

IIoT-Enabled Production System for Composite Intensive Vehicle Manufacturing

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ABSTRACT

The advancements in automation, big data computing and high bandwidth networking has expedited the realization of Industrial Internet of Things (IIoT). IIoT has made inroads into many sectors including automotive, semiconductors, electronics, etc. Particularly, it has created numerous opportunities in the automotive manufacturing sector to realize the new aura of platform concepts such as smart material flow control. This paper provides a thought provoking application of IIoT in automotive composites body shop. By creating a digital twin for every physical part, we no longer need to adhere to the conventional manufacturing processes and layouts, thus opening up new opportunities in terms of equipment and space utilization. The century-old philosophy of the assembly line might not be the best layout for vehicle manufacturing, thus proposing a novel assembly grid layout inspired from a colony of ants working to accomplish a common goal. Value added time per part are compared between the traditional and proposed manufacturing process layout using virtual plant simulation tools. This value added time is directly proportional to operating and capital cost. Moreover, the study proposes real-time multilayer communication that has the potential to vastly improves tasks such as inventory management, proactive/preventive maintenance, inline quality control, flexibility to part variabilities and design development.

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INTRODUCTION

The stringent CAFE [1] standards set forth by the Obama's administration has pushed the automotive industry to radically revolutionize and design lightweight systems using advanced materials such as composites. Despite several outstanding benefits, advanced materials often come with additional costs. Minimizing physical infrastructure and improving efficiency will make the use of these materials affordable. This paper explores a solution offered by IIoT, to minimize cost of the body structure. This solution is validated by implementing in a virtual plant simulation environment.

A baseline body shop was designed, this is similar to BMW i3's [2] body shop, which is the current state of art in mass production of composite intensive vehicle. In this paper the following hypotheses will be validated.

- IIoT enabling - Manufacturing cost reduction
 - Improving the overall equipment efficiency
- IIoT enabling - Capital investment
 - Increasing shop floor efficiency

In the following section this paper will discuss about the baseline vehicle structure used, production volumes, capacity planning, baseline factory layout simulation and proposed factory layout simulation.

BASELINE VEHICLE ARCHITECTURE CONCEPT

A baseline composite intensive vehicle structure concept was developed, using this a baseline body shop is designed to manufacture this vehicle.

The Body structure of the baseline vehicle is split into two parts. An aluminum spaceframe (Figure 1) with the powertrain and a CFRP module (Figure 2) for passenger cell. The lower aluminum spaceframe is common for all three variants and the passenger cell are different for all three variants with few common parts. The three variants assumed for this baseline vehicle are sedan, wagon and fastback.

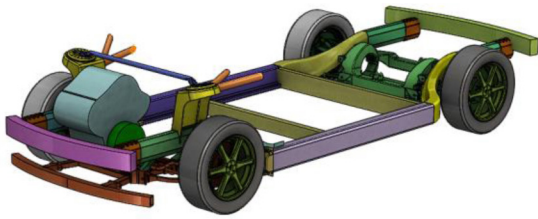


Figure 1. Lower Module with powertrain.

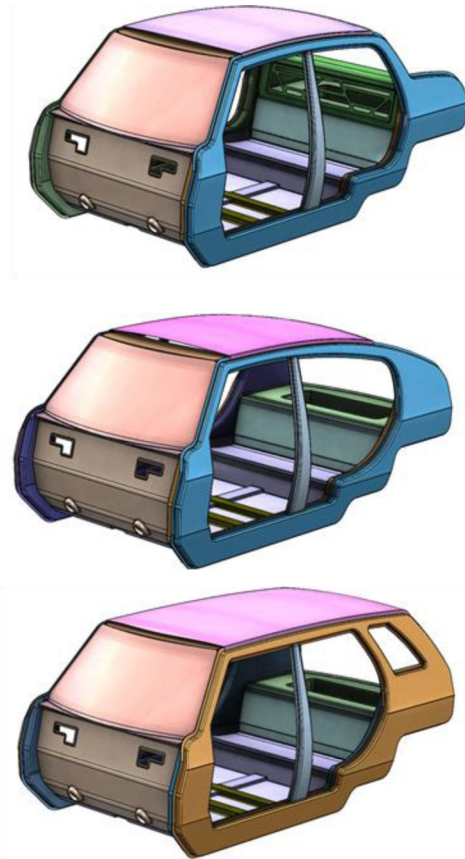


Figure 2. CFRP passenger cell, Top-sedan, Middle- fastback and bottom -wagon

The passenger cell has 54 different composite parts over all three variants. In this example its assumed that these parts manufactured from carbon fiber reinforced epoxy using wet compression molding.

