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Experimental cost reduction in Modern Manufacturing Industries through Software based Mechatronics System: An overview

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Abstract — Nowadays, the changing demand patters by the customers are increasing the pressure on the manufacturers. In this situation, manufacturers to sustain in the market are forced to do the activities like (i) Increase the selling price of their product and (ii) Reduce their internal costs of their product. In this scenario, it is not possible to increase the selling price of the products. The only way is to reduce their internal costs and improve the quality of the products to survive in their field. This paper suggests a methodology to develop and implement software based mechatronics systems in their factory premises for taking necessary steps to reduce the experimental cost, internal cost and improve the efficiency of the organization. The software based mechatronics approach is used to predict and analyze the relevant data pertaining to the selected problems. The usefulness of this approach is not only applicable for pump manufacturing industries but also various industrial segments, which would enable to cater the current and future customer demanding needs.

Index Terms — Minimum Economic crisis, software based mechatronics system, experimental cost reduction, Internal cost reduction, efficiency improvement, economic growth.

1 INTRODUCTION

AS global competition continues to intensify across industries, companies are actively pursuing strategies that will enable them to compete more effectively and improve profitability. In modern manufacturing industries, software based mechatronics system are widely used to operate, monitor and control of various processes. Modern electro mechanical system consists of sophisticated software and hardware components to achieve high accurate, precision and reliable manufacturing processes.

According to Danial (1998) [1], traditional computer programming involves setting down a list of tasks for the computer to execute in the given sequential order. Terutomo (2001) [2] stated that in the early 1980s, the mechatronics based computer aided flexible manufacturing systems were introduced in order to improve the efficiency of the organizations. Claimed by Anders (2004) [3], the complexity of the mechatronics system emphasizes the need for a virtual machine concept for dealing with this trade-off during product development. Godfrey (2005) [4] expressed that mechatronics responds to industry's increasing demand for engineers who are able to work across the discipline boundaries of electronic, control and mechanical engineering to identify and use the proper combination of technologies for optimum solutions to today's increasingly challenging engineering problems.

As per the report given by Amuthakkannan (2007) [5], in high precision manufacturing industries, software based systems are widely used to obtain precision, accurate and reliable data. Based on the report given by Mark, et al., (2008) [6], mechatronics involved the fusion of mechanical technology with electrical and electronics, computer science, material technologies etc. As described by Sophie (2009) [7] mechatronics is the industry's principal route to meeting the ever increasing demand for more performance at lower cost and in a smaller footprint. Agoria (2010) [8] studies show that a mechatronics design approaches is a key to all research avenues in order to drastically improve their overall performance (adaptability, productivity, quality, reliability and life-cycle costs (i.e. reduced energy consumption, reduced waste).

2 PROBLEM STATEMENT

Modern manufacturers are under intense, unrelenting pressure to find new ways to cut costs, improve quality, and boost customer satisfaction. These parameters are usually achieved through developing creative and innovative ideas. The software based mechatronics system is a relevant approach which provides lots of newer, creative and innovative ideas to develop virtual machinery for the prediction and analyzes of relevant data in order to meet experimental cost reduction and performance targets. Realizing the potential for software based mechatronics

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system in the industrial environment, this paper is focused to cater future projected industrial needs. The developments of virtual machinery using software based mechatronics system for cater future demand and its parameters are taken as research problem and solution methodologies are proposed.

3 LITERATURE REVIEW

According to Ritchie and Lewis (2003) [9], the wider literature about the role of existing theory, practice and research will shape future research. Kothari (2004) [10] expressed that the researcher should undertake extensive literature survey connected with the problem. Russell (2006) [11] stated that the contemporary practice of posing research is a wider literature is consistent with more recent articulations of grounded theory methodology and of the closely related case study methodology. The literature review assesses the past and current status of research work in the area of mechatronics system and software based mechatronics approach. The work done by the earlier researchers in these areas are classified in the following aspects:

3.1 Mechatronics System

Dobrivoje (1999) [12] expressed that in the past several decades, the rapid development of electronics industry and ever increasing applications of computers and the automation of various industries, demand for mechatronics applications have increased exponentially. As stated by MBT (2000) [13], the use of mechatronics systems views and validates electro-mechanical processes for the most efficient production operation possible. Christopher (2004) [14] outlined that the stages of a product's life include engineering, production and overall testing helps validate appropriate designs, verify appropriate production, and thus reduce wastes. Godfrey (2005) [4] outlined that Mechatronics responds to industry's increasing demand for engineers who are able to work across the discipline boundaries of electronic, control and mechanical engineering to identify and use the proper combination of technologies for optimum solutions to today's increasingly challenging engineering problems.

