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The contribution of mechanical engineering to the efficient development and production of medicines: a multidisciplinary approach

The contribution of mechanical engineering to the efficient development and production of medicines: a multidisciplinary approach

Juliano Augusto Pereira

Undergraduate in Mechanical Engineering, São Judas University

SUMMARY

Mechanical engineering, commonly associated with traditional sectors such as the automotive and energy sectors, is essential for the pharmaceutical industry, being responsible for more efficient, safe and sustainable manufacturing processes. This article analyzes, from a multidisciplinary perspective, the role of mechanical engineering in drug production, addressing machine development, process automation, environmental control and the future challenges of Industry 4.0. Based on literature reviews and recent studies (BERTOLINI, 2010; LANGER, 2017; SILVA; OLIVEIRA, 2020), it is highlighted how the integration between engineering and pharmacology is crucial for innovation in the health area. It is concluded that advances in drug production depend directly on the technological development promoted by mechanical engineering.

Keywords: Mechanical Engineering; Pharmaceutical Industry; Drug Production; Technological Innovation; Industry 4.0.

ABSTRACT

Mechanical engineering, commonly associated with traditional sectors such as the automotive and energy sectors, is fundamental to the pharmaceutical industry, being responsible for more efficient, safe and sustainable manufacturing processes. This article analyses, from a multidisciplinary perspective, the role of mechanical engineering in the production of medicines, addressing the development of machines, process automation, environmental control and the future challenges of Industry 4.0. Based on literature reviews and recent studies (BERTOLINI, 2010; LANGER, 2017; SILVA; OLIVEIRA, 2020), it is highlighted how the integration between engineering and pharmacology is crucial for innovation in the health area. It is concluded that advances in the production of medicines depend directly on the technological development promoted by mechanical engineering.

Keywords: Mechanical Engineering; Pharmaceutical Industry; Production of Medicines; Technological Innovation; Industry 4.0.

1 INTRODUCTION

The development and production of medicines are activities that involve a high degree of complexity, requiring rigorous standards of quality, safety and efficacy. In this context, mechanical engineering plays a decisive role, being responsible for the design of equipment and systems that enable pharmaceutical production processes (BERTOLINI, 2010).

When thinking about pharmaceutical production, it is common to focus only on the chemical and biological aspects. However, without the proper infrastructure of high-precision machines, automated systems and controlled environments, it would be unfeasible to manufacture medicines on a large scale with the quality required by regulatory bodies. Thus, mechanical engineering transcends its traditional role and becomes a key element in the drug production chain.

This article proposes an in-depth analysis of this interrelationship, discussing how mechanical engineering influences each stage of the pharmaceutical process and pointing out challenges and future perspectives.

2 FUNDAMENTALS OF MECHANICAL ENGINEERING APPLIED TO INDUSTRY PHARMACEUTICAL

Mechanical engineering, as defined by Câmara (2018), is dedicated to the design, analysis, manufacture and maintenance of systems involving movement and energy. Within the pharmaceutical industry, its activities range from the design of equipment for handling substances to the automation of production lines.

Tablet manufacturing, for example, requires the uniform compression of powders in specially designed machines. Such equipment must ensure not only the correct shape and hardness of the tablets, but also the homogeneity of the dosage of active ingredients (LANGER, 2017).

Furthermore, the design of air conditioning systems, contamination control, internal transport of materials and automatic cleaning are examples of how mechanical engineering is present in the daily life of the pharmaceutical industry.

Knowledge in fluid dynamics, thermodynamics and automatic control are applied to design controlled environments, essential for the production of sterile medicines (SILVA; OLIVEIRA, 2020).

3 TECHNOLOGIES AND MECHANICAL INNOVATIONS IN THE PRODUCTION OF MEDICINES

The search for greater efficiency and safety in the manufacture of medicines has driven the development of numerous technological innovations in mechanical engineering.

Highly automated production lines, for example, rely on precision robots for filling bottles, sealing packages and performing quality inspections (RODRIGUES et al., 2019). Such systems drastically reduce contamination risks and increase productivity.

The Clean-In-Place (CIP) system, as highlighted by Moreira (2021), is one of the essential technologies, allowing the automatic cleaning of production systems, without the need for disassembly, which reduces downtime and increases process safety.

The use of intelligent sensors and real-time control of variables such as temperature, humidity and pressure ensures that ideal production conditions are continuously maintained, increasing the quality of the medicines manufactured.

4 CURRENT AND FUTURE CHALLENGES IN MECHANICAL ENGINEERING PHARMACEUTICAL

Rapid technological evolution imposes new challenges on mechanical engineering in the pharmaceutical sector. Among them, the need to adapt to the demands of Industry 4.0, characterized by the integration of physical and digital systems (KAGERMANN, 2015), stands out.

Personalized drug production, also known as precision pharmaceuticals, requires flexible equipment capable of adapting to small batches and mass customization (PEREIRA; GONÇALVES, 2020).

Another challenge is the growing need for sustainability. Reducing water and energy consumption, as well as reducing waste generation, have become essential objectives for the modern pharmaceutical industry.

Furthermore, training mechanical engineers to deal with artificial intelligence, big data and predictive maintenance is essential to ensure the competitiveness of pharmaceutical companies.

5 CONCLUSION

The convergence between mechanical engineering and the pharmaceutical industry is a consolidated and vital reality for contemporary society. Without the contribution of engineering, it would be unthinkable to achieve the levels of quality, safety and productivity required for the manufacture of modern medicines.

The work of mechanical engineers, although often invisible to the general public, is crucial to the advancement of medicine and access to quality healthcare. High-precision machines, automated systems, controlled environments and sustainable solutions are born from the expertise and innovation brought by these professionals.

With the rise of Industry 4.0, new horizons are opening up, requiring even more interdisciplinary training, which combines solid foundations in mechanics with knowledge in information technology and sustainability.

In short, mechanical engineering not only participates in, but also plays a leading role in the future of pharmaceutical production, consolidating itself as a strategic pillar for the promotion of public health and innovation in medicine.

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