

Design and Development of Advanced Mechanical Systems

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Abstract--- To increase efficacy and individual pleasure, researchers and experts have been using fundamental concepts from nature to create the current plans or frameworks. Imported from nature, the invention also aids in the development of innovative designs and systems as well as new advancements in dazzling materials created by humans. Smart materials are basically materials that respond to their environment and convert energy between multiple physical fields. Here, smartness describes the presence of self-adaptability, possessing memory, self-sensing and self-repairing characteristics. These developments are being made in order to satisfy current demands and upcoming advancements in the mechanical area. The kind of MEMS item to be manufactured, the type of assembling and portrayal hardware, and the concept of these devices in relation to the powerful, fluid, and vaporous information sources they consume and debilitate they discharge are all necessary for the reasonable plan of the MEMS cleanroom. The construction, transportation, development, activity, and maintenance associated with coordinated air maintenance of units, walls, fixtures, and cleanroom drawing are all economically designed in light of this URS.

Keywords--- Mechanical System, Micro-electro Mechanical Systems, Cleanrooms.

Received: 02 - 01 - 2024; Revised: 20 - 01 - 2024; Accepted: 02 - 02 - 2024; Published: 29 - 03 - 2024

I. Introduction

The most recent technological revolutions have mostly been characterised by the ongoing advancements in productivity, profitability, and quality across all industries and sectors. When discussing sophisticated technology, intelligent manufacturing refers to the full integration of the factors that affect productivity and quality, which is maintained inexpensively, operates efficiently, has no downtime, and runs continuously and unhindered (Midolo et al., 2018). In addition to causing financial losses, a system outage may also indicate that the system is not functioning reliably. The cost of unreliability is widely known to those employed in the aerospace, nuclear power generation, defence, and space industries. Nonetheless, reliability engineering can be crucial in enhancing the dependability and accessibility of systems in these industries. Reliability engineering techniques are applied throughout the product lifecycle, beginning with the conceptual stage of product design. Reliability engineering is actually a synthesis of numerous scientific and technological fields. It includes methods and approaches for analysing the system's performance and the reasons behind malfunctions (Gupta & Pal, 2019). As a result, dependability procedures are becoming an increasingly important component of product development. Additionally, even after the prototype model is realised, there is always room to increase the product's reliability; however, doing so at the expense of a higher cost and a longer timeline is always preferable to waiting until the product is manufactured (Kavallaris et al., 2018). The golden rule of dependability is to replace components as soon as they fail within their useful lives and to replace every component before they reach the end of their useful lives, even if they haven't failed yet. In the context of reliability, a system is a collection of subsystems (or parts) put together in accordance with a certain design to accomplish a shared goal with performance standards and dependability metrics. A system failure, often referred to as a breakdown, happens when its operation is significantly hindered, falls short of its specifications, or stops entirely. Numerous random and unpredictable processes inside the system and the environment in which it operates can lead to system failure. The system is examined at prearranged intervals as part of preventive maintenance. When necessary, the minor components are then repaired or replaced (Aderibigbe et al., 2023). In order to safeguard and preserve the system's acceptable quality, preventive maintenance is planned. Inspection and repair, replacement, lubrication, waxing, retightening, adjustment, alignment, painting, chemical solution monitoring, and other clearly defined operations are all included. The goal is to plan ahead in order to keep costs as low as possible.

II. Background of the Study

The assumption of a constant rate is rarely met in practical situations. For instance, the number of incoming calls varies depending on the time of day. However, the exponential distribution can serve as a good approximation for the duration until the next phone contact arrives if we concentrate on a time period where the rate is approximately constant, such as 2 to 4 p.m. on workdays. Failure is defined as the inability to function or to perform to a satisfactory level Figure 1. There was always failure, and it was proportionate to the size of the industrial systems. The bath-tub curve can detect the failure's behaviour. It tracks the failure behaviour of a sizable sample of uniform objects that enter the field at a specific start time, which is often zero. Three different shapes or periods can be seen if we look at the things over the course of their lifetime without replacement. The bath-tub curve and these three periods are depicted in the figure. The section on early failures demonstrates that the population will first encounter a high hazard function before beginning to decline. This time frame is known as the burn-in or debugging phase, during which time weak points are eliminated. The surviving population reaches a comparatively constant hazard function period, sometimes referred to as the useful life period, following the initial phase, when the weak components have been eliminated and errors fixed (He et al., 2023).