As per the report given by Eiji and Tatsuo (2007) [15], the manual operation process is a waste of time, waste in transportation, waste of movement, overburden etc. for each task. Ernest and Stanislav (2008) [16] indicated that the integrated structures, mechatronics and robotics, combine computers and their programs into mechanisms are used to monitor them by sensors (transducers). MBT (2009) [17] suggested that making analysis more integral to design; blending of mechanical, electrical, and electronic design is called mechatronics. As per the report given by SPLMS (2010) [18], mechatronics system views and validates electro-mechanical processes for the most efficient production operation possible. Based on the literatures it is clear that software programming is essential to achieve the desired innovative system.

3.2 Software based Mechatronics System

Programmers develop software applications every day in order to increase efficiency and productivity in various situations. Johnson (1998) [19] stated that the LabVIEW software has advanced the state of software development in graphical programming, user interface design, and development environment. NIC (2003) [20] reported that LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications. As described by Christopher (2004) [14], the control software is to be designed to allow operators with little or no computer experience to monitor and control the system.

Eiji and Tatsuo (2007) [15] expressed that well designed software is an excellent computational tool to simulate dynamic mechatronics systems. Instead of measuring a process variable directly with one physical sensor, measurements form several sensors and other knowledge of the process are incorporated using software to obtain an even more accurate measurement. Bitter (2007) [21] point of view, the ability of the software to provide abstraction is also significant because it improves code readability. CNA (2008) [22] studies shows that the control electronics are designed and manufactured with tailored software adaptations to further improve operation in the machines or even to integrate the machine functions.

As indicated by NIC (2009) [23], LabVIEW is a powerful development environment for signal acquisition, measurement analysis, and data presentation, giving you the flexibility of a programming language without the complexity of traditional development tools. NIC (2010) [24] outlined that, with LabVIEW software, it can be quickly create user interfaces that give you interactive control of your software system. Claimed by Pedro and Fernando (2010) [25], LabVIEW is a graphical control, test, and measurement environment development package. It is one of the most important software platforms for developing engineering applications and could be connected with different hardware systems, as well as running standalone programs for simulating the controller's performance. Luis (2011) [26] pointed out that the intelligent and autonomous software programs are capable of interacting with other software components within a given application, and sharing a common goal.

4 BACKGROUND OF THE PAPER

At the starts of the paper, the analyses of various concepts which are essential are to be studied. Peter (1999) [27] expressed that the background concepts provides the research and researcher to make sense of the 'data' and the study to proceed in a systematic way. As described by Brian (2003) [28], the different backgrounds for the selective area are reducing the gap between the theoretical studies and practical analysis. In this paper the back-

grounds of mechatronics system and software based mechatronics approach were presented.

4.1 Background of mechatronics system

The new role of mechatronics in the 21st century is the one of the main technology to support people directly by intelligent machines and systems with sensor, information technology, network, and human sciences. IAG (2006) [29] reported that the Iskra Avtoelektrika Group increased their sales volume by 23 % in comparison with the year before mainly as a result of the mechatronics applications. The share of new products sales is by 5 percentage points higher than in the previous year and represents 30 % of the total sales. As suggested by John (2007) [30], about 15% of all investments in the process industry are currently allocated to mechatronics devices. There is an important tendency of some growing sectors, specifically the equipment industry, which investment has grown at a rate of 11.2% in 2005 and 31% in 2006. Gerard (2008) [31] expressed that an increase in automation, to detect early failure diagnostics of the machines, the mechatronics share of the production costs of machines is gradually increasing to about 10% to 20%.

4.2 Background of software based mechatronics system

Since the dawn of computing in the 1940s, the applications and uses of computers have grown at a staggering rate. According to ACM (2004) [32], software plays a central role in almost all aspects of daily life: in government, industries, banking and finance, education, transportation, entertainment, medicine, agriculture, law etc. As suggested by Godfrey (2005) [4], mechatronics is defined as the synergistic combination of precision mechanical, electronic, control, and systems engineering, in the design of products and manufacturing processes. Agoria (2006) [8] stated that most modern engineering products already make use of the close interaction between classical mechanics, electronics, control engineering and software that is known as mechatronics.

