

Visit to Mazda, Sept 2, 1991

Background

Our hosts were Mr Yoshimi Okada, General Manager, Information Systems Dept 1 and Mr Masahiro Matsumoto, Assistant Manager, Production Planning Department. Others in attendance were Mr Yasuto Tatsuta (Mr Matsumoto's boss), Mr Hideki Kita (CAE for engines), Mr Tuginobu Tomita (CAE facilities), and three people from automatic transmission design and production: Mr Yoshinori Kurihara, Mr Haruto Kurihara, and Mr Susumu Ihara. Mr Matsumoto did most of the talking due to his command of English.

Mazda has about 30000 employees and sold 1.42 million cars in 1990, of which 833,000 were exported. 1990 sales were \$16.3 billion. The headquarters and main plant are shoehorned into odd-shaped and separate pieces of land around Hiroshima's waterfront. Use of space and arrangement of material flow must be done carefully. Like Toyota and Nissan, Mazda has an Information Systems Division that creates advanced CAD/CAE systems for body engineering and other applications. However, Mazda cannot yet design cars directly on computer screens. They see additional computer capability as essential to improve product quality, shorten product development and preproduction lead time, reduce the cost of prototypes, and enable more alternatives to be investigated.

Product Development Process

Mazda has about 4000 car design engineers and 1800 production engineers. Typically about 20 car design projects are under way at any one time, of which half are major product specification changes and the rest are face lifts or partial redesigns. Two thirds of the designers work on body and interior, while the rest work on power trains. As at Toyota and Nissan, many components are purchased from suppliers such as Nippondenso, and much of the production equipment is made inhouse. However, Mazda has spun off its machine tool division to form the subsidiary Toyo Advanced Technologies, Inc., and is using the resources to "in-source" many high value-added items, thus evolving toward the structure of US car makers. This is "the road to survival" in their opinion. Mazda is having problems finding people to do the engineering, especially software people. As at many companies, women are being increasingly recruited into engineering, drafting, and design tasks.

Mr Kita passed out four confidential charts from which he explained the overall product development process. While confidential, these charts did not show anything really different from what other Japanese car companies do, including the overall time required from beginning of exploratory styling to start of production.

Product planning and development are two separate stages, and design is governed in both stages by a series of design reviews. Production people take part in the reviews in both stages. A mechanical prototype to test engines and transmissions is built during the planning stage, and uses an existing car as the platform. Preliminary drawings are issued at the beginning of product development, and tooling design begins immediately. (However, some preliminary tooling design begins even before preliminary drawing release.) A prototype is built from the preliminary drawings. Following tests, the final drawings are made and issued and a prototype is made from these drawings. No final prototype is made. Instead, the last prototype is used as the basis for final revisions after which pilot production models are made at the factory. They acknowledge that this method is risky and involves changes. Die design is affected the most, since engines and transmissions are designed ahead on a much longer cycle. Die change affects outside suppliers who now provide most of the dies.

Later Mr Tomita, in explaining this process again, remarked that car design takes "too long" in the US and Europe. When I asked him why, he said "That's a good question." (Before moving to the CAE department, he spent three years in car design.) His reply was that Japanese car design is so competitive that all the companies struggle to design faster just to keep up with each other, essentially ignoring overseas competitors.

He says that small cars are easier to design and build, and it is easier to change their design. When I replied that small cars present severe space allocation problems, he replied that years of making small cars have given Japanese car makers the required know-how to attack the space allocation problem inside the car, especially in the engine compartment. When I asked him for examples of this know-how he could not provide any. The older engineers merely teach the younger ones what to do.

However, Mazda has developed a number of "design manuals" or "design standards" that give criteria and instructions for design of parts and components, and young engineers can learn from these. Each item, such as a radiator, cylinder block, or piston, is evaluated according to a set of criteria such as stress, strain, producibility, clearance around it, serviceability and so on. Each criterion has a stated reason, an important point since the reasons probably contribute to resolving conflicts and educating young engineers. Among the producibility evaluation criteria are: justification of tolerances for function and surface finish, and access for assembly. These are presented in the form of a manual checklist. No formal producibility or assembleability evaluation software is used. Instead, lessons learned from previous designs are written up according to formal Production Requirements Procedures and sent back to the designers for use on the next design. A database of these writeups is starting to be made.

The design manuals are going to be the basis for an effort to create "automatic design." This apparently means taking the steps in the manuals and programming them into a question-answer interaction between a designer and the computer. Mazda hopes to integrate such programs into one large program that coordinates the activities of many engineers, launching their work, receiving their replies, passing those replies to other engineers, and so on. Naturally, a lot of analysis of the design procedures and information flows will be needed before this integration can be achieved.

