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Sustainable Living Factories for Next Generation Manufacturing

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Abstract

To be profitable and to generate sustainable value for all stakeholders, next generation manufacturers must develop capabilities to rapidly and economically respond to changing market needs while at the same time minimizing adverse impacts on the environment and benefiting society. 6R-based (Reduce, Reuse, Recycle, Recover, Redesign and Remanufacturing) sustainable manufacturing practices enable closed-loop and multi-life cycle material flow; they facilitate producing more sustainable products using manufacturing processes and systems that are more sustainable. Reconfigurable Manufacturing Systems (RMS) and its characteristics of scalability, convertibility, diagnosability, customization, modularity and integrability have emerged as a basis for living factories for next generation manufacturing that can significantly enhance the system sustainability by quickly adjusting system configuration and production processes to meet the market needs, and maintain the system values for generations of products. This paper examines the significance of developing such next generation manufacturing systems as the basis for futuristic sustainable living factories by adapting, integrating and implementing the RMS characteristics with the principles of sustainable manufacturing to achieve value creation for all stakeholders.

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Keywords: Sustainable manufacturing, Reconfigurable Manufacturing Systems, Value Creation

1. Introduction

Sustainable future, characterized by continuously improved quality of human life in terms of happiness and prosperity, associated with food, shelter, sanitation, education, healthcare, job satisfaction, etc., is fast becoming a necessity while the global and local socio-economic and demographic conditions impose constraints for sustainable

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development which is most commonly defined by economy, environment and society.

Manufacturing has been the engine for wealth generation and societal wellbeing worldwide, thus leading to sustainable living with happiness and prosperity. Technological advances in manufacturing continue to play a crucial role in promoting economic growth and generating societal benefits for decades. Sustainable factories of the future are the basis for industrial growth and prosperity for economic, environmental and societal advancement. Visionary thoughts on designing and developing such factories of the future must also include the concept of living factory where the factory environment can continually be updated, adapted and reconfigured to suit the changing industrial needs and marketability of products to meet societal needs.

A sequence of unrelated global events —both political and technological— that all happened in just 10 years (from 1991 to 2001) initiated the current globalization era, and, in turn, triggered the creation of Reconfigurable Manufacturing Systems, and simultaneously deepened the global attention to sustainability.

During this decade of the 1990s the European Union was created (1992) and NAFTA was formed (1994). India was opened to foreign investments (1991), and China formally opened its borders to industrial investments (2001). In the same decade, the US manufacturing industry started to migrate abroad: Boeing R&D to Russia (1993), and the automotive industry first to Mexico (1994), and then to India (1995) and China (1997) [1].

Globalization has changed dramatically the consumption habits of society. Individual consumption of products grew dramatically during this period, and continues to grow rapidly, which prompted *sustainability* concerns. “In 1961 almost all countries in the world had more than enough capacity to meet their own demand; by 2005 the situation had changed radically with many countries able to meet their needs only by importing resources from other nations. Humanity’s demand has more than doubled over these 45 years” [2]. The surge of globalization in the 1990s enabled nations to meet their needs only by importing resources. The growing demand for consumer products is satisfied using increasingly larger quantities of natural resources. Therefore, at the turn of the 21st Century, product and process sustainability turned out to be a major global concern, which requires innovative solutions.

Sustainable living factories are the future in manufacturing system development as they are technologically advanced, adaptively reconfigurable and are economically advantageous offering significant societal benefits. The capability to produce high volume, low variety products and low volume, high variety products would make such living factories truly versatile and novel.

This paper presents the foundational aspects of developing sustainable living factories of the future beginning with the historical development of Reconfigurable Manufacturing Systems (RMSs), followed by a description of deployable characteristic features of RMS and its architecture. A general outline of Sustainable Manufacturing (SM) and its application to RMS is then presented by showing the compounded benefits of marrying RMS with SM for greater productivity, performance and manufacturing quality for the factories of the future.

2. Reconfigurable Manufacturing System – A Living Factory

2.1. The Emergence of RMS

RMSs emerged in the automotive powertrain industry. Because of the high precision needed in powertrain components (about 10μm), the high-tech segment in automotive production is the powertrain industry that produces engines and transmissions for cars and trucks. There are about 100 powertrain plants in the U.S. and Canada, and these are the most expensive plants (by far more expensive than the automotive assembly plants).

Until the 1990s, most powertrain components were produced on dedicated machining lines (DMLs, often referred to as “transfer lines”). DMLs are designed to produce very large quantities of just one product, at a very high production speed, which yields high productivity. For example, engine blocks of cars are machined on a DML at a cycle time of 30 seconds (two engines per minute). The investment cost of DMLs is relatively low, because (a) the machines that constitute the line are designed to operate only at a fixed cycle of axial motions, and (b) multiple cutting tools can operate simultaneously on each machine, which enables achieving high productivity at low cost.

As long as a dedicated line operates at its planned capacity, it produces many parts at very attractive prices. But what happens when, for example, the price of gasoline is going down, and consumers are buying many General Motors’ (GM) full-sized pickup trucks with V8 engines? In this case GM does not have enough V8 engines to produce enough full-sized pickup trucks to meet the demand. GM not only loses sales and profit, but also loses market share, and a sharp rebound in market share is usually not possible.