John (2007) [30] expressed that about 15% of all investments in e.g. the process industry are currently allocated to mechatronics devices. Application of mechatronics can provide a large competitive advantage. Production costs can be reduced by reducing waste costs but also labour costs. There is an important tendency of some growing sectors, specifically the equipment industry, which investment has grown at a rate of 11.2% in 2005 and 31% in 2006. Mark (2008) [6], et al., insisted that computer innovations increased from 26% to 74% between the years 1963 to 2008 in UK firms.

5 Research Approach

As stated by Kothari (2004) [10], research approach is a way to systematically solve the research problem. It may be understood as a science of studying how research is done scientifically. The various steps that are generally adopted by a researcher in studying his research problem along with the logic behind them are to be taken. The solution given in this paper has been carried out by using the research approach as shown in Figure 1.

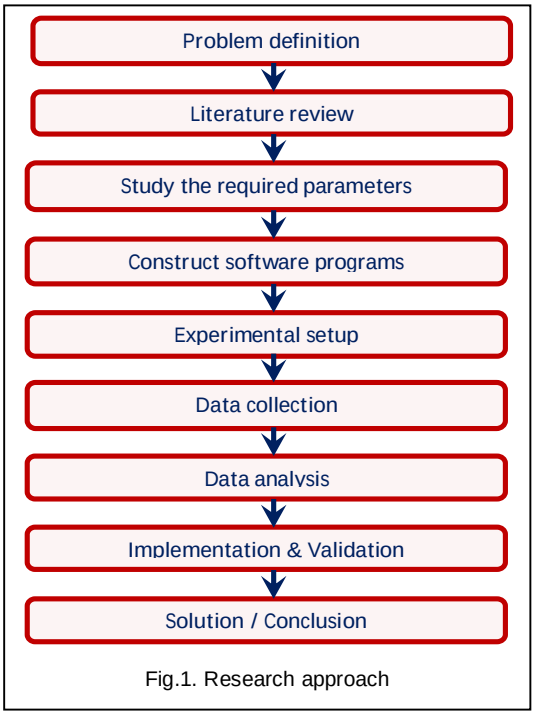

Fig.1. Research approach

As per the field work approach, the relevant conceptual literatures concerning the concepts, theories, and empirical case studies were studied. After the conceptual stage, arrangements should be made for the selection of relevant manufacturing industry to carry out the case studies. The desired parameters of software based mechatronics system were analyzed before conducting the programme. The relevant data pertaining to the selected problems were predicted and analyzed though software based mechatronics system. The optimal solution was tested through proper validations before implementing in regular production.

6 Case Study

Bill and John (2001) [32] expressed that case study leads to obtain very novel idea and no longer limited to the particular individual. Kothari (2004) [10] outlined that a case-study is an in-depth approach to reach the basic relationship between the theoretical and practical aspects.

6.1 Formation of team and time frame

As reported by WoS (2009) [34], the teams or work forces that can meet deadlines and solve the selected problems by planning and streamlining activities. A team comprising of skilled personnel from each department had been formed for planning, monitoring, evaluating and directing. This team had been discussed among the members and with the top management; the time frame for conducting integrative programme had been formulated.

6.2 Product selection

Understanding the importance of product selection, the team has to gone through the customer care records, customer complaints book, service engineers' log book and all. Marco (2009) [35] studies shows that during the product selection the literatures for product life cycle, providing knowledge based environment to support value creation to the customers in term of creation, innovation, lead time reduction, quality improvement, performance improvements were considered. A sample product called Shallowell jet pump is shown in figure 2.

Fig.2. Product (Shallowell jet pump)

6.3 Apparatus selection

The selection of apparatus for manipulating the input signals and output signals are one of the important phases for experimentation. According to Robert (2008) [37], the accuracy of apparatus describes the amount of uncertainty when considering quantization error, unavoidable system noise, and hardware imperfections. Anders (2004) [3] stated that a measuring instrument was designed which had an accuracy of a millionth of an inch, increasing the accuracy of the machines dramatically. Claimed by BEC (2006) [38], high precise, accurate and reliable measuring apparatus will improve the confident level of the employers, employees and customers.