Longer term, their objective is to further reduce the need for mechanical prototypes by the process of "design-stage verification." The tools to be applied to achieve this goal are more design reviews, computerization of design standards and creation of standards for more items, and use of reliability analyses (failure modes and effects (FMEA) and fault trees (FTA)) in cases where conventional design analysis techniques are not sufficient or a conventional product technology cannot be adapted.

In this regard, I asked them about a joint program they had with a US company several years ago. Due to my own experience, I knew that both companies shared production responsibility for a certain automatic transmission, so I asked if they made any modifications to the drawings that the US company gave them. The answer was that they loosened a number of tolerances and clearances and relocated some datum holes to improve producibility. Then they manufactured the parts by holding 99% of the parts to within 70% or less of the allowed tolerance range. Mr Matsumoto emphasized that smaller variance than the stated tolerance was often achieved. These modifications and procedures led to the mistaken conclusion that Mazda had tightened the tolerances. This erroneous conclusion has even been published in widely read journals.

Use of Computers in the Design Process

Mazda has three supercomputers and three IBM 3090's linked together in a backbone LAN. They support over 1000 terminals, workstations, and PC's in the R&D Center, the Test Lab, and the Design Center. CAE applications include typical linear and nonlinear FEM, PAMCRASH, MADYMO for simulating behavior of dummies in a crash test, ACOUSIS for analyzing engine noise (Japanese software), ADAMS for kinematics, plus software for modal analysis, heat and fluid flow, combustion, aerodynamics, molding, sheet metal deformation, and structural optimization. A number of these programs are from Japanese companies, including some inhouse work by Mazda.

In a CAD room I was shown demonstrations of various CAD and CAE applications. Mazda uses its own 3D surface and wireframe CAD system,

which it introduced about 10 years ago. Body design data are transferred directly to the CAM department for conversion to NC data. NC data for prototype mechanical parts can also be generated from these models. Engine compartment parts are assembled into whole compartment drawings but no automatic interference checking is done.

Crash test data are created from a rough automatic mesh of the car body which must be augmented manually to create the final model. Twelve hours of Cray time are needed for a model with 30000 elements.

Interior design is also supported by wireframe models. Car "package" design can be studied using standard human body size data. On the screen I saw a study of driver's eye position with respect to the "A" pillar (driver-side support for the windshield) and another study to see if the steering wheel interfered with visibility of the instrument panel. Front wheel motion inside the wheel well when the steering wheel is turned can also be simulated. I was told that multi-link suspensions can be studied by computer but did not see any demonstration of this. ADAMS can surely support such studies.

Future Computer-Design Needs

Mr Tomita would like better fluid flow, combustion, and structural optimization software. Their world-wide search has not turned up anything that suits their needs so they will probably write their own. This software is intended to help them meet the 1995 CAFE requirements, about which all the Japanese car makers expressed concern. The CAFE rules may force a big change in the way cars are designed, he says. Mr Kita says that at present transmission design is supported by typical FEM software plus their own calculations for deciding gear ratios and dimensions of gears, plus clutch plate calculations like heat, durability, quantity, and size. Solid modeling is used for design of the moving parts of engines and for the transmission case. Mass properties are calculated. Fuel tank capacity is also determined using a solid model.

Some parts are designed using parametric descriptions. A few key dimensions are put in and the rest are determined by the software. This speeds up design of such items. Apparently the Q&A method is already in use for such parts. However, parametric design is not yet used for critical engine parts such as piston, crankshaft and connecting rod

They are in the process of extending parametric design to assemblies of parts, such as engines. The designer inputs a rough layout and the computer asks for or fills in key dimensions based on answers to its requests for material properties. I did not see a demonstration of this and the state of its development is unclear. However, it appears to be a first step toward "design automation" discussed above.

Mr Tatsuta would like better computer support for production engineers. The most basic need is for a database of production process information and verified process plans. Such data would include times and costs, step sequences, when to make inspections, and so on. Such information is pretty basic and other companies appear ahead in this regard. He would also like better CAE for stamping die simulation and verification, mold flow for die castings (they have it for plastic injection molding only), and ways of determining the noise generated by transmissions based on gears, running clearances, and the way these vary as the case deforms under various loads.

Tour of 323 Engine Assembly Line

This line is largely manual with typical automatic transport of parts from one station to the next. Of interest to me were assembly of pistons, cranks, and cylinders. Selective assembly is not used when mating piston, connecting rod, and wrist pin. However, selection is used for pistons and cylinders. There are three sizes of pistons. The cylinders are measured and one size piston is chosen for all four cylinders.

This is a very crowded line, with parts delivered within a few feet of the assembly line. The people are busy essentially the whole time, practically never stopping body or hand motions. Such an arrangement is typical of Japanese car manufacturing and is generally more intense than US practice. Just as in engineering, the result is that fewer people make more cars.