysis is going to drive from the virtual environment
2. Existence of physical system in analysis is optional
3. Help in early validation for the energy optimised setups and machines
4. Use the module libraries of machines components which support the reconfigurability in case of the manufacturing line setups and business extensions.
5. Also provide the opportunity to choose the best possible module combination for the machine build in term of the energy consumptions.

IV. DEVISED APPROACH

This study proposes an approach initiating from the virtual environment in the interaction with the actual shop floor process real data.

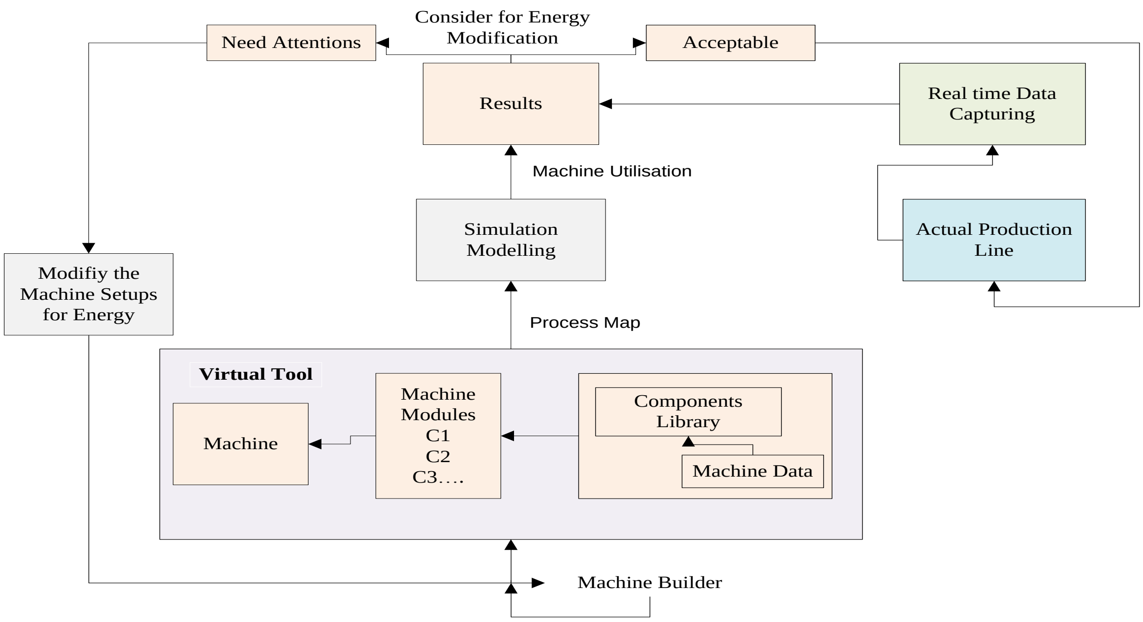

Figure 7 Devised Approach for Energy Analysis in Automotive Industry

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The figure 7 shows the usage of emerging virtual technology for the energy optimisation which could be achieved just through checking the machine station utilisation and developing a simulation model to monitor the system. If any one module within the machine has less utilisation then planned, it could be controlled to keep it off when not in function. This also could help in the actual production system comparison and also its modification. Basically the simulation model should be integrated into the process plan of a certain manufacturing line in order to be able to safely and efficiently turn off/on the electrical supplies. There is a real time data base in the virtual tool has been designed which could be updated with the actual data of the machine installed at the shop floor, as well as also with the data from the machine builder.

This approach can benefit both way for the machine builder as well as for the user of this machine. It is clear form the figure 7 that the results can be feed to the machine builder as well as to the machine user on the prescribed processes and optimised setups. These optimised setups and energy consumption can provide a base for the financial analysis of the line also in the very early stage of the validation and design phase of the production line.

V. Conclusion

The proposed approach is to rectify the energy and resource intensive steps from the assembly operations, which may cause an overall impact on the businesses. The expected benefits deemed are in the term of integrated state-of-the-art improvement in product quality, workflow and processes. The ability of manufacturing organizations to integrate business functions and departments with new systems into an enterprise database allows them to have a unified enterprise view. These systems are based on the simulation/virtual manufacturing concept, according to which, production data management systems and simulation technologies are jointly used for optimizing manufacturing cost in term of the energy consumption before starting production. The benefits deemed are

1. Shortened product development
2. Early validation of manufacturing processes
3. Faster production ramp up
4. Faster time-to-market
5. Reduced manufacturing costs, via adopting energy and resource efficient processes.
6. Improved product quality
7. Enhanced product knowledge dissemination
8. Increase in flexibility
9. Increase the reusability of the prototypes develop for the analysis
10. Real time production decision incorporation within the system
11. To increase the integration of the different areas in the production environment to bring the decision on the real time result in a circular way.

To accomplish these benefits it needs a proper methodological approach to be followed, while research work is in process for getting these goals.
This approach has the capacity to extend in practical environment especially to develop the PLC programming for the machine and their sub-components, for the situation when the machine station has less utilisation and controlling through automatic on/off condition.

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