As you can see from the graphic, the hazard function is constant. When failures happen at random across time, the exponential distribution can be used to model this form. The wear-out phase, the last section of the bath-tub curve, is when the danger function rises with time. The interval between events in a Poisson process is described by an exponential distribution. The most prominent statistical characteristic that makes it the most commonly employed in reliability studies is its absence of memory attribute. Reliability theory has modified it to model the bathtub curve's constant hazard rate component. It works well for adding failure rates to a reliability model. An exponential distribution is not appropriate for modelling the whole lifespan of technological devices or organisms since failure rates are not constant, and more failures occur at the early or wear-out phases of a system's operation. The time it takes to finish a service at a petrol station, auto repair shop or grocery store is the random variable under study. The exponential distribution is employed in practice (De Pasquale, 2021). Reliability theory uses an exponential distribution to model the distribution of time between consecutive random events, such as the interval between two customers' consecutive job arrivals at a computer centre, the interval between a radioactive particle's decay or a Geiger counter's beeps, the number of dice rolls required to roll a six eleven times in a row, the interval between phone calls or machine breakdowns, or the lifespans of wear-prone parts like transistors, bulbs, tubes, batteries, etc.

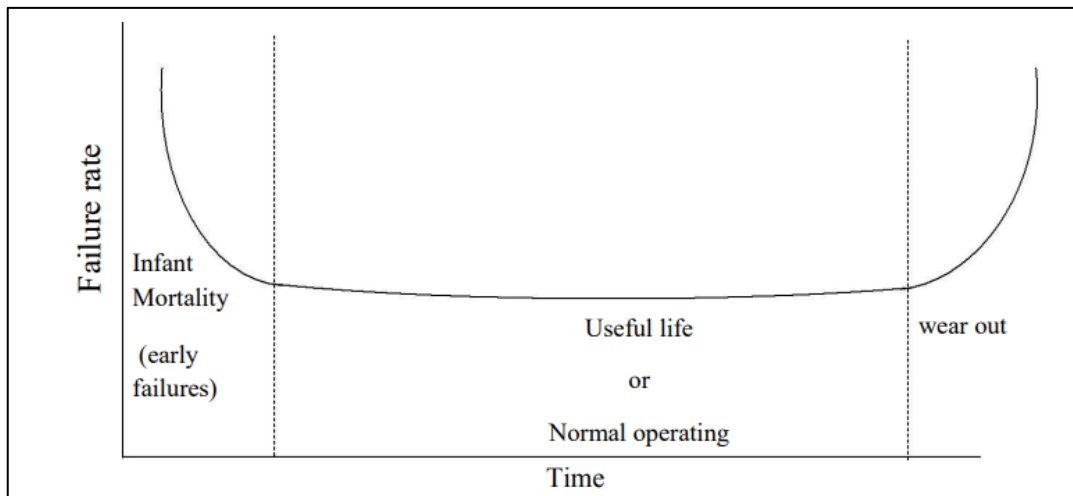


Figure 1: Failure Analysis

III. Methodologies

The kinds of components utilised, their numbers, and the way they are grouped in the design all affect how well the system performs. By breaking a system down into manageable-sized subsystems, each of which has a distinct function, a system can be examined. System structure is the graphical representation of components ordered according to a certain design in order to achieve specified functionalities. It could be a basic or complicated system. The system can be simplified if the units are set up in parallel or pure series. Nevertheless,

some systems are too complicated or have a combination of parallel and series configurations to be broken down into groups of parallel and series configurations (Adegbite et al., 2023).

3.1. Design Frame Work

In a series configuration, the system's reliability is equal to the product of the reliabilities of its individual parts. The component that affects the system's dependability the most in a series configuration is the one with the lowest reliability. The proverb "a chain is only as strong as its weakest link" is aptly illustrated by this instance. All of the rings in a chain are connected in series, and the system collapses if one of them breaks. Furthermore, the chain's weakest link is the one that will break first. Similar to how the weakest link determines the chain's strength, the weakest component determines a series system's dependability. Because of this, a series system's reliability is always lower than that of its least dependable component. From the perspective of dependability, a group of components is said to be in parallel if just one of them must function for the system to succeed or if all of them must fail for the system to fail. Another name for parallel units is redundant units. One crucial component of system design is redundancy. Redundancy is one of various strategies to increase system reliability (Mehmood et al., 2018). It is widely used in the automotive break systems, computer memory systems, power generator systems, and aircraft engine systems. For a system with statistically independent parallel components, the likelihood that unit 1 will fail, unit 2 will fail, and all of the other units in the system will fail is the probability of failure or unreliability. In a parallel system, all of the units must fail for the system to fail. To put it another way, the system is successful if either unit 1 or unit 2 or any of the units are successful Figure 2.