6.4 Data acquisition card

Christopher (2004) [14] expressed that choosing the right combination hardware and software can save hours of development time and strongly influence the performance of built application. As stated by Cory (2005) [39], data acquisition card is in some sense a hybrid device in that aspects of both the conventional digital receiver and the sub-sampling receiver are used to acquire the desired signal. Arun (2006) [40] indicated that the Data Acquisition (DAQ) system has been interfaced to computer through parallel port for transferring the acquired data to the computer. As described by Bitter (2007) [21], taking data from a data acquisition card can now graph the outputs on a digital graph. Pedro and Fernando (2010) [25] explained that the data acquisition system plays a key role in the control system design. A sample DAQ (PCI-6034E) card is shown in Figure 3.

Fig.3. Data Acquisition Card

6.5 LabVIEW Software

The National Instruments' LabVIEW Software is a graphical development environment which provides advanced functionality and performance that engineer and scientists can use to develop sophisticated applications. Johnson (1998) [19] suggested that LabVIEW is a new kind of graphical programming language that has brought the power of the computer to the scientists and engineers in a powerful new metaphor that is natural to the user. As per the report given by Thomas (2003) [41], an experienced LabVIEW user can program the application easily with this information. Gary and Richard (2006) [42] outlined that LabVIEW brings the ease of graphical programming to the arcane world of real-time system programming. Jeffrey and Jim (2006) [43] point of view, LabVIEW create programs using a graphical notation (connecting functional nodes via wires through which data flows); in this regard, it differs from traditional programming languages like C, C++, or Java, in which program with text. Sumathi and Surekha (2007) [44] reported that LabVIEW introduced graphical user interfaces and visual programming into computerized instrumentation, joining simplicity of a user interface operation with increased capabilities of computers. NIC (2010) [24] reports show that LabVIEW is a highly productive graphical programming language for building data acquisition and instrumentation systems.

6.6 Software development

Johnson (1998) [19] explained that the increase in productivity comes from the interactive approach to software

development. As expressed by Christopher (2004) [14] software approach is used for hardware and other capabilities, which also minimizes the integration time and effort for future developments. VMWare (2006) [45] reports shows that software development teams to more efficiently utilize software development and test lab assets, accelerate software development cycles, and increase the quality of delivered software systems. Sumathi and Surekha (2007) [44] suggested that instrumentation software enabled the creation of a simulated physical instrument, having the capability to control physical sensing components. Pedro and Fernando (2010) [25] outlined that software platforms for developing engineering applications and could be connected with different hardware systems, as well as running standalone programs for simulating the controller's performance (validating the controller by simulation then implementing it). Sample software development using LabVIEW software is shown in figure 4.

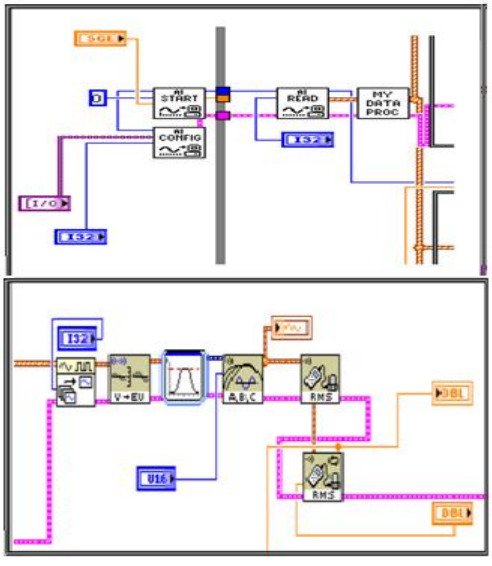

Fig.4. Software development (LabVIEW)

6.7 Experimental setup

The experimental method is a scientific method. It is oriented to the future in the sense that the researcher is seeking to evaluate something new. The experimental groups are given a description of the basic design rules derived from the literature like Yogesh (2006) [46], Lisa, et al. (2008) [47] and Lucienne and Amaresh (2009) [48] and applied these while designing. The designers in the control group are only given the design task. The task is based on one of the cases in the empirical study. A sample experimental setup is shown in figure 5.

Fig.5. Experimental setup

7 Prediction and Analysis of Data Using Software Based Mechatronics System

The prediction and analysis of present data in a process / product will play a vital role in an organization during the decision marking about the quality improvements, performance improvements, processes improvements, newer innovations etc. In order to examine the existing data in products / processes, this paper insists them to utilize the software based mechatronics system. Godfrey [4] stated that mechatronics is the synergistic combination of precision mechanical engineering, electronic control, and systems thinking in design of products and manufacturing processes. According to Mahalik (2003) [36], an automatic control system could perform a repetitive job; but could not take any decision in the event of variable circumstances. So, the introduction of software based system monitors the status of the process continuously and takes corrective action dynamically to stabilize the process.

