Visit to Nissan, Sept 4, 1991

Background

This meeting was a follow-up to the one held on July 8. The subject was engine and power train design. My hosts were Mr Jun-ichi Kobayashi and Mr Masataka Hidaka. Mr Kobayashi directs CAD planning and spent many years as a manufacturing engineer. His contacts in that department stand him in good stead as he thinks about Nissan's future CAD needs. Mr Hidaka joined Nissan 6 years ago and spent 4 of those years in new engine design. Now he has joined the R&D department to develop new computer tools to help engine design.

Like all new hires at Nissan, both Kobayashi and Hidaka spent several months working on the assembly line as part of their initial training. "I learned about assembly insertion force," said Mr Kobayashi. "It doesn't show up on the drawing." I told him our group did research on predicting insertion force. He apparently didn't know it was possible. Insertion force and access to the assembly point strongly influence the time required for assembly, which directly affects the cost. Until these matters are modeled, attempts to predict assembly time and cost will be of limited usefulness.

The point is made here because the tone of the entire day's discussion was about the contrast between the relative ease of predicting engine performance compared to the difficulty predicting assembly cost (of cars as well as engines). At the same time, early prediction of cost is becoming more and more important. If good cost models of production can be made based on concept designs, then the real tradeoffs can be evaluated. "That's the theory of concurrent engineering," says Mr. Kobayashi. Right now, the spec for engines is set too early, based on performance only. Too many spec changes are needed after the first prototype is built, presumably to reduce the cost.

Engine Design Process

Mr Hidaka showed me data on engine development times that are confidential but that are not too different from what other car companies showed me. Basically, new engines take somewhat longer than new cars, but adaptation of existing engine designs to new cars can be done at the same pace as car design. This does not prevent problems from arising, but Nissan has never delayed a new car introduction due to a late engine design. They just do whatever is necessary to get the design done in time.

The engine department has sections for performance planning, project development, parts design, and advanced technology and CAFE. The project sections handle different types of engines (4 cylinder, 6, V8, diesel), while the parts sections focus on different kinds of parts (external parts, lube-head-valve parts, fuel system and controls, emission controls, turbochargers, and so on). Each project section is given responsibility for adaptation of an existing engine to a new car, while the advanced technology and performance sections investigate new engines.

There is also a "simultaneous engineering" department. Its job is to study and develop new design methods and materials which require new manufacturing technologies, such as injection molding and the associated simulation software. Note the difference in philosophy here between Nissan and Nippondenso. The latter feels it must integrate new process creation with new product design.

Transmissions are designed in a different department that has a similar structure. However, communication between engine and transmission design is not as good as it should be. This is partly due to a natural conflict that arises in front wheel drive cars: there is never enough space between the front wheels to fit both engine and transmission. Styling wins most of these conflicts since it sets the wheel spacing. In sporty cars, engine design forces the wheels farther apart, but, in other cars, engines and transmissions must fight it out for the given space.

I was shown their engine lineup. Some designs are 8 - 10 years old, others are new last year. Many are revisions of earlier ones. Currently they make 64 different engines, compared to 70 for Toyota, 22 for Mazda and Honda, and 30 for Mitsubishi. They showed me a graph of the trend of engine types offered by all these companies, plotted every year from 1978. Over that span, the number of engines offered by each company has increased by a factor of 3 to 4 times. Production rates for engines can be as high as 50000 per month.

Engine design is a process of designing, building, testing, and evaluating prototypes. The number, their timing, and the overall design time are confidential. Manufacturing engineering begins right after the first prototype is built. But, beginning three years ago, production engineers attend design reviews and offer feedback during design of the first prototype. In future years, this participation will be pushed farther upstream, or at least Mr Kobayashi wants it to be. This will ultimately mean participation in new technology development or evaluation. As things stand, there is considerable task overlap between the cycle of prototypes and development of production systems.

To support the trend to earlier participation, Nissan will need new attitudes as well as new computer tools. Right now the critiques are limited and detailed, such as where certain holes should be located or what direction their axes point. To illustrate, he cites some "quite distinctive" differences between the new engines Nissan and Toyota produced for Infiniti and Lexus. Nissan's engine has an intake manifold with 8 separate chambers, one for each cylinder. Toyota's manifold is a single casting, illustrating more concern for ease of assembly in his opinion but possibly causing some sacrifice in performance. When I asked if specific performance compromises had been identified in Toyota's engine, Mr Kobayashi said no. Apparently they are uneasy about being unable to explain such obvious differences.

Mr Kobayashi also noted that Toyota's strength includes large numbers of manufacturing engineers. They can throw people at a problem. Nissan cannot do that, so it needs better computer tools.

