PEUGEOT'S MANUFACTURING TECHNOLOGY CHALLENGES EC ASSUMPTIONS

by Daniel E. Whitney, Liaison Scientist, Manufacturing

Summary

Peugeot-Citroën is Europe's third ranking automobile maker with 13% of the market (33% in France). According to M. Jean-Serge Bertoncini, Director of Information and Informatique, Peugeot has over 2100 robots in its plants and has automated as many types of automotive assembly operations as advanced Japanese plants have. Example capabilities include, beyond the usual robot spot welding: installing all 5 wheels, windshield, rear window, dashboard, front and rear seats, and doors, plus performing portions of engine and gearbox assembly. These activities were developed inside Peugeot-Citroën and used their own software and optimization techniques.

After repeatedly hearing Michel Carpentier, the director of EC Research Directorate XIII (the ESPRIT program), say that Europe was behind, Bertoncini brought Carpentier by corporate jet to Peugeot's best plant and showed him what Europe can do. Needless to say, Carpentier was impressed.

PSA, the parent of Peugeot-Citroën, is still in the process of merging Peugeot and Citroën, and this process reveals new wrinkles in Concurrent Engineering. Different cultures, locations, engineering areas of expertise, and types of computer systems had to be joined gradually without upsetting the ongoing design of cars. Even now there are different design styles in some areas. A somewhat involved concept and advanced design procedure permits each division to design its own cars while drawing on common expertise in advanced development program management plus various engineering and manufacturing areas. In addition, PSA has learned to use the same component (e.g., engines) in both brands while tuning them differently to appeal to each brand's traditional market. A company with a single product line or that grew internally rather than by merger would not have seen the same problems and evolved the same solutions.

André Rault, a 1966 PhD from Berkeley in controls, joined PSA three years ago with the goal of bringing a more systematic approach to its design methods, especially for mechatronic components like transmissions and brake systems. He has brought in software called CAMAS* from the University of Twente that permits hierarchical Bond Graph models to be

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* NOTE TO EDITOR AND SCIENTIFIC DIRECTOR: CAMAS, ENPORT, AND SIDOPS ARE NAMES GIVEN TO SOFTWARE OR MODELING SYSTEMS BY THEIR AUTHORS. THEY ARE NOT NECESSARILY ACRONYMS. IN THE TEXT I SAID THAT THEY ARE NAMES. I THINK THAT SHOULD BE SUFFICIENT. I'D LIKE TO SEPARATE ACRONYMS FROM NAMES IN CASES LIKE THIS. IF IT APPEARS AWKWARD TO HAVE NAMES APPEAR IN ALL CAPITAL LETTERS, MAYBE THE EASY WAY OUT IS TO UNCAPITALIZE ALL BUT THE FIRST LETTER: Enport, Camas, Sidops.

built. Several quite accurate models of complex items have convinced the engineers that this is a valuable method. Rault has now launched an ESPRIT project to create a library of proven bond graph models of common mechatronic components, together with their geometry (a link not supported by CAMAS) so that systematic bond graph modeling and design of complex mechatronic things can be done more easily in industry.

CAD and Product Development

As a relatively small car company, PSA has not had the resources for CAD that larger firms have. But PSA has moved faster than most large firms to implement new techniques in both design and manufacturing, recalling the case of Volvo, another small but innovative firm. PSA has implemented its own robot off-line programming system based on CAD solid models of both car bodies and robots, and has installed its own trajectory optimization and task planning optimization methods. It has also carried out a careful but still incomplete study of cost savings from both the robotics work and several CAD and Artificial Intelligence (AI) applications. Some of the benefits were unexpected: first design takes as long by solid modeling as by hand but modifications and Computer-Aided Manufacturing (CAM) are done much faster; robot task optimization can often reduce the number of robots needed by 10% (FF1.7 million per robot if the surrounding equipment is included).

M. Bertoncini challenged the notion of companies developing their own CAD tools as the Japanese have. "Too few people have the skill, the art really, to develop an architecture like you find in CATIA or CADDS.[1] We know we don't have it and we suspect the Japanese don't either." But PSA's reliance on outside vendors has pushed it to take a possibly sub-optimum approach to the ubiquitous problems of data incompatibility between commercial CAD systems and difficult data transfer from one stage of design to another: it has chosen one vendor for each of its "lines of design:" CADDS for styling and body engineering, CATIA for mechanical design, MEDUSA[2] for factory layout and equipment design, and so on. This prevents easy merging of the different lines and many not be a long-term solution.