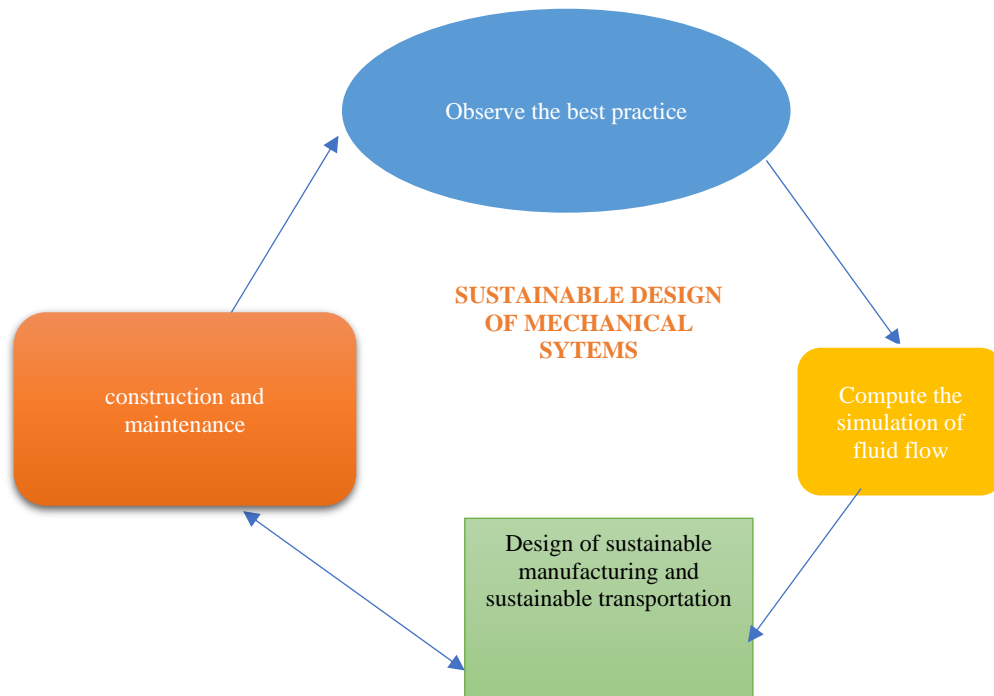


Figure 2: The Proposed Sustainability Design Framework

3.2. Components of the Framework

The main goal of the current work is situated in the centre of this framework, and the immediate and general sub-objectives are represented in the adjacent boxes on the next level, which are numbered 1 through 6. The work flows in a clockwise manner. Additionally, each sub-objective box's design element is further enhanced by tertiary level action items that are recorded in the boxes at the framework's outermost edge. For instance, the fifth sub-objective describes how to build and validate a clean room using the right materials and achieve energy efficiency (Zha, 2007). This sub-goal is accomplished by the action items listed in boxes 5.1 to 5.3, which are, respectively, the design of suitable lighting and recessed areas, the design of walls and panels that can be customised with the least amount of waste, and the design of enclosures to separate the uses of polyurethane foam and machines (Faudzi et al., 2020).

IV. Results and Discussion

Mathematical and statistical technique for analysing several input factors and determining the best process variables (response) for a particular input. Low and high numbers can be used to indicate these points. With star and centre points, it has a 2k factorial. This allows for the usage of both coded and uncoded components. The intermediate level is designated as "0," while the maximum and minimum levels are designated as "-1" and "+1," respectively. The experimental data was validated using ANOVA analysis. R2 analysis, the least squares approximation, and residual plots used to predict the significant input parameters with confidence levels were all included.