7.1 Experimentation

As suggested by Auston (1997) [49], experimental methodology would also improve the quality of researches. Pande and Holpp (2002) [50] expressed that experimental is a method for developing and conducting controlled assessments of how a process or a product performs, usually testing two or more characteristics under different conditions. In addition to helping target causes of a problem, it can be essential to get maximum benefit out of solutions. USEPA (2007) [51] insisted that the experimentation may make sense to start testing techniques at the organizational levels help to identify synergies and opportunities and evaluate how well they worked. Adapt the validated results to fit into the organizational systems and culture.

Anders (2004) [3] pointed out that conducting experimentation is the purpose of achieving cost-efficient and accurate enough prediction of data to support optimization and well-informed design decisions during research and

development. Claimed by AISB (2005) [52], carrying experimental methods of the arts into research in order to create a new form of inquiry that has real agency on social, conceptual and economic levels. Agoria (2006) [8] studies show that the experimental models, being able to reproduce many typical experimental tests, permit, still in the design phase, to optimize the process to a much larger extent than traditional tools.

As stated by Nikolay (2007) [53] after the completion of successful experiment, the acquired knowledge reaches another point at which the individual is able to control the entity. Wolfgang and Stanislav (2008) [54] indicated that experiments include analytical or approximate calculation or simulation models derived from engineering sciences. As described by Sophie (2009) [7], experimentation is required to determine what parameters are necessary to be found by the research at long term to achieve the goal. Sample experimentation is shown in figure 6.

Fig.6. Experimentation

7.2 Experimental outcomes

The measurements of outcomes are usually needed accompanied by some investigation of process. The ability to turn information and data into effective action brings desirable outcomes for a research / organization. Anders (2004) [3] stated that the outcome of the experimentation is crucial for future research.

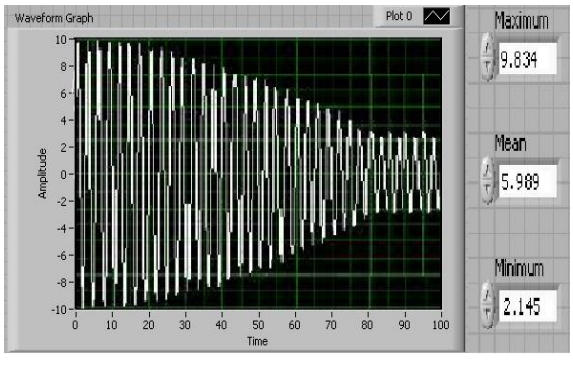

Fig.7. LabVIEW front panel

Claimed by AISB (2005) [52] the outcomes in order to evaluate a research's success and is crucial to shift the focus onto the dynamics of the evolving discourse that led to the concrete results. Wolfgang and Stanislav (2008) [54] expressed that designing more efficient, effective, rational, better directed, with a better outcome becomes a welcome addition to the information for researchers. The sample outcomes of vibration level through LabVIEW front panel are shown in figure 7.

TABLE 1
PREDICTION OF VIBRATION LEVEL

Sl No	Pump No.	Time (Sec)	Amplitude (µm)		
			Max	Min	Avg
1	TRS10250011	60	5.83	2.14	3.98
2	TRS10250012	60	5.76	2.07	3.92
3	TRS10250013	60	5.90	2.21	4.05
4	TRS10250014	60	5.94	2.25	4.09
5	TRS10250015	60	5.66	1.96	3.81
6	TRS10250016	60	5.54	2.75	4.14
7	TRS10250017	60	5.90	2.21	4.05
8	TRS10250018	60	6.00	2.31	4.15
9	TRS10250019	60	5.80	2.01	3.91
10	TRS10250020	60	5.60	1.91	3.76

Max = maximum, Min = Minimum, Avg =Average

As stated by Mark and Peter (2001) [58] the innovations and changes that occur in all successful organizations are disruptive and dysfunctional unless their purpose is well articulated and communicated, they are coordinated, and those affected by them feel a sense of ownership and influence over their nature and outcomes. Based on the statement given by Luis (2011) [26], the outcomes of present research will involve not only researchers and academics in general, but also companies who wish to assess the potential for transfer of results to their applications. The sample outcomes of vibration analysis are shown in table 1.