In their terms, they now have in place "new tools for doing design the old way." Now they must develop new ways. Whether their CAD strategy up to now will support the new ways is not clear. They have not done the intensive design process studies that Volvo has. Only in the last two years have strong connections built up between design and manufacturing.

Improving the Systems Approach in Car Design

Dr. Rault noted that PSA, like other French companies, is short on systems mentality. Thus he found that little analytical skill existed in Citroën's critical hydraulic suspension system group, and that tolerances were little understood because the French educational system does not teach random variables to engineers. He was assigned to improve both of these situations.

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[1] CATIA is the solid modeling software sold by Dassault Systemes. CADDS is similar software sold by ComputerVision.

[2] MEDUSA is drafting software sold by ComputerVision.

As an example, Peugeot recently did a competitive teardown of several models of a Japanese luxury car and were surprised to find the same wiring harness in each, in spite of different wiring needs. This strategy results in slightly more weight and much lower fabrication, installation, and test costs, plus fewer errors, compared to using separate harnesses for each model. Only a systematic analysis can reveal the benefits of one strategy over the other. A more systematic approach to such problems can be expected at PSA in the future.

Rault has also brought Bond Graph [Paynter] modeling to PSA, utilizing software called CAMAS. CAMAS is like the original bond graph simulation system ENPORT in many ways. It supports hierarchical models of complex hybrid systems. In an X window one can have a model with two nodes: ENGINE and TRANSMISSION. Clicking on one of these nodes reveals a more detailed model, and clicking on its nodes reveals even more detail. At each level, the graph obeys the bond graph notation rules. At any level one can substitute explicit mathematical statements in a FORTRAN-like language called SIDOPS to handle nonlinearities and other details. CAMAS automatically converts the bond graph model into a set of SIDOPS statements and evaluates them numerically.

CAMAS has been applied to modeling of automatic transmissions.[3] These are good examples of mechatronics because they have either hybrid or all electronic controllers as well as many gears, clutches, shafts, friction elements, and inertias; bond-graphs are amply equipped to model such systems. The first model, while still approximate in some areas, accurately predicts that PSA's current transmissions jerk the car somewhat while shifting. A previous analysis of manual transmissions correctly identified gear backlash as their main source of noise. These successes have impressed the engineers, making further applications likely. A complete car and suspension system model is being built. Rault has also launched an ESPRIT project to harden and commercialize Twente's software.

CAMAS in its present form is really for modeling and simulation, and does not support design directly. It has no link to geometric models and it has no way of helping the designer improve the design. The fast fourier transforms and other classical analysis techniques that Rault would like added will not really fill this need.

However, the EC project mentioned above will address several other gaps, including providing links to geometry and FEM. More importantly, it will create a library of elements that combine proven bond graph models and the elements' geometry. This will be called the Open Library for Mechatronics Components.

Once this project is well underway, Rault expects that a methodology for mechatronics can be developed. [Rault] He sees it as a person with a controls background would: as a systems problem of simulation, control system design, failure mode analysis, and engineering analysis all carried out in a concurrent engineering environment. The hierarchical nature of CAMAS will be essential for this.

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[3] In the Computer Systems Department at Ford, a similar model has been built. At the research level, there is frequent communication between the two companies.

Conclusions

Rault is bringing new research into Peugeot's design office and showing that it is ready to do real work. Apparently this is happening on his own initiative. It reinforces the point that companies must search out research and speed up the technology transfer process. The Japanese have shown that they are very good at this.

The EC project Rault has started will not only create a useful tool but will contribute to generic knowledge of use to many industries. The project is (potentially, at least) a good example of what can be done when a university and a company work together.

I note in another article[4] that most academic researchers on concept design have not taken the Bond Graph method seriously. It deserves more attention because of its ability to model hybrid systems and to check a model for internal structural and physical consistency. This added sophistication is being brought to bear in concept design by an industry researcher, a point to ponder.

References

[Paynter] Henry Paynter, Analysis and Design of Engineering Systems, Cambridge: MIT Press, 1961.

[Rault] André Rault, "Mechatronics and Bond Graphs - Industrial Impacts and Prospectives in the Automobile Industry," internal working paper, PSA, to be published in a special issue of the Journal of the Franklin Institute.

Point of Contact:

Dr André Rault
Peugeot SA
PSA / DITA
62, boulevard Victor-Hugo
92208 Neuilly-sur-Seine
France

phone +33 1 47 48 60 59
fax 47 48 35 30

[4] "From Fuctional Specification to Concept Design -- Strengths and Weaknesses in Some Current Approaches"