Development of the Mechatronic System Design and its Applications

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Abstract**:** Increasing requirements on the productivity of complex systems, such as manufacturing modern machines and their steadily growing technological importance will demand the application of new methods in the product development process. A smart machine can make decisions about the process in real-time with plenty of adaptive controls. Mechatronic System Design has been one of the most advanced technologies and modern system designs in recent years and finding more applications in a wide range of today's modern world. This paper proposed a brief overview and basic characteristics of the mechatronic system design. Also, focuses on the most recent development in the mechatronic system design that has been made in the last several years. The architecture and key elements of the mechatronic system design along with principles and methods of processing and controlling mechanism have been discussed and analyzed. This paper also presents the challenges and strategies faced by the most recent development of mechatronics.

Keywords**: Mechatronics, Mechatronic System Designs, Electrical Engineering, Electronics Engineering, Modern Machines.**

1. INTRODUCTION

In present days there is a growing current trend towards the use of advanced technology for the rapid development of the manufacturing modern machines. Mechatronics invented nearly 50 years ago, in 1969. Mechatronics is also called mechatronic engineering. Ko Kikuchi stated that mechatronics constitutes from the combination of both **mecha**nics and elec**tronics**. Mechatronics represents a blending of three basic techniques: mechanics, electronics, and information technology. This combination enables more compact, higher performance and lower cost products. Mechatronics is a technology, requiring competencies in multiple disciplines: electronics, automation, mechanical engineering, micro IT. The intention of mechatronics is to produce a design solution that unifies each of these various subfields which deal with the integration of mechanical engineering, electronics engineering, and control engineering. We found mechatronics everywhere around the home appliance and industry application. Such as medical instruments, automation and robotics, servo-machines, and washing machines etc.,

It also needs additional knowledge of electro-technics, power electronics, microelectronics, microsystems, sensors, and design and simulation techniques [1]. The complexity of this technological evolution is difficult for description, but the change to be achieved consists of mastering the reception of information and its transfer to a mechanical base. Mechatronics has been used for large programmes in very specific industries for nearly a decade and only afterward it developed for industrial design workshops and research laboratories. The most recent development in this field has shown a visible entry into industrial products and processes, but not so much into product design, which is limited to large companies and highly specialized activities.

2. Literature Survey

2.1 Devdas Shetty et al

Modern machines have been designed by using mechatronic systems; in [Devdas Shetty et al.,] presents, the mechatronic system using the simulation of complex structures with improving the dynamic behavior and interactions of the components and also current trends of advancement in mechatronic systems with integrated design issues. Forgetting inexpensive prices, the automotive industries use equipment for manufacturing, integrating and controlling in the production flow. Trends in the development of new equipment for the automotive applications in mechatronic systems design described. The necessity of the mechatronic system design and benefits to include mechatronic systems design into the traditional electrical and mechanical fields and importance towards future generation have been discussed, and the overview of the mechatronics degree program has also been discussed [4].

2.2 Hirpa G. Lemu et al

A survey on "the need for mechatronics education in Norway and Poland" presented by [Hirpa G. Lemu et al.,] the approach for synergistic integration in mechatronics and with the use of 4 Sys ML-view model approach, the challenges in synergistic integration, size and complexity, reuse, as well as requirements handling and traceability, support for decision making, and maintaining consistency are presented and discussed [8].

2.3 Yasodharan et al

Medical mechatronics plays a vital role in the medical instruments by optimizing traditional instruments and also creates innovative and intelligent smart instruments, in medical mechatronics, electronic instruments and equipment are used for medical applications such as diagnosis, therapy, research, anesthesia control, cardiac control, and surgery. In, the research opportunities and challenges described and reviews on artificial intelligence and mechatronics system design. Mechatronics as a latest trend in machine control, The TPS-3920 system is accompanied by the SES-LATHE software. The overall aspect of mechatronic systems design in an industry from its origin to its present applications described.

3. DEVELOPMENT OF THE MECHATRONIC SYSTEMS

Deliberate over the example of an automobile system. The radio was one of the extensive electronics in an automobile until the 1060s. Other functions were purely mechanical or electrical, for example, battery charging system and starter motor. There were no any alert systems developed only reinforcing the bumper and structural members to protect residents in case of accidents. Seat belts totally mechanical based were introduced in the early 1960s and developed for resident safety. All engine systems were controlled by the driver and mechanical control systems. Mechatronics system design development from the purely mechanical system is a logical and practical step in the development of science and technologies [7]. The electronics is the basic component that can't be replaced the mechanical system. The development of the mechatronic systems is shown in Figure 1.