7.3 Experimental validation

According to Janeri and Lewis (2003) [55], as a consequence, numerous suggestions are made about how to cross-check the validity of a finding or conclusion (validation) or to allow sufficient access to the research process for others to do so themselves (documentation). Checking accuracy of fit which involve deriving hypotheses from one part of the data and testing them on another by constant checking and comparison across different. Anders (2004) [3] pointed out that validation aims at checking if a model is suitable for its intended purpose by comparing the experimentation results to what is expected by the user or to results obtained from studying the real system.

Agoria (2006) [8] studies show that validations of the present outcomes are to be done prior to starting the regular operations. Eiji and Tatsuo (2007) [15] reported that the validation of the proposed model identified by experiments shows well corresponding to real attendant's propelling behaviour. As expressed by SPLMS (2010) [18] validation enables manufacturing companies to accurately and efficiently define the manufacturing process plan for their component parts. Luis (2011) [26] point of view, for ensuring high quality solutions; the proposed systems are to be undergone verification and validation.

8 Results and Discussions

As stated by Murray (2008) [56], positive results helps create and maintain team spirit and commitment to the team objectives, most importantly, it may drive innovation within the team. Rouhani (2006) [57] insisted that the research results are significant, taking into the account that traditional industry has to be changed into global competitive, innovative and technology developed industry. As expressed by Russell (2006) [11], the experimental results of an investigation can be conducive to further innovative work. Janeri and Lewis (2003) [55] reported that the discussions suggest a revision of the research objectives, or a radical change in the way in which the data are collected, and then there may be more reason to consider or not. Mark and Peter (2001) [58] pointed out that the discussion aims to describe and explain some different funding options for qualitative research and to highlight the processes and issues involved in each. Lisa, et al., (2008) [47], discussion concerning a problem / solution often produces useful information. Various newer concepts can be developed through such an exercise.

8.1 Cost and time saving applications

AISB (2005) [52] outlined that the skills required to create reliable mechatronics design at low cost are acquired by experience. BEC (2006) [38] suggested that machine builders are expected to develop machines with higher throughput that, at the same time, reduce operational costs and increase safety. As expressed by Agoria (2006) [8] a mechatronics design approach is a key to all three avenues and there is likely to be hybrid integrations of two or more approaches in order to meet cost / performance targets for particular sectors and applications. Brian (2007) [59] explained that the simplicity of the mechatronics design provides relatively low experimental costs, less time to construct and more data reliability. The expected cost and time saving applications are shown in figure 8.

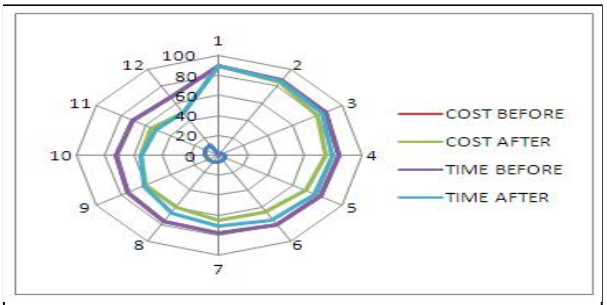

Fig.7. Cost and time savings

8.2 Reliability of software based mechatronics system

John (2007) [30] studies show that a more reliable process data will lead to higher quality products, processes and services. As described by Wolfgang and Stanislav (2008) [54] correct and reliable information, at the right time, and in a usable form is currently one of the problems. Luis (2011) [26] indicated that science and industry are constantly evolving that whether it is possible to create a system capable of facilitating communications, yet be portable, reliable, eventually self-powered and very simple to use. These parameters are fulfilled by mechatronics design.

9 Conclusions

This paper conclusion is based on the conceptual analysis of the software based mechatronics approach. Present manufacturing industry attention illustrates the need for the integration of manufacturing process and a software simulation for reaching a better solution within short time and low cost. This paper brings few ideas on software based mechatronics system to fulfill the manufacturing environments' expectations. This approach had bring the number of benefits like low cost for experimental, reliable data, lead time reduction, productivity improvements, quick change over, more profitability, more customer satisfaction and innovative technology developments.

This paper has an approach in that software based mechatronics approach to ensure an approach that will benefit end-users. This approach to manufacturing via process monitoring and control, supported strongly by product performances and characterization of the final product to ensure a component / process of high quality in all aspects has been applauded. This innovative approach has yielded extremely positive benefits to all manufacturing industries internationally.

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