New Trends in Computer Simulation as Integrated Tool for Automotive Components Development

G. F. Batalha   R. C. Schwarzwald   G. L. Damoulis

Department of Mechatronics and Mechanical Systems Engineering,
Escola Politécnica - Universidade de São Paulo
Av. Prof. Mello Moraes, 2231 05508.900 - São Paulo-SP, Brazil.

Abstract: New market requirements have becoming more persistent through the introduction of new technologies that can lead the actual vehicle designs to reach very high safety standards, world class quality levels, reasonable production costs and schedule timing for product development, due new design features and introduction of new materials. To reach those targets, process integration, since the early concept development phases until the start of production, must provide a streamlined scalable environment that encompasses every step in the process from early feasibility to final validation. The experience in supplier process development in the last four years at Volkswagen in Brazil shows that the development of product and processes can be integrated and that the synergy effect of this integration can make it possible to develop mature products and install robust processes to produce them.

INTRODUCTION

Successful industrial applications of the explicit finite element simulation of crash events in the automotive industry during recent years triggered a similar demand for the simulation of the stamping process of body-in-white components. As an example, in the car body development the design of body panels and finishing of tools as well can be supported effectively by the simulation of the sheet metal forming process with the finite element method (FEM), as well as the integration of the manufacturing processes (including assembly), and tolerance control.

This paper describes how such programs have been applied to lay out industrial simulation processes, accomplished by optimization of the methodology, the integration into the development and the updating procedure for the model data and the computational processes for the development of automotive components. Moreover, this paper will highlight the importance of incorporating the know how of experts in various fields in the early development stage through the whole automotive supply chain (expertise centers).

Changes on the usual product development process in the automotive industry

Fierce competition in today's global markets, the introduction of products with short life cycles, and the heightened expectations of customers have forced business enterprises to invest in and focus attention on their supply chains.

In a typical supply chain of the automotive industry, the short life time of the products must be supported by the design and construction of tools sets to produce each of the part that are build in the car.

Traditional tooling development is integrated in the product development flow that can still be classified as a push based development strategy. Typically, the toolmaker receives a tool project of a 3rd part company, that makes the project according to the drawings and specifications of the part producer, which got the drawing from the cars manufacturer product engineering.

CP712, *Materials Processing and Design: Modeling, Simulation and Applications,* NUMIFORM 2004,
edited by S. Ghosh, J. C. Castro, and J. K. Lee

The whole process starts with the drawing release of the product engineering, which allows the part supplier to put the order on the toolmakers. From this time on, the tool will be build according to a timing plan. If there is the need, and normally there is, of any product change during this time, the tool must be stopped, reworked or even built again.

Statistically in a new car project, 10% of the investment has been paid for these changes after the engineering release. There is no economic value added in this operation, so it must be eliminated or strongly reduced.

As the market pulls new products in a higher speed than in the past, there is no longer chance to make 6 years development of a new car in order to check every detail before the drawings release.

According to some carmaker specialists, to be competitive in the global markets today, the time between concept definition and start of production must be no longer than two years. For the long lead items, that have its tooling construction time of about one year, there is no chance for major modifications during the tooling construction.

For the long lead items, there must be a tool to avoid modifications in the critical phase.

Definition of long lead items

Long lead items are classified according to their development timing. A part family of a car is considered long lead when its complete development and introduction as serial part takes more than 18 months. The main issues are the concept definition, tooling construction and product certification.

Main long lead items in a car: Dashboard, bumpers, steering wheel column, suspension, motor block, head and rear lamps, seats, wheels, door panel, and body-in-white structural parts as cross beams and some crash reinforcements.

Cost impact of project delays caused by long lead tooling construction schedule

There are two different cost impacts of changes implemented after tooling build start. First, as mentioned above, reworking the tool or rebuilding completely new tool sets may represent a significant overrun of the forecasted investments.

Secondly, if the changes cannot be completely implemented due the timing pressure, there may be an increase on part production cycle, rework or any other variable cost that was not planned and considered on the part cost. These costs refer to the impact of bad quality development.

