Smart factories – An overview*

Muhammed Nabil K M[1*], Hare Prasaad P[2], Narendra Reddy T[3], Prakash Vinod[4] Senthil Kumar S[5] and Thangavel S[6],

*[*1&5]Vellore Institute of Technology (VIT), Vellore; [2&6]Kongu Engineering College(KEC), Erode; [3&4]NMTC Dept., CMTI, Bengaluru.*

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ABSTRACT

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Smart Factory,
Real Time Factory,
Internet Of Things,
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Cyber-Physical System.

Due to the current structure of digital factory, it is necessary to build the smart factory to upgrade the manufacturing industry. This paper provides brief review on Smart factory and its implementation on traditional factory. They adopt the combination of physical technology and cyber technology and deeply integrate previously independent discrete systems making the involved technologies more complex and precise than they are now. Furthermore, a hierarchical architecture of the smart factory was proposed first, and then the key technologies were analyzed from the aspects of the physical resource layer, the network layer, and the data application layer. We have discussed the various features of the Smart Factory through an factory experts and example from the already existed smart factory. The Smart Factory architecture serves as solution pattern for the conception of modern production plants, which are characterized by mechatronic changeability, individualized mass production and internal and external networking. In addition, we discussed the major issues and potential solutions to key emerging technologies, such as Internet of Things (IoT), big data, and cloud computing, which are embedded in the manufacturing process. Finally, we discuss the main limitation of the Smart factory and its ongoing research towards overcoming the limitations toward the future.

1. Introduction

Over the past several years, the topic of Smart Manufacturing has been a conversation among manufacturing experts, strategists and thought leaders. However, despite its recent coverage in the press and journal articles, many in the front lines of manufacturing aren't quite sure what Smart Manufacturing entails its importance or how it is even relevant to their organization. GE (General Electric) coined the name "Industrial Internet" as their term for the Industrial Internet of Things, and others such as Cisco termed it the Internet of Everything and others called it Internet 4.0 or other variants [2].

Industrial equipment that communicates with users and with other machines, automated processes that require little or no human intervention, and even mechanisms that facilitate real-time communication between the factory floor and the market are generating dynamic process innovations (Iansiti and Lakhani 2014; Porter and Heppelmann 2014). In order to preferably implement Industry 4.0, the following three key features should be considered [1]: horizontal integration through value networks, vertical integration and networked manufacturing systems, and end-to-end digital integration of engineering across the entire value chain. The setting for vertical integration is the factory, so the vertical integration means implementing the smart factory that is highly flexible and reconfigurable. Therefore, the smart factory is believed to be able to produce customized and small-lot products efficiently and profitably.

*Corresponding author,
E-mail: muhammednabil. km 2017@vitstudent
(Muhammed Nabil K M)

However, it is important to differentiate the vertical IoT strategies such as the consumer, commercial, and industrial forms of the Internet from the broader horizontal concept of the Internet of Things (IoT) [2], as they have very different target audiences, technical requirements, and strategies.

For example, the consumer market has the highest market visibility with smart homes, personal connectivity via fitness monitors; entertainment integrated devices as well as personal in-car monitors. Similarly, the commercial market has high marketability as they have services that encompass financial and investment products such as banking, insurance, financial services, and ecommerce, which focus on consumer history, performance, and value. Enterprise IoT on the other hand is a vertical that includes small, medium, and large-scale businesses.

The organization of this paper is as follows, Section 2 will discuss the market potential and in Section 3 we will discuss the Characteristics and will discuss the Features regarding the Smart Factory. In Section 5 we will discuss the Challenges and the Future problems. And will conclude the discussion with the future direction of smart factories research and providing our own possible solutions for the previously discussed challenges.

2. Market Potential and Smart Manufacturing

The smart factory market is expected to be valued at USD 244.82 billion by 2024, growing at a Compound Annual Growth Rate (CAGR) of 9.76% during 2019–2024. (Ref Fig.1)