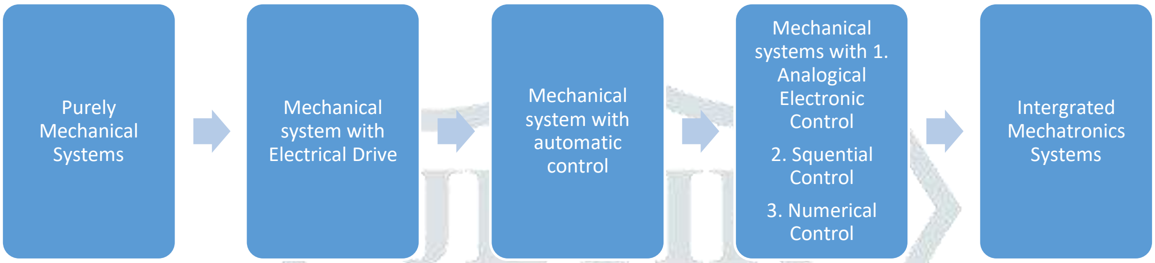

Figure1 Development of Mechatronics Systems

3.1 CHALLENGES AND CHANGES IN DEVELOPMENT OF THE MECHATRONIC SYSTEMS

Forthwith, there are several challenges in the development of mechatronics systems:

- Challenge in design related because of CAD tools for mechatronic is globalize in the mechanical, electronic and data-processing requirements.
- Challenge in production-related because the integration of mechanical and electronic subsets requires competences and assembly conditions which are not always available in the workshops.
- Challenges in quality and reliability related because the definition of operating conditions in degraded mode for complex systems is not obvious.
- Challenge in culturally related because of mechatronics establishes demands for the level of competences – “in-house” or between industries.

3.1.1 *Challenge in Training*

The mechatronics engineer is more of a present architect, a generalist more than a specialist. Among the schools, the relative weight of modules such as project management, automation and IT varies greatly and often depends on the main practice. The mechatronics engineer is required to create a synthesis between various experts. They may become a specialist in one technique but for their first mission is to think of the system as a whole.

3.1.2 *Challenge in Cultural*

Mechanics and electronics user need a common language even if their fields of competences are different. Although the impact of mechatronics is easy to understand in certain large-size groups, there is still a real cultural barrier between “mechanical” tradition and the electronics world. Mechatronics reality is more complex and the cultural shock between mechanical engineers and electronics engineers is real in practice.

3.1.3 *Challenge in Design*

The product’s lifecycle phases, broken down into autonomously researched subsystems, no longer provide adequate answers to the quality/cost/time challenges imposed by the present market. Therefore two enhanced complementary approaches were established: simultaneous engineering (or concurrent engineering) and the mechatronics (“system”) approach. It is very important to take into consideration the “complexity management” resulting from these enhanced practices by paying attention to the following components: diversity of applications and skills; multi-tasking across disciplines; diversity of modeling levels; continuity with other levels of abstraction. Specialists in mechatronics design characterize the development cycle, which positions the different phases (from specifications to product validation) according to the abstraction level in the following way: functional level, system or network level, component or geometrical level. In this complex design layout, modeling and simulation play an important role in the fine analysis, as well as for the transfer of know-how and development time reduction. The key success factors include the ability of the designer to find and master the right level of vagueness for the problem and to link with the other levels. The design tools are progressively adapting to these constraints and enhance tools bring enhanced solutions in dealing with the network level. Geometrical level modeling also benefits from important advances in terms of multi-physical coupling (ability to simultaneously deal with several physical dimensions in a single or dual environment: mechanical, thermal, electrical, magnetic, fluid, etc.) and coupling with other levels. The development of micro-systems (MEMS or micro-mechatronic systems) was the first to use these enhance possibilities, which are progressively evolving into "micro-systems" in all industrial sectors.

3.1.4 *Challenge in Reliability*

In the mechatronics field, reliability is often perceived by manufacturers as one of the issues which are least mastered. For some of them, it represents a critical point for the spreading and the future development of the mechatronic technology. The concept of a mechatronic product or approach is principally characterized by the notion of coupling between different technologies, different disciplines or physical areas. The mechatronics utilizes this coupling to the maximum to offer greater technical and economic performance, which creates added value. The increase in the coupling levels provokes a rise in the complexity of systems, their control, design, and manufacturing processes, which also spreads into related processes such as purchasing and marketing. This complexity at all levels increases and there are risks of malfunction, unpredictable behavior, and unforeseen behavior. The methods and tools to master reliability, which is available to the designers, are very diverse and often too specific for systematic use in mechatronic design.