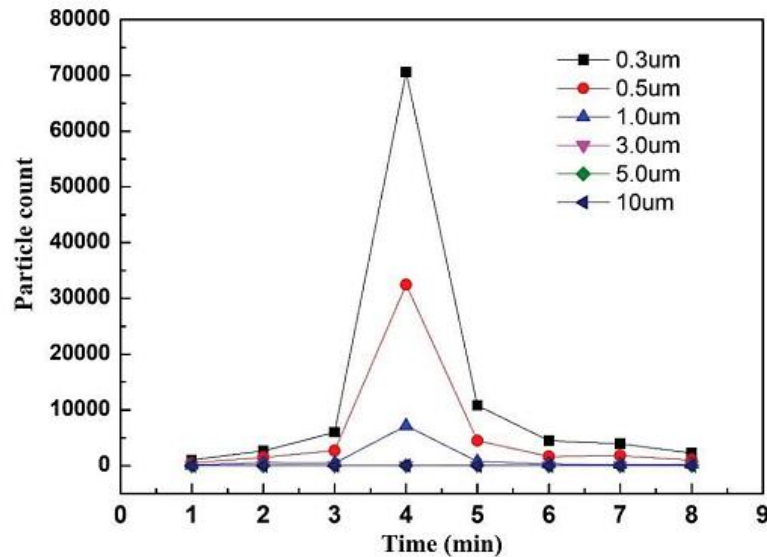


Figure 3: System Efficiency

The number of molecules at the objective region in Figure 3 for molecule sizes of 0.3 μm , 0.5 μm , and 1.0 μm was initially low until the pollutant particles came at the objective and underwent the appropriation process; after that, the number of molecules steadily increased. Eventually, the molecule counts progressively retreated and returned to the normal count because the ideal air provided by the FFUs continued to remove the particles. It takes about four minutes for the molecule count for all molecule sizes to reach its maximum.

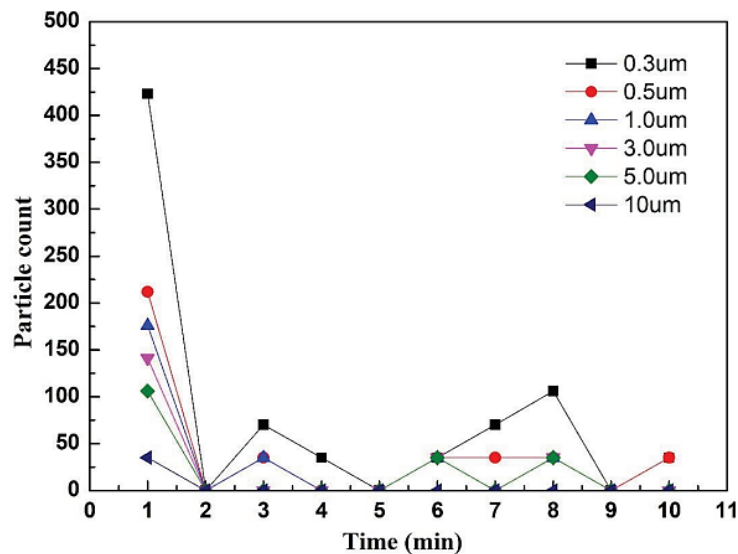


Figure 4: System Efficiency in Particle Count

As should be evident in Figure 4, the most extreme value of all particles shoots up to the greatest speed at the objective and then continuously considers the descent time advances because the objective region 1 is farther away from the molecule generator.

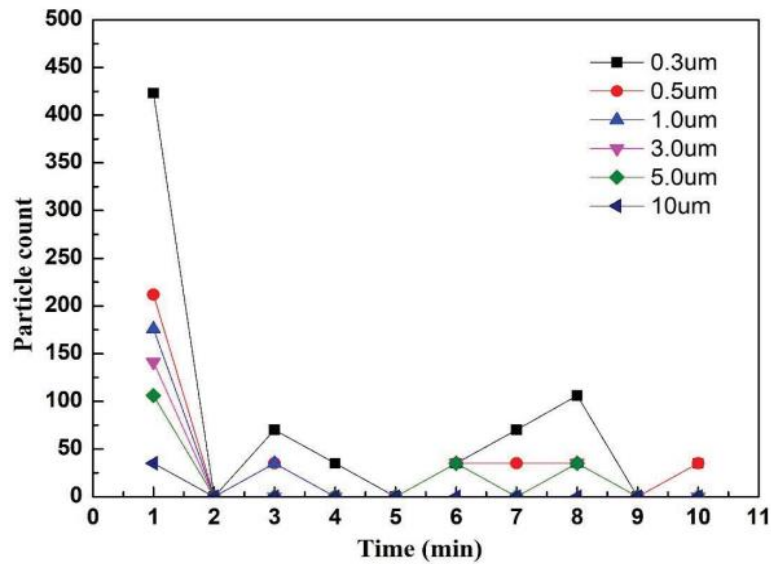


Figure 5: Throughput Analysis

Any molecule traveling from the source to the target sees five possible air changes per minute, which greatly reduces the possibility that it will reach the objective because the air in the lithography room travels from the top to the lower portion of the room of level 2.4 m in just 12 seconds Figure 5.

