Visit to Hitachi Sawa Works and Taga Works, July 3, 1991

Mr Takahashi accompanied me to Hitachi's Sawa and Taga works. Sawa makes automotive components, Taga makes a variety of consumer products.

Background of Sawa Works

At Sawa, our host was Mr Sato, responsible for improving Sawa's CAD and CAE capability. He came there 5 years ago from Hitachi's Mechanical Engineering Laboratory, a more research-oriented facility. At that time, CAD at Sawa was little more than computerized drafting of ordinary machine drawings. He has had something of a hard sell and has written at least one of the new engineering applications himself, a program that does vibration analyses on rigid assemblies. It works by linking models of individual shapes such as bars and plates, for which individual vibration models have been worked out. The assemblies are joined observing the boundary conditions, so a valid model results. Uses include studying the effect of vibration on solder joints between circuit elements and circuit boards. This is a fairly sophisticated approach and indicates that Mr Sato is a good analyst who has the horsepower, if not the manpower, to change how Sawa operates.

Sawa's business comprises electrical and fuel components such as alternators, generators, engine controllers, pressure and flow sensors, microcomputer controlled carburetors, turbochargers, distributors, brake system controls, fuel delivery systems (injectors and manifolds), air conditioning systems, and so on. The plant has annual sales of ¥200 billion as of 1986 ($1.5 B), 2700 employees, and 100,000 sq meters of space. Major customers are Nissan, Fuji, Mazda, Suzuki, Honda, Ford, Chrysler, and Audi. Competitors include DELCO and the powerful Nippondenso.

Their introductory video heavily emphasized reliability, testing, reliability, design, reliability, and so on. Apparently this video is shown to prospective customers. It showed many robots and automated machines, including a line in a clean room for making injectors, a robot assembly line for alternators, and typical automatic production of circuit boards.

Another video of CAE showed use of super computers to evaluate flow out of injectors into fuel manifolds, including studies of the effect of fuel particle size (100 microns is too big) as well as supercomputer simulation of air flow from air conditioner vents into the car. Also shown was a simulation of use of active suppression of air conditioner noise using extra loudspeakers. A last supercomputer application was a dynamic analysis of stresses on a Nissan engine ring gear caused by meshing of Hitachi's starter pinion. Mr Sato stressed the importance of being able to access Nissan's CAD data in order to do this analysis.

So this factory makes heavily engineered products to exacting specifications under strong price and quality competition from other vendors in a world-wide market. They are still in the process of building a strong CAD/CAM/CAE capability under Mr Sato's direction. An important sub-issue is computer data communication between Hitachi and its suppliers. (See later report on Nissan's attitude and methods for communicating with *its* suppliers.)

Product Development Methodology

Sawa has some luxury in being able to work to the development pace of car companies. This gives Sawa much more than that available to the Image and Media Systems Lab people developing video cameras. Also, it is typical that 20 engineers might work on one item such as an alternator. Since alternators are far less complex than video cameras and change much less from model to model, this means that Sawa has effectively lots more engineers per project.

When I remarked to Mr Takahashi later that Sawa should send some engineers to I&MSL, he said that although no exchanges have occurred between Sawa and Yokohama, people from the slow life often cannot adjust to the pell-mell environment of designing fast-paced consumer products. Slow cycle automotive people are used to extreme reliability requirements, to which they respond with lots of analysis, many experiments, many prototypes, and heavy reuse of prior designs.

More importantly, the four year pace has given Mr Sato the chance to think ahead about his future needs for CAD/CAM/CAE.

The product development process consists of a series of prototypes and accompanying analyses developed in response to a specification from a customer. The process was illustrated with their current effort on a new small alternator for Nissan. The original RFQ came in 1989 for an anticipated car launch in the 1995 model year (fall 1994). The spec included target power, size, weight, and cost. The spec was negotiated and probably adjusted in monthly meetings for a year while Hitachi did lots of computer studies based on varying existing factors and technologies. Later this year Sawa must deliver primary samples which Nissan will road and lab test for performance, reliability, and noise. Responses from other vendors will be tested during this period, and a decision will be made a year from now. If it wins a contract, Hitachi will then have over two years to develop final designs and process plans, design and facilitize the factory, and start up production. During this time, Nissan will finalize its engine design, perhaps altering the mounting conditions for the alternator and requiring additional noise and vibration studies.