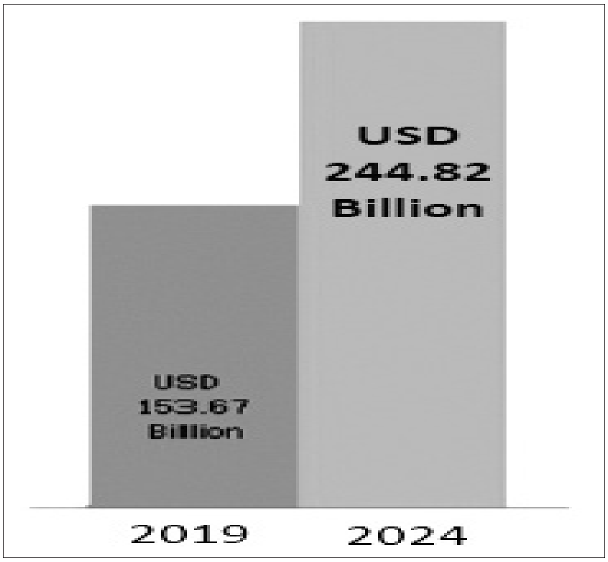

Fig. 1. Market potential

One of the key technologies toward the future of the smart factories is Industrial Internet of Things. Industrial Internet of Things (IIoT), which encompasses a vast amount of disciplines such as energy production, manufacturing, agriculture, health care, retail, transportation, logistics, aviation, space travel and many more. This rise in demand can be attributed to the emergence and adoption of intelligent technologies across all the major industries comprising mining, energy, petrochemicals, and manufacturing.

A report by Capgemini's Digital Transformation Institute suggested that the industrial manufacturing, aerospace and defense and automotive industries are most aggressively pursuing smart factory initiatives. It stated that 76% of manufacturers are either planning or pursuing a smart factory initiative, and it could add more than $1 trillion in value to the global economy in five years. (Ref Fig 2)

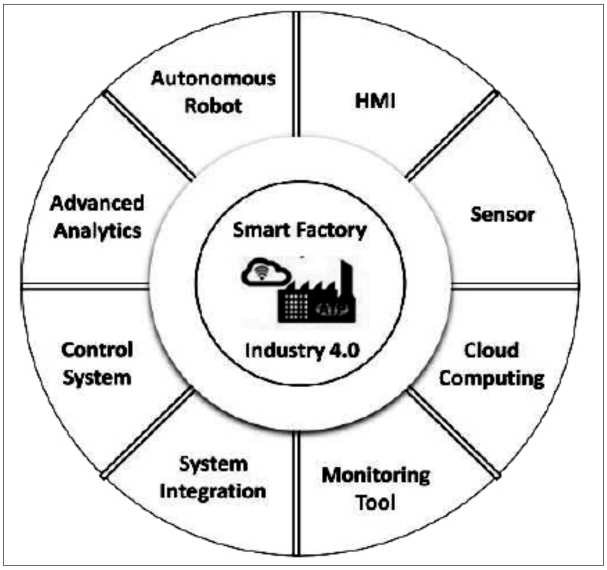

Fig. 2. Smart factory components

Smart Manufacturing is being predicted as the next Industrial Revolution. And, as with many other advances throughout recent years, it all has to do with technology connectivity and the unprecedented access to and contextualization of data. It integrates data and information from multiple open and vendor applications and products that can be composed to form new solutions. It can be applied to a single machine line, an entire factory or across a network of suppliers and customers. In fact, linking and integrating among and across all of these in synchronized time is possible.

These improvements make it realistic to manage manufacturing operations with more precision and better collaboration among employees, suppliers and partners. SM will create an open atmosphere where fact based decisions can be made and decision makers will have the trusted data when it's needed, where it's needed and in the most useful form. Solving problems will be based on a total picture.

3. Characteristics of Smart Factory

As many manufacturers grapple with the myriad organizational and ecosystem-wide changes exerting pressure on their operations. The smart factory offers is a flexible system that can self-optimize performance across a broader network, self adapt to and learn from new conditions in real or near-real time, and autonomously run entire production processes. Responsive, adaptive, connected manufacturing 5 ways that can successfully address some of those issues. The ability to adjust to and learn from data in real time can make the smart factory more responsive, proactive, and predictive, and enables the organization to avoid operational downtime and other productivity challenges. (Ref Fig 3)