They include non-dynamic models time based and dynamic models which include the time and state of the system, trial techniques, statistical analysis, estimation methods, behavior simulators, evaluation software, simulation tools by Monte-Carlo. Similarly, optimization tools like generic algorithms/non linear simplex, next the risk control tools i.e., malfunction analysis, error trees, Markov analyzed. Mechatronics is characterized by the absence of a method and generic tool, which could be easily integrated into the design flow from the very beginning since the idea of reliability must be included very much upstream in the process, particularly with regard to the choice of architecture and components. In this area, the need for evolution in concepts and tools is the most obvious. There is still much work to be done for the theoretical concepts and tools. The manufacturers and researchers must work together closely to meet the reliability challenge.

4. CHALLENGES AND CHANGES IN DEVELOPMENT OF PRODUCTS

The needs to include electronics and software in products create a set of challenges, related to the notion of getting engineering disciplines to work together. Surveys have been carried out showing which have shown the priority challenge in this field is shown in Figure 2.

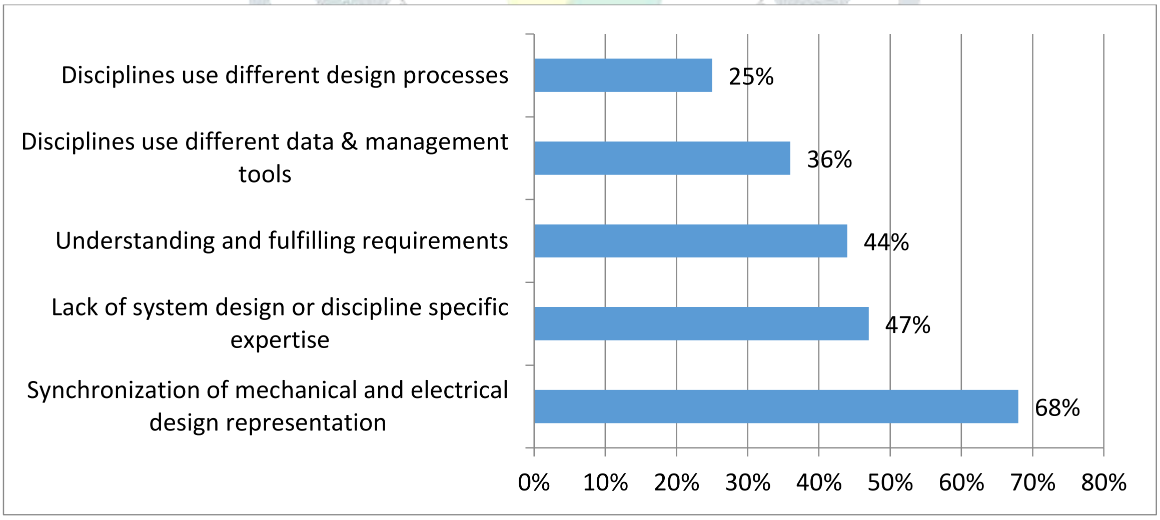

Figure 2 Development Challenges of Mechatronic Product

Three of the challenges listed – synchronization of mechanical and electrical design representations (68%), disciplines use different data management tools (36%), and disciplines use different design processes (25%) are symptoms of one and the same problem: the efforts of manufacturers to get mechanical, electrical, and software engineers to work together from technical and process perspectives. The overall conclusion is that the way used to run product development will not allow success in the future and that some fundamental changes must be made. The resolving of the integration issues during the development cycle very among different type of manufacturers is shown in Figure 3