Use of Computers in the Design Process

The engineering analyses supported by Hitachi software presently include:

- FEM to study vibration of cast housings and circuit boards
- magnetic field analyses of rotor, stator, gap, materials, windings, etc
- a spreadsheet for quickly doing the basic electrical calculations such as power-speed-voltage tradeoff curves (an example of what Mr Sato calls a "handy program") - a nice color graphics interface and graphic output, including documentation of all the engineer's calculations, like an engineer's notebook
- sensitivity analysis software to determine the effect of varying certain parameters in the hope of obtaining a less sensitive design or of finding a way to improve performance by changing parameters
- rotor dynamics to predict bending and vibration
- various commercial FEM programs, two mold flow programs, Hitachi's inhouse CADAS CAD software, and occasional use of the assembleability evaluation software from Hitachi PERL

On a tour of the CAD lab I saw several displays of simulation outputs plus demos of several of the above capabilities. Others were

- fuel particle flow in several vendors' designs of manifolds
- analysis of impact of injector valve on valve seat
- starter motor magnetic flux
- airflow over a hot wire anemometer
- sensitivity and modal analysis of alternator end casting vibration (display on workstation of mainframe calculations done earlier)
- parametric creation of new "designs" for alternators by combining menu choices of 18 parameter values (3 shaft diameters, 5 lengths, 3 outer shell diameters, and so on).

In the last program, the designer chooses the parameter values, and the computer creates a consistent set of drawings, except where the combination chosen could not be resolved by the computer. Such areas are left blank and the designer draws them in using typical 2D CAD methods. In this way, routine products can be put out very quickly, as long as they do not challenge the state of the art and require real design engineering. Such programs have been written for alternators, starters, and distributors. They are not linked to any of the CAE software so they are good only for deploying existing proven designs. Thus it is really a documentation management program rather than a design program, but it hints at what might be done in the future. In particular, it contains no AI, no feature-based representations, and no constraint-based descriptions. Application of these methods would permit substantial design variations to be accommodated without leaving blanks.

With the exception of a few Silicon Graphics and HP9000 workstations, these demos ran on Hitachi workstations or PC's and often utilized output from three Hitachi mainframes elsewhere in the building. UNIX appears to be the OS of choice.

Much of the effort to computerize design is driven by the need to make all components smaller and lighter, with the ultimate aim being the car-maker's need to meet the 1995 CAFE standards. To make things lighter, one chooses lighter (often relatively weaker) materials and thinner sections. These, in turn, are subject to vibration which in turn causes noise or, worse, structural failure. Low noise is a major Japanese automotive design goal and competitive feature, so the goals of low weight and low noise naturally conflict. Identifying and resolving design conflicts is a major challenge for both designers and researchers. Here the response is to build up over the years an extensive analytical capability and drive it night and day to gradually improve and refine the designs. Trial and error on the computer seems to be the main modus operandi.

An interesting point is that a bench test is different from a test in a car, since benches are rigid compared to cars, which have resonant vibration frequencies of their own. Thus the software has been written to simulate either environment so that test data can be compared with computer predictions. One of their test setups is a GENRAD vibration stand, analyzer, and display linked to the computer.

Mr Sato categorized his emerging software tool set as follows:

Design Stage	**Tool or Type of Tool**
Conceptual	Commercial CAE tools (visualization)
Product	Routine design work, small changes to existing designs, commercial CAD tools
Production	FEM tools for designing press processes
Testing	GENRAD vibration system and other lab analysis and experimental support software

Concerning what he would like to see in the future, he will provide what the designers ask for. On his own wish list are

Design Stage	Tools Desired
Conceptual	Easier communication of files and data between Hitachi and both its customers and suppliers: includes geometry models and CAD data, plus test data, analysis results, etc
Product	Sensitivity analyses, parameter manipulation, expert system for effect of tolerances on performance and reliability. Structural optimization for both shape and dimensions
Production	Better assembly analysis tools? No clear wish here
Testing	No clear wish here

Visit to Taga Works

In the afternoon we travelled to the Taga works. There the host was Dr Murakami, who came to Taga from PERL several years ago with the same mission as Mr Sato has at Sawa.