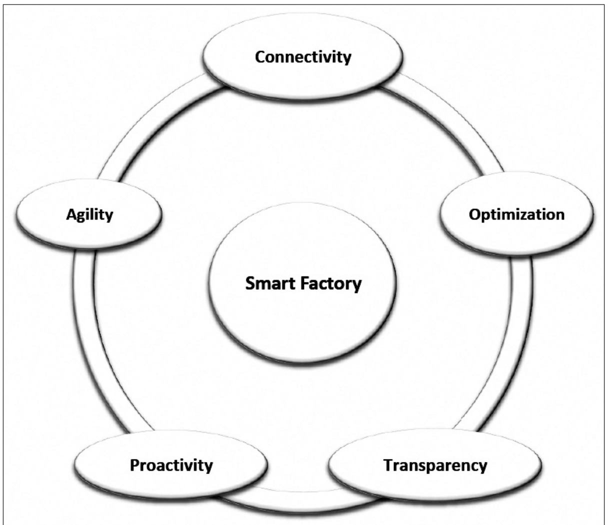

Fig. 3. Characteristics

Figure 3 depicts the smart factory and some of its major features: connectivity, optimization, transparency, proactively, and agility. Each of these features can play a role in enabling more informed decisions and can help organizations improve the production process. Proposed characteristics of smart factories are given below.

- **Connectivity:** Most important feature of the smart factory, its connected nature. Smart factories require the processes and materials to be connected to generate the data necessary to make real-time decisions through smart sensors.

- **Optimization:** An optimized smart factory allows operations to be executed with minimal manual intervention and high reliability. The automated workflows, synchronization of assets, improved tracking in the smart factory can increase yield, uptime, and quality, as well as reduce costs and waste.

- **Transparency:** In the smart factory, the data captured are transparent. A transparent network can enable greater visibility across the facility and ensure that the organization can make more accurate decisions.

- **Proactivity:** A proactive system, employees and systems can anticipate and act before issues or challenges arise, rather than simply reacting to them after they occur. The ability of the smart factory to predict future outcomes based on historical. Identifying anomalies, restocking and replenishing inventory, identifying and predictively addressing quality issues and enabling the Digital twin.

- **Agility:** Agile flexibility allows the smart factory to adapt to schedule and product changes with minimal intervention. Agility can increase factory uptime and yield by minimizing changeovers due to scheduling or product changes and enables flexible scheduling.

4. Architecture of Smart Factory

The Smart Factory architecture serves as solution pattern for the conception of modern production plants, which are characterized by mechatronic changeability, individualized mass production and internal and external networking. The system architecture is complemented by a set of cross-manufacturer specifications on mechanical, electromechanical and information technology – related aspects, which were developed, applied and demonstrated by means of example of the pilot plant of Smart Factory.

In the context of Industry 4.0, the intelligent manufacturing attracts enormous interest from government, enterprises and academic researchers. According to the paper [3] by Baotong Chen, the architecture of smart factory is explained in the terms of hierarchy category. Every step is categorized based on the hierarchy of the use in factory. In figure 4 we can the hierarchy based smart factory architecture.

