

Visit to Seiko-Epson, August 30, 1991

Background

The plant I visited is in Shiojiri, about 2.5 hours on the train from Tokyo. It makes dot matrix printers, laser printers, ink jet printers, and personal computers. Discussion on this visit was exclusively on dot matrix printer design and manufacture. My hosts were Mr Akio Mitsuishi, General Manager of printer design and development, Mr Asada, a print head designer, and Mr Mitsuyoshi, General Manager of CIM.

Seiko-Epson was formed in 1986 through the merger of Suwa Seikosha Co, Ltd., a famous maker of watches, and Epson Corporation. The combined company has 13300 employees in Japan and 11000 in 27 other countries, including the US. Products include printers, personal computers and laptops, memories, semiconductors, motors and rare earth magnets, and, of course, watches. The company makes LCD displays, some of which it uses in its laptops. It also makes, uses internally, and sells a line of accurate assembly robots.

Epson makes two main kinds of dot matrix printers, those with 9 pins for low end use and those with 24 or 48 pins for high end use. Heads are made at another plant using automatic assembly. Mr Mitsuishi claims that no one else can assemble print heads automatically, especially insertion of the wires. I confirmed on one other visit that a competitor inserts its wires manually.

Like most Japanese companies, Epson has trouble finding new employees, especially software engineers. Shiojiri is not as exciting as Tokyo but "houses are inexpensive and the environment is good."

Product Development Process for Printers

The organization of the design process changed about two years ago when Mr Mitsuishi introduced team design. His motto "common goal" helps the designers create the best printer, not the best print head, for example. Prior to that time, separate groups designed each subassembly, which led to problems. However, even before team design was introduced, there were design reviews in which each part was critiqued.

Design occurs directly on the computer screen with little or no pencil sketching first. They use their own CAD software for this (see below). However, they do not use any formal DFA methods, although they have considered it for two years. He studied the IBM ProPrinter, which was heavily publicized in the US about 5 years ago as an excellent example of DFA. It contains many complex plastic parts whose use has greatly reduced the number of parts compared to competitive printers of that time, including Epson's. These parts snap together, reducing the need for screws.

Epson's recent printers are similar to the ProPrinter in this respect. In spite of this fact, Mr Mitsuishi was not completely satisfied with the ProPrinter. He admires its ingenuity but worries (with some personal knowledge, apparently) that it is hard to find vendors in the US who can deliver the complex plastic parts that such a design method requires. (Many Japanese say the same thing: high quality suppliers are hard to find.) Epson has its own precision mold making and plastic part making division for such items.

Product design, excluding technology development and print head design, typically takes about a year and involves a team of 15 to 20 people. A typical printer has about 100 parts plus at least another 50 in the print head. About 5 production engineers support design.

A tour of an automated printer assembly line (details below) showed that their printers have been designed so that most of the assembly operations are from above or the sides, and can be accomplished by rather accurate XYZ robots (± 0.03 mm repeatability). Manual intervention is needed for one turnover and to handle wires and a few tests, as well as to undo jams in the screw feeders for 5 screws that hold in the power supply and a circuit board.

Almost all the parts are plastic, except for a sheet metal foundation for the head transport mechanism and several precision steel shafts. The plastic parts are glass-filled ABS and many are quite precise gears and levers. The division where these are made also makes lenses for eyeglasses and laser printers.

They are particularly proud of their print head design because it permits automatic assembly. The wires must pass through entry holes that are arrayed in a circle and exit through holes that are arrayed in two straight lines. To guide them from one pattern to the other, four intermediate guides are provided, each with holes in a different oval pattern. Special software was written to decide what these intermediate hole patterns should be so that the 6 holes for each wire lie in a straight line. Assembly then requires only the correct straight line motion.

Wires are about 0.2 mm in diameter, and the holes are about 0.25 mm. This size is typical in the industry. Each wire is about 2.5 cm long and quite straight. It is welded to an armature at one end, giving the whole thing the shape of a tiny golf putter. One of their robots inserts each wire individually by grasping the armature, using no vision or force sensing. I tried this with my own hands and poor vision and found that the wires almost fall in by themselves.