Mr Hidaka then showed examples of CAD / CAE in engine design. Several are typical stress analyses and simulations of crank motion. More interesting are mathematical models of engine performance. One inputs the bore, stroke, valve timing, intake volume, and other parameters, and the computer returns a graph of torque and power vs RPM. The basis for such calculations primarily is historical data. While some parameters can be predicted well, factors such as "driveability" are more difficult. Such parameters are dynamic, involving acceleration, whereas the above mentioned chart is static and the data can be obtained on a simple test stand. Nonetheless, their existing predictions are so accurate that they discount the need for major improvements compared to the backward state of producibility analyses.

The different parts design sections have different attitudes toward CAD. Big parts are designed in 3D but little ones are done in 2D. Reconstruction of 3D information is required for mold-making and CAE. The designers of small parts resist the complexity of 3D modeling, and the large part designers utilize only the software's ability to represent the outer hulls of parts, omitting the interior details. Mold-making thus reduces to hand carving of models made from reconstructed 2D drawings, a distinctly awkward and old-fashioned method. The problem arises because of the legacy of the software: it was originally designed for body stylists, who design simple parts with no interiors, just complex surface shapes.

Yet "complex" is a mischaracterization, because in fact body parts do not have many details or features in their surfaces compared to connecting rods or other mechanical parts. A con rod is essentially a large collection of fillets, joined in complex ways by surfaces with shallow draft angles on them. The real requirement is thus for complex filleting, not arbitrary surfacing, and no one's software can provide this. Toyota made the same comment. Many car companies have evaluated Ricoh's Design-base, which is supposed to have superior filleting capability, and all have so far rejected it. The same thing has happened to ProEngineer, except that its constraint capability and easy interface are still attractive and companies are beginning to adopt it for less fillet-oriented design.

Yet there are problems as designers begin to adopt 3D. The inability of solid modelers to handle all the data and the inability of wireframe models to convey the design visually to manufacturing people have been discussed before. In addition, there are design errors. In the old days, designers took pains to insert check or reference dimensions to discipline themselves and others. Now that habit is disappearing and errors are occurring at an increasing rate.

The manufacturing engineering department responsible for making forging and casting dies for engine parts has responded to shortcomings in existing 3D CAD by developing its own 3D modeling system. Other departments have done the same and now several modelers exist. The manufacturing department's program is called F-CAD and was introduced in 1988 as the result of a PhD by one of its engineers, Mr Suzuki.

F-CAD's main strength is its ability to handle arbitrary and complex fillets. But it can't support revision, so a problem occurs because many dies are changed during tryout. As a result, the drawings are not updated to a datafile.

Future Needs

The opinions expressed here are those of my hosts, who are trying to convince their management. Whether Nissan will adopt their ideas is unknown at this time.

New engine designs promise to be quite different from existing ones. An example is modularity, in which two cylinders can be added to a four cylinder engine to make a 6, for example. Interior and exterior engine parts will be different from current ones. More commonality will be needed, and engine performance must not be allowed to suffer because of it, due to the need to meet the CAFE requirements. Mr Kobayashi wants 3D modeling to be adopted throughout engine design.

He also wants better cost prediction methods early in design that can analyze complex parts, not just screws and brackets. He does not know the proportion of engine cost that goes into assembly. One reason is that so many components are purchased. He feels that part count should be reduced. When I asked if that might increase the cost of each part more than the amount saved in assembly cost, he replied that representatives of Boothroyd & Dewhurst claimed not. But apparently the cost-complexity issue is still open. (Sony says that their parts are so simple that combining them does not increase the cost.)

In addition to encompassing modular engines, new CAD must account for several engine designs at once. This is because cost pressure will force reuse of parts and production equipment. The cost saving opportunity requires that new parts be designed so that the cutting capability or assembly capability of old machines is still applicable. Deep knowledge about cutting conditions is needed.

Any time cost, performance, and manufacturability must be considered together and traded off, accurate cost estimates are needed. Normally these are available when the manufacturing engineers do their planning, which now occurs too late to help the concept design tradeoff process. Therefore, manfuacturing planning needs to occur earlier; the approximate data available at that time should be sufficient, he says.

Estimating assembly time / cost is harder than estimating machining time / cost because the human element is more important. If a person cannot see where the part is going in, if force must be used, or if the person's body is bent, then more time is needed. If the line is planned for too little time, the workers rush, and quality falls. Then more inspectors and repair people are needed.

To support this kind of design does not require new kinds of DFA like Boothroyd & Dewhurst's but rather more of the old fashioned kind of manufacturing engineering applied earlier in the design process. This requires more manufacturing engineers, not more computers. "And I'm in charge of CAD planning!"

Getting him to focus on the difference between computer communication and computer-aided engineering tools has been difficult, but finally he agreed that CAE for manufacturing and assembly is feasible. Until he saw my video about feature-based design for assembly a second time he did not understand it. "I thought features were only for machining," he said.

He feels that in general relations between Nissan and university researchers are weak. The university research generally does not address industry's needs. On the other hand, advanced methods like Taguchi's are just now starting to be investigated.