Automotive industries are used to work on serial costs reduction and quality system evaluation, but in many cases do not understand, apply or verify the cost of the lack of quality on the development phase. This must be a preventive approach to avoid costs in the serial production.

The fragile swallows in the South American product development chain

The development of new car models in Europe, Japan or USA normally goes two possible ways: Mass production products or premium products. In both cases, the investments have a high confidence level of rapid return. In the countries of South America, like Brazil and Argentina, the permanent economic instability increases the risk of long-term investments like a new car project.

These facts, which cannot be changed in a short time because it depends on the world economy, leaded Volkswagen do Brazil and other car manufacturers to change its strategy. The automotive industry in Brazil will be a vehicle development center for 3rd world countries, or developing countries.

In order to accomplish with this target, the supply chain basis must improve a lot the way of developing parts with higher quality levels, but lower investments and costs. One of the main issues concerning this task is how to develop tools faster and parts delivery with high quality.

Simulation and prototyping as a tooling concept check spite of product concept check

Both simulation and prototyping were born linked to the product development. The simulation and prototyping of tools is not a new approach, nevertheless a new trend in this area is to simulate and make prototype tools focusing on process capability.

The aim is to simulate or to build prototype tools, which can assure that the serial tooling will be built to fulfill the quality, volume and cost requirements.

Integrated tools for automotive components development

Some key factors have to be focused in order to guide the organization to a faster and better tooling development. First, the company has to implement a procedure that assures the technical integrated development, which we will call development box.

Secondly, the company top management has to incorporate experts know how through the automotive chain development.

The third step is to create competence centers for tooling and product development through the supply chain. The last step will be the built of an international net of specialist that will be able to focus on development of tools using the best knowledge available. This net will be called virtual development teams.

The development box

There are a lot of studies and ways of managing the supply chain in the automotive industry. These studies normally focus on the supply chain after start of production, which means, supply chain development with focus on the integration of the product and tooling development is still a new approach.

The development box concept shown in the figure 1 is a model that, when implemented, can save time and money during the product and tooling development because it is a simultaneous process, which uses the information of many sources in real time and in a preventive way.

In the conventional process, the development process flow is sequential, what does not permit timing savings or technical synergies among the specialists, which are involved.

In the development box concept, one technical team is set to develop one product and its tooling from the concept analysis until the start of production. The results of the use of this concept will be discussed at the end of this paper.

Virtual development teams

In the product or tooling development, the involved people face daily difficulties regarding the concept definition and the next steps of tooling building. These difficulties may be a decision about the implementation of a calibration step in a stamping process or the implementation of a rot runner in an injection tool. If the tooling building stage is still in the beginning, there is normally no big delay. But if the tooling is already on the milling process, there may be timing, financial or quality consequences for the whole development process.

The only way to avoid delays or costs and work with preventive focus is to put all available information together before starting the tool construction. This event we will call tooling sign-off and will be summarized as a technical meeting to present, discuss, define and release the tooling concept and its peripherals before any action concerning the tooling construction.

A very simple sign-off process can be applied by two toolmakers sitting together and taking decisions. But, in case of building tooling for critical parts, there must be more information available.

The critical parts sign-off process in the automotive industry has to put together the main roots of the whole development process. Engineering, toolmaker specialists, production, quality, logistics, part supplier, process specialists, raw material supplier and simulation company. This will create a knowledge support for two actions. Better simulation of the process and tooling start release.

The Virtual Layout of the industrial process

Forming Processes Simulation at the Automotive Development Chain

High-end producers aim to maintain greater product differentiation with respect to mass producers. One important aspect of this differentiation is the look and aesthetic quality of the car [1].

This mostly results from the body geometry chosen and the stamping process. In the past it was possible to maintain quality differentiation through off-standard rework during vehicle finishing operations, as products were able to command premium prices.

However, increased market competition has significantly eroded this advantage of high-end producers. These manufacturers are now seeking to minimize the additional cost of quality and find novel ways to design and manufacture high-quality products.