Based on the architecture of the Smart Factory, it

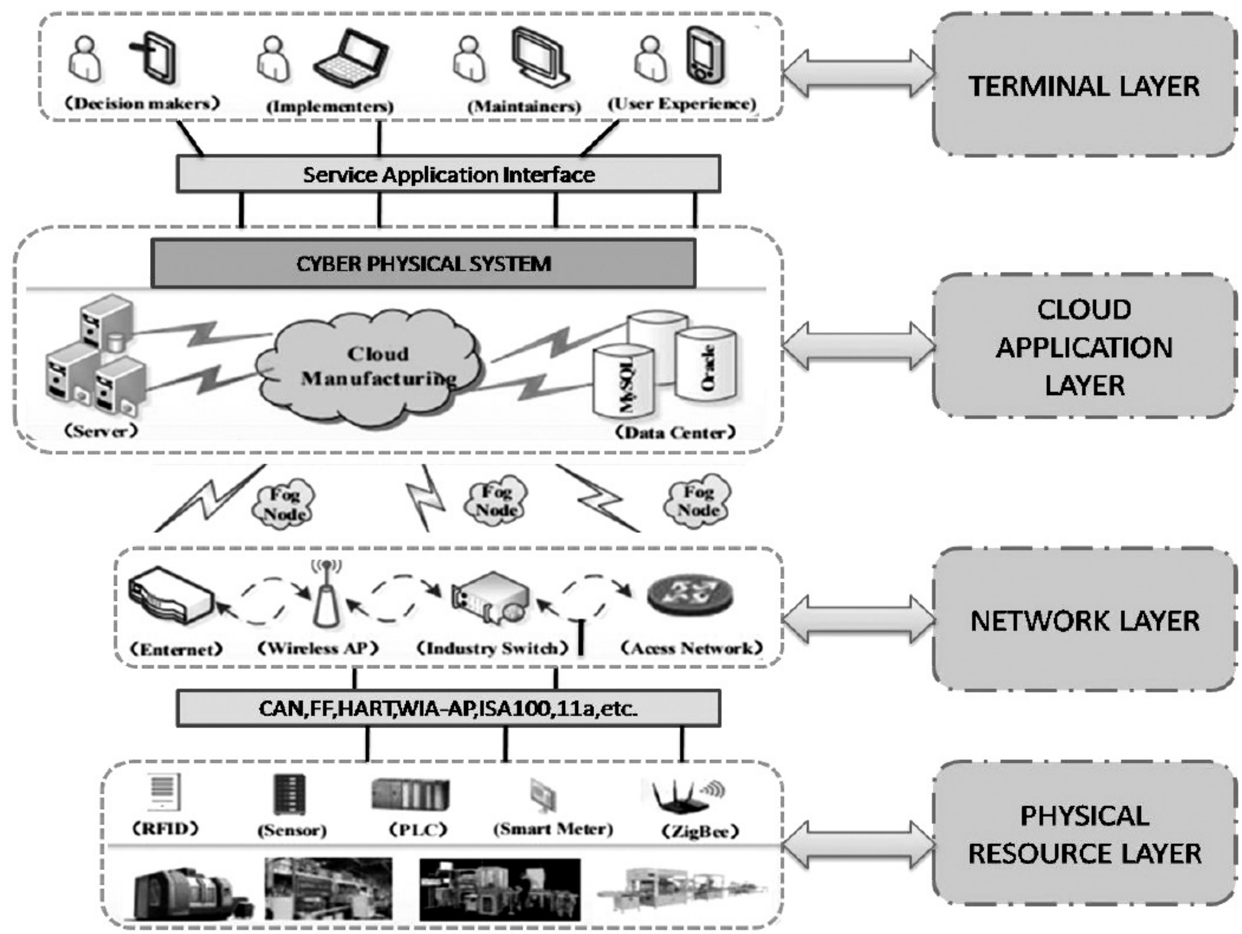

Fig. 4. Architecture of smart factory in hierarchical form

can be divided into 4 parts:

- Physical Resource Layer
- Network Layer
- Cloud Application Layer
- Terminal Layer

i. Physical Resource Layer

The physical resources include all manufacturing resources involved in the entire life cycle of manufacturing, which represent the basis for achievement of intelligent manufacturing. The efficient manufacturing of customized products puts forward new demands on manufacturing equipment, production line and data acquisition. Therefore, to meet the requirements of smart factory, present problems of key technologies should be solved.

ii. Network Layer

Industrial networks represent the integration of various kinds of network technologies such as field bus and sensor networks. The network layer, which is characterized by perception and control, plays an important role in the smart factory. Due to the improvements of cloud computing technology, real-time and reliable network techniques are required for data transmission, information sharing between intelligent equipment, and manufacturing cloud platform. The advanced information technologies (e. g., IWSNs and field bus) and their related technologies provide an important way to meet above mentioned requirements. Field buses (e. g., Foundation Field bus (FF), Profibus, and Hart) gradually meet enterprise requirements of open, universal and compatible networks, and most of them have already been standardized [3], [4]. However, there are still many issues such as routing, congestion control, errors handling and segmentation technology in network layer. The IWSNs and the other related technologies involved in the smart factory are discussed in the Fig. 4.

iii. Data Application Layer

The essence of data application is to discover knowledge from data resources and build the industrial value chain. The industrial big data mainly include structured data and semi-structured data. As data mining technology advances, data-driven innovation will further promote intelligent manufacturing.

Considering the large amount of manufacturing resources, resources concept may vary among different perspectives. A formal description is presented by ontology for domain knowledge. Namely, ontology is a semantic representation of related concepts and their relationship in intelligent manufacturing. It is significant to construct the ontology for knowledge sharing, reuse, and reasoning.

5. Features of Smart Factory

Some of the features of smart manufacturing we regarded for the implementing in real life factories are:

- **People As a Key Player**
  Increasing the level of individualization of the work environment through Digitization and intelligent design of workplace

- **Distributed Intelligence**
  Automation integrated software perform the task independently and make autonomous decision through decentralized intelligence.