Background of Taga Works

The Taga works makes a wide variety of consumer products (50% by yen sales) such as washers, vacuums, and fans; office equipment (30%) like word processors, laptops, and laser printers; and industrial labor saving devices (20%) such as electric motors, hoists and factory ink-jet printers. Their introductory video tied this assemblage together by the fact that all (laptops, too?) contain electric motors. The plant covers 400,000 sq meters, has [only!] 2500 employees, and turns over $960 million per year.

Product Development Illustrated with Fuzzy Control Washer

A recent washing machine was used as the example product for illustrating use of CAD/CAM in design. This is a "fuzzy controlled" machine with one button: START. Using sensors, it determines the amount of clothes, the average weight of material in the clothes, and the degree of completion of washing. It adjusts the wash, rinse, or spin time to suit. It has been on the market for about a year and costs ¥119000, or $881 at ¥136/$. (A BigMac is ¥380, or $2.80, and a good electric iron - without any fuzzy control aspirations - can cost anywhere from ¥9000 to ¥28000, or $66 to $207.)

This washer took three years to develop, involving 10 to 15 engineers at a time, including all the test and inspection teams. Three prototypes were made during this period. The most difficult design challenges were the motor controller and the shape of the agitator. At least 15 agitator shapes were thought up and tried, being machined out of solid blocks of ABS.

The marketing objective was to produce a user-friendly smart appliance having the ability to run and diagnose itself. It has a timer like microwave ovens and coffee makers so it can be set to run at night when everyone is asleep and be ready in the morning for drying to be done. Since Japanese apartments and houses are very small, it is likely that someone sleeps near the washer, so it must be very quiet. It also must be small and light, so all the parts must be light.

All the noisy solenoid valves have been replaced by quiet motor-driven ones, a quiet balancing system was designed, and gear noise was removed by reversing the motor to create the agitation. They do not know if this will cause motor failures in future years. This must be the reason why motor controller design was difficult. No special materials or sound deadening paints were used. No software for predicting noise was used either. However, like Japanese cars, this washer aims at the trend toward quieter and friendlier products, and much of the CAE used was directed at achieving these goals.

Clothes quantity and weight are measured by filling the tub with a known amount of water and spinning up, then letting the motor coast and measuring the decay time. This is done twice with different water levels to determine quantity and weight separately. A conductivity sensor measures soap concentration and dirt quantity in the water. Wash and rinse times and their water amounts are adjusted accordingly.

While they call this fuzzy control, I think it is in fact a set of lookup tables. Most fuzzy logic applications I am aware of use linear interpolation between preset responses for full set membership to generate a graded response for partial set membership. [For example, "if clothes are heavy weight, use full water level" and "if clothes are medium weight, use half water level" would generate 3/4 water level for clothes that measure halfway between heavy and medium.] So while fuzzy control is a great marketing idea and the machine is truly useful, the technology development is in the sensing and in converting sensory readings into good estimates of clothes weight, not in design of the controller itself.

Final assembly of this washer is entirely manual, but motors and other drive train parts like clutches are built up by robots. The cabinet and tub are made from sheet metal cut and bent automatically. Controls, lid, and agitator are injection molded plastic. Since both outer cabinets and drive trains are redesigned infrequently, automation can be applied to their fabrication and assembly. But control surfaces and lids change as fast as twice per year. This causes a strain on Taga's design talent. Marketing creates the pressure. Mr Takahashi agrees that these redesigns are superficial but he adds that a shortage of engineers keeps Taga from undertaking the deeper redesigns that they would like to pursue.

Use of CAD/CAM/CAE

Only recently has CAD / CAM / CAE come to Taga. In this sense, the Image and Media Systems Lab is well ahead of Sawa, which is in turn well ahead of Taga. They have had Hitachi's CADAS for several years but only recently got Moldflow for plastic molding analysis and ADAMS for kinematic analysis, both linked to SDRC's I-DEAS solid modeler. Their first attempt recently to transfer CAD data to the machine shop did not work very well. The factory's software development center set all this up for them.