V. Conclusions

A controlled environment where the temperature, moisture content, and toxic particles are maintained within the bounds recommended by ISO norms is necessary for the assembly of very precise, highly responsive, and minimally measurable objects. The main reason composite materials are important in many scientific and technical fields today is because of their special mechanical and physical response properties, which include fatigue resistance, specific strength, light weight, and fracture toughness. Their usefulness in comparison to traditional materials is increasing daily. The hybrid fibre reinforced polymer composites that might be utilised as a leaf spring in car suspension systems and ballistic applications are the main focus of this study. The key characteristics that encourage these materials to be used into suspension systems are their rigidity, capacity to absorb impact forces, and ease of machining. The originality of this inquiry is demonstrated by the merging of several engineering studies, material combinations, and machining optimization.

References

- [1] Midolo, L., Schliesser, A., & Fiore, A. (2018). Nano-opto-electro-mechanical systems. *Nature nanotechnology*, 13(1), 11-18. <https://doi.org/10.1038/s41565-017-0039-1>
- [2] Gupta, A., & Pal, P. (2019). Micro-electro-mechanical system-based drug delivery devices. In *Bioelectronics and medical devices* (pp. 183-210). Woodhead Publishing. <https://doi.org/10.1016/B978-0-08-102420-1.00010-8>
- [3] Kavallaris, N. I., Suzuki, T., Kavallaris, N. I., & Suzuki, T. (2018). Micro-electro-mechanical-systems (MEMS). *Non-Local Partial Differential Equations for Engineering and Biology: Mathematical Modeling and Analysis*, 3-63. https://doi.org/10.1007/978-3-319-67944-0_1
- [4] Aderibigbe, A. O., Ohenhen, P. E., Nwaobia, N. K., Gidiagba, J. O., & Ani, E. C. (2023). Advanced sensing techniques in electro-mechanical systems: surveying the rise of smart sensors and their implications for system robustness. *Engineering Science & Technology Journal*, 4(6), 323-340. <https://doi.org/10.51594/estj.v4i6.628>

- [5] He, Y., Yu, A., Liu, X., & Wang, Y. (2023). Micro Electro-Mechanical Systems (MEMS). In *Handbook of Integrated Circuit Industry* (pp. 895-911). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-99-2836-1_48.
- [6] De Pasquale, G. (2021). Additive manufacturing of micro-electro-mechanical systems (MEMS). *Micromachines*, 12(11), 1374. <https://doi.org/10.3390/mi12111374>
- [7] Adegbite, A. O., Nwasike, C. N., Nwaobia, N. K., Gidiagba, J. O., Ilojiana, V. I., & Dawodu, S. O. (2023). Electro-mechanical system reliability and fail-safe designs: evaluating the best practices for ensuring system robustness and longevity. *Engineering Science & Technology Journal*, 4(6), 438-455. <https://doi.org/10.51594/estj.v4i6.666>
- [8] Mehmood, Z., Haneef, I., & Udrea, F. (2018). Material selection for micro-electro-mechanical-systems (MEMS) using Ashby's approach. *Materials & design*, 157, 412-430. <https://doi.org/10.1016/j.matdes.2018.07.058>
- [9] Zha, X. F. (2007). A web-enabled open database system for design and manufacturing of micro-electro-mechanical systems (MEMS). *The International Journal of Advanced Manufacturing Technology*, 32, 378-392. <https://doi.org/10.1007/s00170-005-0336-y>
- [10] Faudzi, A. A. M., Sabzehmeidani, Y., & Suzumori, K. (2020). Application of micro-electro-mechanical systems (MEMS) as sensors: A review. *Journal of Robotics and Mechatronics*, 32(2), 281-288. <https://doi.org/10.20965/jrm.2020.p0281>