In other respects, too, the print head is a good example of DFA. All assembly is from one direction, and it is held together by a few spring clips.

In general, print head assembly appears to have many aspects in common with watch assembly, and the sophisticated expertise built up in watch assembly has been utilized in printer manufacture.

Use of CAD/CAM/CAE

Seiko developed its own CAD software for 2D drafting in 1979. Originally used on a Univac machine, it was ported to Apollo workstations in 1985 and transferred to the printer division at that time. The company now has 400 networked workstations, 250 of them in the printer division. Printer design is done by 350 people, of whom 100 mechanical designers each have their own workstation. Electronic design is done on DEC or HP computers, while software development is done using Sony's NEWS workstation. In the production engineering division, 200 production engineers are networked to the design division's database.

For the moment there are no plans to convert to 3D modeling for general product design. The reason given is the investment in special software to support printer design, such as that mentioned above for print head wire trajectories. However, SDRC's solid modeler or ProEngineer is used to support NASTRAN, MARC, and RASNA (all FEM packages) for various kinds of CAE. Moldflow software is used by the molding division to critique part designs, but the part designers themselves do not use it.

In spite of Epson's reputation for high reliability printers, I was told that no special software is used to predict lifetime of critical parts, such as the welds that join print wires to armatures, the belts that drive print heads, or the coils in the head (subject to a lot of heat). They simply test or attempt accelerated life tests. The vibration behavior of print wires is very complex, giving rise to base frequencies of 1 KHz or more plus many higher harmonics. They are attempting to simulate the physics of fatigue in such parts but they have not made much progress. Mr Mitsubishi is willing to fund research on this topic.

Future Needs

Mr Mitsubishi cited four areas where he would like improved computer support: tolerances, design for assembly, routine data transfer, and cost modeling.

He feels that CAD generally is just an electric pencil with the advantage that it is easier to erase electric pencil than physical pencil. Other than that, CAD offers him no real engineering support. He would love to have a way to decide if the correct tolerances have been specified.

He is aware of simple rules for DFA such as making assembly moves from one direction (not possible with his current printer designs) but he does not know of many others that are really helpful. [Note that his printers are much less complex than, say, Sony's or Hitachi's video cameras.]

Routine data transfer causes problems all the time, not only between Epson and its vendors but even in-house. The problem is most acute when transferring NC data from design to mold-makers. Molds require draft angles and different vendors require different angles, depending on their skill. The base design usually has no

draft angle. Keeping all this straight is apparently a big problem. Another source of data transfer problems is in tolerances, where designers may specify asymmetric tolerances (+7, -5) whereas most CAM software requires symmetric specifications.

These are not what we would call data transfer problems since they are not the result of a translation protocol failure but rather are at a higher level of design specifications and management.

Finally, he would like CAD to help him predict costs.

Tour of Automated Printer Final Assembly Line

This system has 35 basically identical XYZ robot assembly stations. The first half was installed 7 years ago and took 15 people less than a year to design and install. The second half was installed 2 years ago. It can build two kinds of printers, but these apparently differ only in the number of wires in the printhead. Production capacity is 350000 per year, two shifts.

Parts are delivered by automatic guided vehicles (AGV) to places where people dump them into vibratory bowl feeders or place delivered pallets on racks.

A typical station has one or more feeders (two bearings, for example) and special tooling on the end of the robot that can grasp one bearing at a time and then assemble them one at a time. Some robots have more than one gripper on the tool and can grasp and install a second part or even a third one, since the cycle time is a comfortable 30 seconds.

Gear teeth are mated by slowly turning one gear; in one case the gear on the rubber drive belt is turned by a finger that stretches the belt; in another case, a blast of air is used.

Several shafts are installed by the "parallel parking" maneuver since both ends must be inserted in closed holes. These assembly moves are effortless sequences of fixed pivot tool rotations and linear robot motions.

At the end of the line, ladies handle the wires and paper needed for final testing, but packaging is entirely automatic. A curious feature of final installation and test of the print head is that the head is installed and removed 5 times at 5 different stations. It appears that only one of these removals is really necessary. No satisfactory explanation for this was obtained.

This system is a local showplace, and descriptions in many languages, including Russian, are available at the door.