

Expanding Virtual Simulation in Product Realization

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ABSTRACT

Virtual Simulations tools are extensively utilized by many industries today in product development processes. In auto industry, however, this utilization has not reached its full potential. So far virtual simulations have been playing a supporting role in traditional product development processes founded on physical builds. To reach the full potential of virtual simulation, in reducing the product development time and costs, a paradigm shift in the product development processes and the role of both physical and virtual simulations is need. For an integrated realization process, innovation, analysis, integration, and continuous correlations are necessary design practices for achieving the desired product attributes. This paper, discusses the expansion of the virtual simulation role in an integrated product realization process to reshape the traditional product development process. The realization process discussed flows from the perceptual domains, of the individuals involved, through the virtual domain, to the physical domain of the finished product instead of the traditional segmented activities of concept, design, and manufacturing. The elements needed for expanding the role of virtual simulation in the realization process are discussed in addition to some virtual product development examples.

INTRODUCTION

In a globally competitive market, improving quality and reducing product development time and cost are the major attributes for success in any industry. To stay competitive automotive companies are continuously striving to minimize the product development process time and hardware build from concept to production. Companies who have succeeded to reduce the design and development time have done so through the use of virtual modeling and simulation tools.

From a very limited utilization rate in the 1970's, virtual tools are now being extensively utilized by the auto industry in almost every aspect of the product development process. With the rapid development of computation hardware and software the ability to address simulation needs for all subsystems and most performance targets has been continuously increasing. Virtual simulations today, range from simple component analysis to full product optimization [1,2,3,4,5,6,7].

In auto industry, despite the vast success of virtual simulations in reducing hardware build time and cost in the product development processes the full potential of savings is yet to be achieved. Traditional product development process thinking has limited the full potential of virtual tools from being achieved. The full potential of virtual simulation cannot be achieved in a physical build founded processes. As long as virtual simulations are used to support the physical build there will be a limit to how much saving can be achieved. Focusing on short term cost cutting, virtual simulations will always be just a quick fix to the shortcomings of the physical build paradigm in the traditional product development processes. Changing paradigms, however, requires understanding of the role of both virtual and physical simulations in the product development process. In the following, we discuss an integrated approach to the product realization process and the expansion of the virtual simulations role in this process.

TRADITIONAL PHYSICAL BUILD BASED DEVELOPMENT PROCESS

New Product Development (NPD) is the process by which a new product idea is conceived, investigated, taken through the design process, manufactured, marketed and serviced through obsolescence. Quality planning, which is used

interchangeably with NPD, can be viewed as the activity required for determining customer needs in addition to developing the products and processes required to meet those needs [8]. For understanding the product quality planning in general [9], the Product Realization Process (PRP) is defined by the Automotive Quality Management System (QMS) International Standard, ISOTS16949:2002, the particular requirements for the application of ISO 9001:2000 as one of major parts of the standard [10], as shown in Fig. 1.

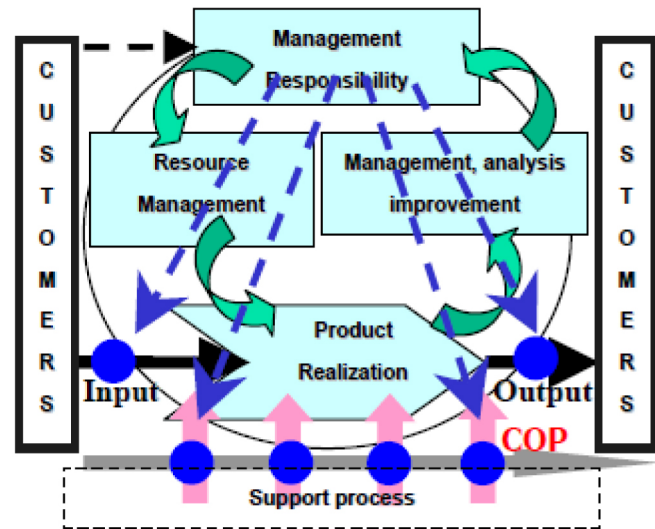


Figure 1. QMS model [9]

To achieve the PRP (NPD)'s objectives the methodology for managing new product development, Advance Product Quality Planning (APQP), in the automotive supply chains was introduced [11]. Since its publication and adoption by ISO/TS16949:2002 the APQP, shown in Fig. 2, played an important role in the automotive industry worldwide [9].