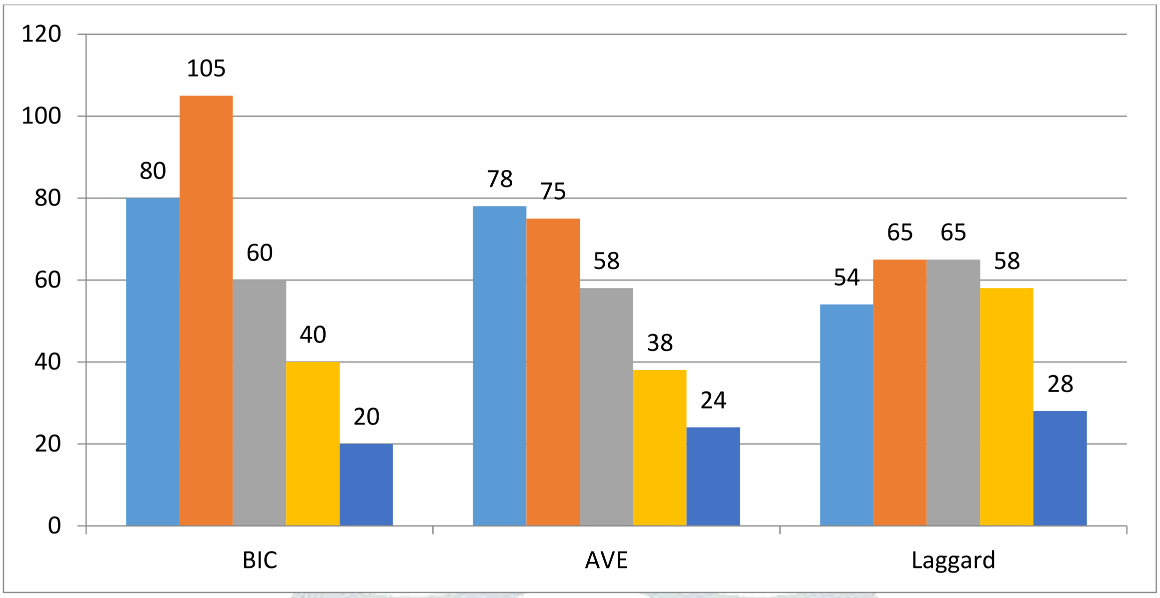

Figure 3 Development Phase of Integration Issue Resolution

Best in class performers start resolving integration issues early in design investments are committed to tooling in the manufacturing ramp-up and production phases (80%). As a result, they avoid the costs and time delays consorted with resolving integration issues at a later stage. Among average performers, the commitment to resolving integration issues has shown a robust start in design (85%), but it drops off dramatically during the verification and test phases (76%). The companies, which are lagging behind are much less committed to resolving integration issues prior to design release - i.e., in the design (50%) and verification and test phases (67%). They use the manufacturing production phase (58%) to resolve many integration issues but this late resolution contributes to high development costs and missed launch dates because investment capital has already been committed to tooling, providing for expensive and time-consuming change.

5. MECHATRONICS STRATEGIES

Manufacturers consider a number of strategies in select a few with a high degree of frequency are shown in table 1. Mechatronics development is a reality for today's manufacturers [2]. Driven by competitive or customer pressures to include electronics and software in their products, they must find ways to present the technical and process challenges in getting mechanical, electrical, and software engineers to work together and meet the industrial norms or be/stay close to the best-in-class performers.

Table 1 Development of mechatronics strategies

MECHATRONICS STRATEGIES	
Increase internal discipline-specific core competencies	89%
Implement or change your new product development process	75%
Access partners with discipline expertise	52%
Improve engineering IT design environment	50%
Change your engineering organization	41%

- Industry norm steps to success
  - *Implement integrated data management technologies*

    Mechanical, electrical and software engineers work on different representations of the same designs. Manually synchronizing their work-in-process changes across different data management tools issues errors, costs, and delays in the product of development process. Implement integrated data management technology and using these technologies to reduce the cost and risk.

  - *Deploy discipline-specific design processes, not integrated ones*

    A single integrated design process across all disciplines seems perceptive, and the statistics show that all process re-engineering efforts are wasteful. Continue to use or deploy separate design processes across disciplines and be persisting in coordinating the engineering groups.

  - *Balance frequent measurement of progress between time to market and quality*

    Make a commitment to observe progress on a periodic or real-time basis. While tracking product cost during work-in-process changes prior to design release as well as orders change after design release, track against due dates to meet time-to-market targets and balance it with respect to product quality based.

- Best in class next steps
  - *Add rigorous measurements in the design phase to catch integration issues*

    While a resolution of integration issues in the verification and test phases are good ways to catch issues prior to design release, the cost could be removed with a greater emphasis on finding and resolving integration in the design phase. During periodic progress and status meetings, persisting review all interactions across disciplines and review virtual prototypes to ensure work-in-process changes are communicated.

  - *Implement integrated data management technologies*

    Use this type of technologies to present different and assess changes in design representations, product structures, and bills of material between mechanical, electrical, and software engineers. Leverage other product lifecycle management and collaboration tools to enable these separate discipline-specific engineers to work together.

6. APPLICATIONS OF MECHATRONICS

Followings are the applications of mechatronics

- Commercial applications of automobiles, ships, appliances, sports.
- Industrial applications of robotics, machine control, vibration testing, and instrumentation.
- High-reliability applications in military, space and aerospace, seismic monitoring, tilt, vibration and shock measurements.

7. CONCLUSIONS

The introduction of enhanced technologies in the industry requires long cycles and mechatronics is no exception to the rule, namely in terms of complete design cycle control and reliability related issues. Mechatronics requires knowledge of different skills, which does not simultaneously exist in the company. With that regard, the following activities should be implemented.

- Initial training to create a multicultural spirit in the future designers.
- Continued training to seek convergence in language and methods between the different skills centers within the company and research to improve modeling and quality control tools.
- Designing within a "project-based" and cross-sharing engineering logic.
- Manufacturing with integration in mind, when components on the production lines have by nature different constraints.
- Marketing aimed at rethinking the needs of the clients in terms of functions. Integrating electronics into a mechanical component leads to a rethinking of the complementary services (traceability, maintenance history). It is a real information revolution which may be enabled by mechatronics.

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