- **Open standards**
  The seamless exchange of information in value-creation networks through horizontal as well as vertical integrations of different manufacturers possible by Open standards

- **Virtual real-time representation**
  Virtual real-time representations across the entire value creation process of their physical counterparts and provide information for continuous process improvement in real-time

- **Fast integration & flexible configuration**
  With Plug and Produce, people, machines, processes and the flow of goods are networked together.

- **Digital life-cycle management**
  Digitizing the life cycle management through the networking of all machines and automation from their development and production to recycling part.

6. Challenges in Smart Factory Implementation

For implementing any new technology in well established or traditional setting there will be new difficulties and challenges for its establishment. Some of challenges which are described are from the paper [2] when they observed the working of the factory.

1. People Challenges

- Lack of common vision for understanding the concept of Smart Factory
- Complexities are introduced by attachment to the prior generation of production technologies and the perceived threat to established competencies

2. Technology Challenges

- The technology is highly complex in nature, creating an uncertain business case for implementation.
- The cost is very high for smart factory implementation.

3. Process Challenges

- Manufacturing companies facing difficulties in changing traditional routines and work process to affect the digital transformation.
- Modern business transformation models are needed to enable transformation and to attract people.

Based the point of view of technological changes that has to make in factory, some challenges are describe below

1. **Intelligent Requirements of Equipment:**
   To monitor and control the underlying manufacturing resource for reconfiguration of production line, dynamic scheduling, and information fusion in smart factory it is necessary to improve the intelligence level of manufacturing equipment

2. **Deep Integration Networks:**
   Deep integration of information and industrialization are achieved through IWSN (Industrial Wireless Sensor Network).Limited energy, energy efficiency is a key issue that affects the deployment of IWSNs.

3. **Knowledge-Driven Manufacturing:** The knowledge-driven manufacturing brings opportunities to transformation from traditional industry to intelligent industry. The data mining technology is a serious challenge to enterprises

Since the smart factory's diversity and scope means that expert customization is your key requirement. Look for a professional retailer of programmable logic for smart manufacturing. Their products have to work across many industries and integrate a huge variety of information flows, from the back office to visualization and control systems on the factory floor. For applications where off-the-shelf products do not quite fit, you need a partner who offers modified-standard and full-custom designs, tailored to the individual demands of your application. You should also make sure that you get the same high quality, ruggedness and longevity that are offered in comparable standard based products.

One of the mainly seen challenges even for implementing the simple smart factory setup, Integration of Hardware and Software's of different Manufactures into a System is quite difficult and the problem of Return of Investment.

7. Conclusion

Industry 4.0, Smart factories and Smart Machines continue to drive dramatic efficiency improvements across the supply chain, within the factory and inside machines. Advances in connected sensing technologies will help provide valuable information to reduce energy consumption, save time, reduce waste, reduce downtime and prevent accidents.

We can conclude that the Smart Manufacturing is important in coming future because, for Creating this manufacturing revolution requires significant collaboration among companies, governments, and academic institutions. The EU and the United States, they have set up initiatives to fund and encourage smart manufacturing. In a global initiative, the industrial internet consortium is sponsoring a number of pioneering collaborative projects, called testbeds, which focus on different steps of the manufacturing process.

- For example, Infosys, working with Bosh, PTC, and Intel, are collaborating on an effort called the asset efficiency testbed.

We have discussed some of the features of the smart factory which makes it unique and later discussed the architecture as well as the challenges that can be viewed while implementing the smart factories.

Now for we discuss the some of the already implemented smart factories. They are:

- GE's Brilliant Factory
- Airbus: Smart Tools and Smart Apps
- Siemens' Amberg Electronics Plant (EWA)

For smart factory to improve big data technology with intelligent manufacturing should be used and company must develop their own model smart factory implementation with three guiding principles in mind: cultivate digital people, introduce agile processes, and configure modular technologies to optimize production.

References

1. Sjödin, David; Parida, Vinit; Leksell, Markus; Petrovic, Aleksandar: Smart Factory Implementation and Process Innovation: A Preliminary Maturity Model for Leveraging Digitalization in Manufacturing, 'Research Technology Management', vol. 61, no. 22-31, 2018, 10.1080/08956308.2018.1471277.
2. Yoon, Soocheol; Um, Jumyung, Suh, Suk-Hwan; Stroud, Ian; Yoon, Joo-Sung: Smart Factory Information Service Bus (SIBUS) for manufacturing application: requirement, architecture and implementation. 'Journal of Intelligent Manufacturing', 2016 10.1007/s10845-016-1251-9.
3. Gilchrist, Alasdair: 'Industry 4.0', 2016 10.1007/978-1-4842-2047-4.
4. Chen, B; Wan, J; Shu, L; Li, P; Mukherjee, M; Yin, B: Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges, 'IEEE Access', vol. 6, 2018, 6505-6519, .
5. Capgemini: Smart factories: How can manufacturers realize the potential of digital industrial revolution. May 17. https://www.capgemini.com/resources/smart-factorieshow- can-manufacturers-realize-the-potential-of-digitalindustrial/, 2017.
6. Brettel, M; Friederichsen, N; Keller, M; Rosenberg, M: How virtualization decentralization and network building change the manufacturing landscape: An industry 4.0