The APQP consists of following five phases [9]:

Phase 1. Plan & Define Program

Phase 2. Product Design and Development

Phase 3. Process Design and Development

Phase 4. Product and Process Validation

Phase 5. Production Launch, Feedback Assessment and Corrective Action

In real practice, these phases may overlap and many tasks are done in parallel (concurrent engineering) to streamline and maximize resource utilization.

Aside from the Managerial aspects the APQP technical execution follows the Ulrich and Eppinger development process [12], shown in Fig. 3.

In Ulrich and Eppinger model, planning is the phase where the project gets approved and the product development process starts. The output of this phase specifies the target market, business goals, key assumptions, and constraints. In

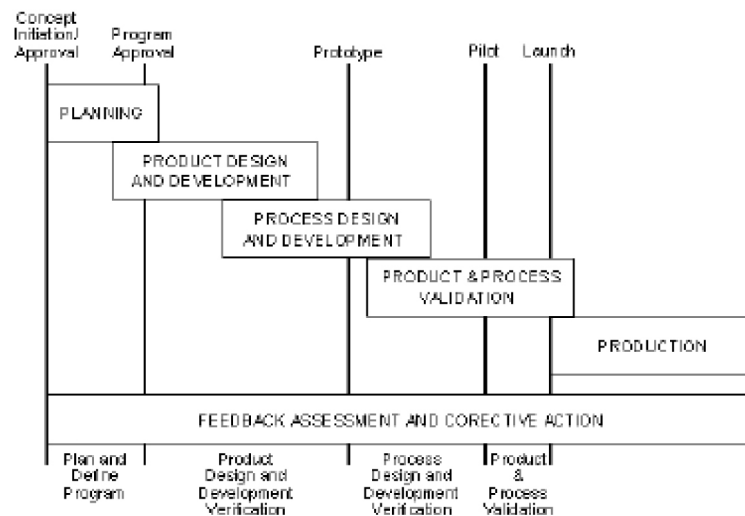


Figure 2. APQP Phases [9]



Figure 3. Ulrich and Eppinger development process [12]

the second phase, concept development, the target market needs and customer requirements are identified. One or more concepts are then selected from several alternatives for further development and testing. During the system-level design phase the focus is directed towards the products definition and architecture. The product's individual components and its final assembly process are defined. In the detail design phase, the complete specification of the geometry, materials, and tolerances of all the components as well as the identification of all the supplied parts are completed. The establishment of a production system process plan is made and tools are designed for each part to be produced. During the testing and refinement phase multiple preproduction types of the product are constructed and evaluated. The prototypes can be divided into alpha or beta prototypes. Alpha prototypes are not necessarily fabricated by means of the actual processes to be used in production. Beta prototypes are usually built with parts supplied by the intended production process. Testing makes it possible to refine the product before the start of production. The last phase production ramp up consists of training the work force and resolving all remaining problems in the production process.

In the APQP the first two phases of Ulrich and Eppinger namely planning and concept development are combined to form the Plan & define program of phase 1. The product and process design phases of the APQP are same as the system-level and detail design phases of Ulrich and Eppinger. The product and process validation phase of the APQP is the same as the testing and refinement phase of Ulrich and Eppinger. Finally, the last phases in each of the two processes deal with production ramp-up or launch.

The mile-stones of Prototype and Pilot builds in the APQP, detailed in the Ulrich and Eppinger model, manifest the physical build paradigm inherent in the traditional automotive product development processes. It is clear that for those involved in the traditional automotive product development it is very hard to execute without physical builds for the following reasons:

1. Finding what works in the physical reality can be achieved by simple trial and error.
2. The need for deep understanding of the theoretical foundations is limited with physical builds.
3. Risk factors and personal responsibility of the decision making are limited with physical builds.