The overall approach may still differ, as mass producers are unlikely to consider any significant amount of rework, while high-end producers are still likely to accept occasional rework if it helps them achieve measurable differentiation in the market. In the long term, market competition will continue to drive down costs. This implies also the need to develop optimum technologies for up-front simulation of stamping processes.

Design of Sheet Metal Forming Processes

Sheet metal forming process design involves specifying the individual forming steps, the geometry of the forming tools and the arrangement of any draw beads present. Other important parameters are the choice of the sheet material, the blank shape, the blank holder and the lubrication conditions [2].

Current design procedures rely heavily on empirical testing and are often very expensive and slow, since tools may have to be built, tested and modified several times before satisfactory results are achieved.

Reliable simulation techniques would help by allowing manufacturing problems to be identified and corrected early, before prototypes are built. Forming simulation results could also be used during the initial component design to improve manufacturability and quality (simultaneous engineering).

Various studies have been performed to evaluate simulation accuracy by comparison with experimental data. Considered parts included some simple benchmark geometries (U-profiles, cylindrical spherical and rectangular dishes) as well as more complicated industrial components such as a C- pillar, a front fender and a car door.

Quantities used for comparison were in each case the shape of the deformed sheet, thickness and strain distributions as well as the forming force history [1].

Today's sheet metal forming industry is searching for fast, effective and reliable techniques for product design [3].

At the product design stage, the tooling and blank geometry that would provide the required final product are not known, so trial and error techniques are adopted. Thus the need for a fast analysis engine is crucial to shorten the design process and decrease total cost.

The finite-element method is effective in analyzing general structural problems. In sheet-metal-forming practice, two main finite-element approaches have been used: incremental and one-step.

The one-step method has proven to be more feasible in the product design stage. In a typical one-step solver, the final part geometry and boundary conditions are known and are used to predict blank geometry and size, thickness, strain and stress distributions and spring back prediction [3].

Results of the integrated development box (IDB) use at Volkswagen do Brazil as world-class cars developer

Volkswagen in Brazil has faced several problems in the last three years. Increase in competition, lack of products and costs increase have forced the company to downsize and lost the market leadership of more than 30 years.

Because of the economical and market situation, the company has focused on the launching of new products tailored for the 3rd world market.

The main important project is the *Tupy*. Named as FOX in Brazil and LUPO in Europe, this small car is a very cheap one to be produced and exported to the whole world. This project has been decided in the end of the year 2.000 and the start of production was in the middle of 2.003.

The *Tupy* project is nowadays known in the Volkswagen Concern as the most successful project of the Volkswagen group. The vehicle was launched 4 months earlier against planning and there was no investment overrun.

One of the main reasons for this successful launching was the preventive integration and work of the supply chain in the development phase and an intensive use of virtual tools.

The tooling sign-off has been performed for all critical and long lead timing part tools.

During the discussions another strategy has been found out, which permitted a huge timing and cost saving. For the injection tools, as well as for some stamping tools, one of the sides of the tool was built in the prototype phase as the final production tooling.

The sign-off project, linked to the use of final tooling in the prototype phase, represented a saving of 40% in the tooling investment costs and a timing reduction of 30% in the tooling construction.

ACKNOWLEDGMENTS

The support of the Volkswagen Brazil, the VW quality and engineering teams is gratefully acknowledged as a reference for this paper.

REFERENCES

1. "Changing the Stamping Process"; Balbir Singh; Aleksy A. Konieczny; Automotive Engineering/April 1997, pages 43-46;

2. "Development of Industrial Sheet Metal Forming Process using Computer Simulation"; A.N. Heath, A.K. Pickett, D. Ulrich, ESI GmbH, Germany

3. "Simulating Manufacturing Processes"; Marek Kawka, Akitake Makino et all; Automotive Engineering/April 1997, pages 31-33

4. "Use of CAD/CAE in the CASE activities"; Y.Yano, T Akashi; Simulation of Materials Processing, Theory, Methods and Applications, 2001.