perspective, 'Int. J. Mech. Ind. Sci. Eng.', vol. 8, no. 37-44, 2014.

7. Wan, J; Zhang, D; Sun, Y; Lin, K; Zou, C; Cai,H: VCMIA: A novel architecture for integrating vehicular cyber-physical systems and mobile cloud computing, 'Mobile Netw. Appl.', vol. 19, no. 2, 153-160, 2014.
8. Lasi, H; Fettke, P; Kemper, H-G; Feld, T; Hoffmann, M: Industry 4.0, 'Bus. Inf. Syst. Eng.', vol. 6, no. 4, 239-242, 2014.
9. Zhou, J; Intelligent manufacturing-main direction of 'Made in China 2025', 'China Mech. Eng.', vol. 26, no. 17, 2273-2284, 2015.
10. Blackburn, M; Alexander, J; Legan, JD; Klabjan, D: Big data and the future of R&D management, 'Research-Technology Management', vol. 60, no. 5, 2017, 43–51.
11. Braun, V; Clarke, V: Using thematic analysis in psychology, 'Qualitative Research in Psychology', vol. 3, no. 2,2006, 77–101.
12. Gopalakrishnan, S; Bierly, P; Kessler, EH: A re-examination of product and process innovations using a knowledge-based view, 'Journal of High Technology Management Research', vol. 10, no.1, 1999 ◘

Muhammad Nabil K M is Student, M-tech (Mechatronics), VIT, Vellore. He obtained B-Tech in Mechanical Engineering from Anna University, Chennai. His areas of Interest are – Machine Learning, Mechatronics - Design, and Intelligent Systems. He has published paper on Design and Implementation of Smart Motorcycle Helmet for Obstacle Awareness at 13th International Conference on Science, Engineering and Technology (ICSET)-2018.

Hare Prasad P is Student, B-Tech (Mechatronics), Kongu Engineering College, Erode. His areas of Interest are- Automotive Engineering and Microcontroller applications. He has published paper on Increasing Wear Resistant of Electrical Contacts By Protective Coating at National Journal of Technology, Vol. 15 Issue 2, June 2019.

T Narendra Reddy is working as Scientist, Nano Manufacturing Technology Centre (NMTC), Central Manufacturing Technology Institute (CMTI). Areas of interest: Product development on nano accuracy machines & measurement systems

Prakash Vinod is working as Scientist, Head of Nano Manufacturing Technology Centre (NMTC), Central Manufacturing Technology Institute (CMTI). Areas of interest: Design & Development of nano accuracy machines & measurement systems, Machine tool testing, Noise & Vibration analysis for product development.

Senthil Kumar S is presently working as Associate Professor, Department of Design & Automation, VIT University, Vellore. He obtained his Bachelor of Engineering (B.E.) Mechanical Engineering in First Class from Government College of Engineering, Salem. He perceived his Doctor of Philosophy (Ph.D.) in Mechanical Engineering from VIT University, Vellore, India. His area of interest includes Fundamental Research in Engineering & Technology. He has published a paper on Acoustic emission–based monitoring approach for friction stir welding of aluminum alloy AA6063-T6 with different tool pin profiles at Proceedings of the Institution of Mechanical Engineers Part B Journal of Engineering Manufacture, March 20, 2013.

Thangavel S is presently working as Assistant Professor of Mechatronics Engineering in Kongu Engineering College. His area of specialization includes MEMS, Relay logics, IoT, Servo control and Electrical Machines. He has published two papers: 1)."Design of Capacitive MEMS accelerometer for Hand arm vibration", ICBDM-2014. 2)."Sitting posture health monitoring for scoliosis patients using capacitive micro accelerometer", International Conference On Nanomaterials and Nanotechnology, 2015.