Looking beyond the surface, however, one will find that it does not matter how many physical builds there are in the traditional development process they all are merely simulations. The only un-simulated reality is the product use in the hands of the end user (customer) and even that is not unique and represents multitude of environments. Therefore, insisting on using physical builds for performing simulation during product development adds to the process the following disadvantages:

1. Physical builds are usually very slow and lengthy.
2. High costs are usually associated with physical builds with minimal return on investment.
3. Limited insights due to inability to pin point causes of failure or success.
4. Limited ability to provide design direction for product optimization.
5. Lagging behind the development phases usually renders some of the physical builds useless.

INTEGRATED PRODUCT REALIZATION

To address the technical execution of the PRP presented in the QMS of Fig. 1, the concept of realization should be revisited over the whole product development process from an idea to production. Considering that product realization means bringing a product to reality and focusing on the underlying human activities instead of the traditional departmental definitions such as design and manufacturing can help in developing a better product realization process.

When interacting with the physical world humans have use their own perception of it as their own reality. Each individual has his or her own perception of this reality. In order to understand physical reality and collectively share their perceptions of it, humans have introduced a third domain known as the virtual world. It is a domain where perceptions, hypotheses, observations, imaginations etc are shared. It takes the form of simple arithmetic, complicated mathematics, drawings, internet, digital and computational forms etc. Therefore, realization is the human interaction with a reality to figure it out, utilize it to achieve desired results,

and/or alter it by eliminating or bringing new objects to it. It is also clear that realities include other dimensions or domains that go beyond what is physical. Among these realities we consider three forms or domains [13]:

- **Perceptual reality**: represented by individual paradigms or the internal images of other realities.
- **Virtual reality**: represented by modeling and simulation of physical and perceptual realities.
- **Physical reality**: represented by the physical universe that can be realized with the senses.

Examining all three realities it could be identified that: the perceptual is the domain where the individual realizations are being formulated (developed and validated), the virtual domain is the domain where collectively shared realizations are being formulated, and the physical domain is the domain where physical realizations are being actualized.

Based on this realization concept, it could be stated that a typical product realization process from a concept to a physically produced object spans all three realization domains. The realization process starts from ideas at the perceptual domain to conceptualization and development in the virtual domain to validation and production in the physical domain. In fact, it becomes clear that a set of design drawings is the virtual realization of a product and manufacturing is the physical realization of that specific product. In addition, a simulated manufacturing process model for product development is an element in the mapping from the virtual to the physical domain [13].

Figure 4, represents the perceptual, virtual, physical activities in a four-phase integrated product realization process model. The dotted lines, in the figure, represent the interfaces and transition between phases. The model reflects the natural integration of the realization phases from inception in the perceptual domain to conception and development in the virtual domain to production in the physical domain. In addition to being lean, this integrated product realization process model is established with the following essential attributes and criteria [14]:

Profitability

Through achieving the following four criteria:

- Maximizing innovation
- Maximizing Quality
- Minimizing cost
- Minimizing time to Market

Modularity

From process perspective, modularization generally has three criteria:

- Managing complexity;
- Performing Parallel work
- Accommodating uncertainty.

Simplicity

The logic of simplicity is straightforward: focus on the important things and simplify tasks by avoiding complexity in three main dimensions:

- The number of elements (parts)
- The number and strength of interdependencies between elements
- Vagueness or uncertainty

Transparency

In a fast-moving industry the products that are designed today may have never existed previously. The designer's previous experience may be inadequate for the task. Therefore, clearly defined process helps those involved:

- Obtain a comprehensive view of its entirety.
- Not only having access to know-how but also know-why.
- A systematic approach.

Innovation sustainability

Innovating is the most difficult attribute to achieve due to the high level of uncertainty. In order to cope with fuzziness and create clear vision for innovation teams, organizations need to:

- Work in cross-functional manner and manage the foundation elements of innovation activities.
- Estimate and anticipate downstream, future information in order to make the correct decisions early.

Continuity

The realization process should have well integrated phases with seamless transition to provide continuity and optimized flow with the following criteria:

- End-to-end scope: It integrates the front end and the field support back end with all the product development phases.
- Customer driven: voice of the customer drives and integrates design priorities throughout the end-to-end process.