[Prof Kimura told me later that Hitachi has a System or Software Development Lab that is responsible for finding and trying CAD products and getting the factories to use them.]

So the fast response to the market has been accomplished "by our sweat and tears." Right now it is faster to redesign by hand than to create a solid model and run Moldflow. Usually only small changes occur so their experienced designers know what to do to design a new mold. Presumably a feature-based approach would speed things up, since many of the plastic parts consist of regular flat surfaces with rims around the edges and bosses underneath to take screws. Expressing this in terms of features would not be difficult.

They do not have any software to analyze water flow patterns created by different agitator designs. Energy transfer to the clothes is more important than water flow in this kind of machine anyway, but still there is no software.

The CAE Lab contains numerous Hitachi workstations operating under UNIX. There are also several Silicon Graphics terminals. In the lab they showed me use of Moldflow plus a verification part that agreed fairly well with the simulation. Another demo concerned using ADAMS to predict how the tub would sway for particular unbalance loads. This information can be used to size the clearance between the tub and the outer housing. The FEM program ADINA is used to test the strength of a crimped joint in the tank, based on loads caused by unbalance. Another use for ADAMS is to predict how a vacuum cleaner will track when pulled by the hose, based on various caster designs and locations.

The CAD office also contains Hitachi workstations and UNIX. Drafting is the main activity. Some computers are linked directly to the factory floor or to the purchasing department, to which drawings are sent defining the specs for inhouse and purchased parts. "Engineers have a lot of power over purchasing decisions." Altogether they have many workstations and have invested a lot in computers and LANs.

Another interesting program is a parametric design system for hoists. When an order is received, the engineer types in the specs, such as capacity, lifting speed, and so on. The computer searches the database of past designs and finds the one(s) whose individual specs match exactly or come the closest. Some items in the spec may be missing completely so they are left blank. The designer then retrieves the useful drawings and makes the missing ones. Mr Sagawa, representative of the software service department, said it took them a year to write this program. It has been in operation for 6 months.

This is a version of what GE calls "purchase order engineering." It is called variant design in the academic world. GE told me that 85% of their engineers do this kind of work and it has been largely automated on workstations. I saw a more sophisticated version at Cooper Industries where high capacity industrial air compressors are made. The compressor vanes are the most complex to design, so existing designs are used to the extent possible. A similar database exists with 10000 prior designs in it, and the three nearest are found by least squares optimization of the parameter matches.

Discussion

At this and several other plants I have visited, there are a few female engineers and "draftsmen." In view of the rising shortage of engineers that every company is feeling, this trend toward women engineers is expected to increase.

It appears that the shortage is causing many problems. A major one is that companies can no longer make the design changes they want to, or cannot put them into effect as fast as they would like. Yet rapidity of model changes is the main competitive weapon between Japanese companies and is the biggest advantage they feel they have over international competitors. This must mean that every Japanese company has the same problems, but Hitachi feels that some of its competitors, certainly Sony, can do things faster. They feel that Sony may have some "secret weapons" such as better management methods or better computer tools. They are frankly puzzled and worried.

It is interesting to compare this reaction to Sony's, which is that the engineers just work hard and marshall their experience effectively. At Nissan I was told the same thing. Nissan especially disavows the importance of computer aids in relation to management and work methods, ascribing the "Japanese advantage" to precisely the points made by Prof Fujimoto.

While it is true that engineers at most companies I visited work hard and stay late, I think it is disingenuous to say that computer aids have had little effect. As far as I can tell, every company I have visited has bought the best and latest US hardware and software and applied it intensively. Rates of penetration differ, and some companies use their own hardware (Hitachi) or software (Nissan), but the trend is the same. Still, CAD / CAM / CAE cannot do enough of the job to relieve the pressure on the engineers. They are now so tired out that some companies are openly discussing slowing down the pace of new designs. (See Hitachi Construction Machine Co. report.)