

Design and Manufacturing: An Industry 4.0 Perspective

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Industrial investments include the use of advanced technologies which refine, accelerate, improve quality, and boost stakeholder profitability. As part of the Industry 4.0 strategy, a number of methods and technologies can be applied in order to provide a solid basis for improvements in all aspects of a product's lifecycle, including the following:

- Computer-Aided Design and Manufacturing (CAD/CAM) system integration and Computational Design Engineering (CDE);
- Implementation of Flexible Manufacturing Systems (FMSs) with improved performance based on appropriate parameter optimization, as well as Discrete Event Simulation (DES), computer-based simulations which support FMS implementation, application of digital twin (DT) technology for real-time optimization, and Industry 5.0 transformation.
- Additive Manufacturing (AM) and 3D printing technologies are attracting interest in numerous design and manufacturing engineering areas, including textiles, fashion-related product design, robotic arms, furniture design and manufacturing, etc.
- Business models, the Circular Economy (CE), and Human-Centric Design are also important aspects, along with topology optimization (TO) and finite element analysis (FEA).
- Human-machine interaction using different technologies, i.e., Internet of Things (IoT), Virtual and Augmented Reality (VR and AR), Artificial Intelligence (AI), and Genetic Algorithms (GAs), is also a key consideration.

All of the above factors, among others, offer considerable opportunities for transforming the traditional ways of product design and manufacturing towards more innovative computer-based ways of working. The processes of design and manufacturing have undergone great change, and so to has the work of researchers, engineers, and academics regarding the incorporation of high-end applications into all stages of the product lifecycle (PL), helping to shape the future of industry by creating both new opportunities within specific sectors and new challenging demands [1–3].

A novel conceptual classification based on a multi-objective simulation–optimization (MOSO) method is presented by Jerbi et al., with the aim of designing improved FMSs. Four MOSO alternatives are selected, implementing the Design of Experiments (DoE) principles. Meta model-based approaches use Goal Programming (GP) and Desirability Function (DF). The rest integrate Gray Relational Analysis (GRA) and the VIKOR method. The results prove that GP and the VIKOR method can, in some cases, provide improved performance compared to the DF and GRA methods.



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An evaluation of the effect of various 3D printed geometries on textile fabric regarding fabric drapes is presented in Spahiu et al.'s study. The drape coefficient of a created composite structure is measured. The results obtained are compared with those derived from the application of an algorithm developed for determining drape parameters and 3D form representation using digital color images and their image histograms. The measured drape coefficient values are determined with 4% accuracy.

In their study, Konstantinidis et al. identify the digital footprint of Industry 4.0 in the current manufacturing ecosystem, and a systematic literature survey is conducted. The influence of Industry 4.0 on traditional business models, small- and medium-sized enterprises (SMEs), decision-making processes, human–machine interaction, and circularity affairs are investigated. As a result, research gaps and business opportunities, as well as their relevance to Industry 5.0 principles, are identified.

The development of two different applications for designing furniture based on the Computational-based Visual Brand Identity (CbVBI) design methodology is described by Manavis et al. Two alternatives are used—the Application Programming Interface (API) of the Solidworks™ CAD system (VBA event-driven programming language) and the visual programming language of Grasshopper™, incorporated within Rhinoceros3D™. Integrating the design process and manufacturing technologies via programming and automating the use of CAD systems are steps that can yield a great deal of design alternatives in a very short time.

Fountas et al., in their research, studied multi-objective optimization of three experimental cases with a laser sintering/melting method using a virus-evolutionary genetic algorithm (GA). The results obtained by the proposed algorithm are statistically comparable to those obtained by the Greywolf (GWO), Multi-verse (MVO), Antlion (ALO), and dragonfly (DA) algorithms. This proves that the virus-evolutionary genetic algorithm is superior to the heuristics that were examined, at least on the basis of evaluating regression models as fitness functions.

Sucuoglu is involved with the design of a structurally optimized mobile robotic system. Topology optimization (TO) and finite element analysis (FEA) were applied to reduce the structural weight. The optimized components were manufactured using Fused Deposition Modeling (FDM) with ABS (Acrylonitrile Butadiene Styrene) as material. A custom power analysis tool was developed for energy optimization. The proposed framework reduces total energy consumption by 5.8%, cuts prototyping time by 56%, and extends mission duration by ~20%.

An advanced autonomous HVAC control system tailored for a chemical fiber factory and emphasizing the human-centric principles and collaborative potential of Industry 5.0 is presented by Balasubramani et al. Central to the system's innovation is the integration of digital twins and physical AI, enhancing real-time monitoring and predictive capabilities. A virtual representation runs in parallel with the physical system, enabling sophisticated simulation and optimization. Digital twins facilitate scenario testing and optimization, while physical AI allows the system to learn from real-time data and simulations.

The review presented by Massaro analyzes the Electronic Digital Twin (EDT) tools characterizing the industrial transformation from Industry 4.0 to Industry 5.0. This research article focuses on the possibility of combining industrial machines' advanced technologies, electronics, and mechatronics with Artificial Intelligence (AI) algorithms. It includes perspectives on the limits and advantages of EDTs.

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List of Contributions

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