To develop the body-shop the peak production volume per year was assumed to be 108,000 units with eight production years as show in the [Figure 3](#). These numbers are similar to mid segment passenger cars.

Line rates and cycle times are picked so that the peak monthly production could meet the target volume with an extended shift model. The agreed capacity with regular shift model is 14,600 units per month ([Figure 4](#)). Using this value, line rates and cycle-time for the body shop was determined.

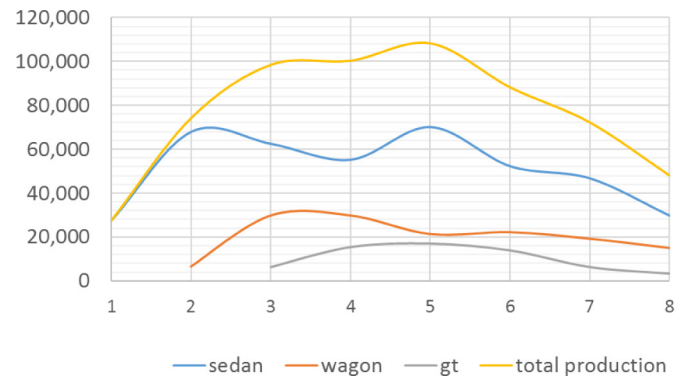


Figure 3. Production volumes for 8 years, X Axis - Production years and Y axis - Production volumes.

The desired line-rate for the body shop is 38 vehicles per hour and the cycle time is 109 sec. With this data a baseline body shop is designed. For the scope of this study, only the body shop for CFRP module is considered. A Bill of material for the CFRP module was generated from the cad models. Information such process times, precedence diagrams are generated. Adhesive bonding is the most common joining method for composite structure. The time for adhesive application is often limited by the speed of the robot and the assembly time is limited by the curing time of the adhesive. These data were used to develop a body shop layout. To meet the required line rates two parallel lines, have to be commissioned. Each line has eight station over ten takts. Conventional principles for line balancing were used to develop a most optimum line. This study was performed under the assumption that individual parts are manufactured in a press shop and are stored in buffer and supplied to the body shop in time.

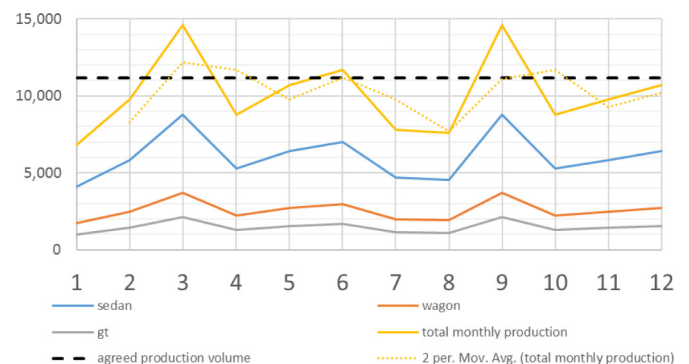


Figure 4. Volume demand for production year 3, X-Axis - months and Y axis production volumes.

Baseline Body-Shop Layout

After performing line balancing, the entire operation is divided into 8 stations and are performed in 10 takts. Station 6 is performed over 3 takts and this is where the body side outers are bonded to the under-pan for the structure ([Figure 7](#)). These body side outer rings are also unique to each vehicle variants. Each body side outer is a sub assembly of 3 large parts which are bonded on a sub assembly line as shown in the [Figure 5](#).