Designing for Productivity Saves Millions

Reducing the number of a product's components and its manufacturing steps starts in the design phase.

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Designing for productivity is a process which combines both design and manufacturing disciplines. A screw may be a quick and easy solution to hold two assemblies together for a designer, but for the manufacturing department, driving that screw for hundreds of thousands of parts instead of making the assembly snap-fit can cost far more than the design time saved.

Simplifying an assembly by reducing the number of parts can also provide astronomical savings for a company mass producing products. Many times, even the costs of additional design time, retooling, specialty fasteners, and new materials do not outweigh the savings generated by the more efficient design.

Whether manual or automatic assembly is used is many times less important than that the analysis to simplify the assembly was done. Some companies have simplified an assembly, done a cost analysis on automating it, and decided to stay with manual assembly. But those cost savings from simplification of the assembly remain, and sometimes are even larger because there is no additional capital expense from the automated equipment to pay off.

The basic principles of Design for Productivity were outlined by Geoffrey Boothroyd and Peter Dewhurst of the University of Rhode Island (formerly of the University of Massachusetts). Boothroyd and Dewhurst have developed a software system for IBM PC, XT, AT and compatible personal computers which encapsulates their Design for Assembly Handbook. A 45-minute instructional videotape is also available.

The handbook and software detail a system which uses numbers to evaluate whether a product is being assembled most efficiently. The seven software programs operate by entering the names of a product's parts on the screen and answering basic questions about each part.

As each question is answered, a worksheet is automatically created on the computer screen. Complete analyses for the basic assembly systems are printed out after the questions are answered.

Boothroyd and Dewhurst are also working on a Design for Electronic Assembly handbook to analyze the most efficient methods of assembling components on a circuit board. Another way of speeding the design for assembly analysis is also being investigated. This method would include the software in CAD/CAM systems so that ultimately the manufacturing cost of a product or assembly could be determined by pressing a button with a minimum of inputs.

DFA analysis used extensively

Many companies are using design for assembly analysis regularly. Hitachi has been teaching a method for years. Xerox and IBM teach its employees the entire Boothroyd/Dewhurst system.

IBM offers a two-day seminar on Design for Assembly methodology at regular intervals at its IBM Corporate Quality Institute.

"We stress the idea that successful assembly automation hinges upon purposeful design for automatic assembly," says Morris Krakinowski, a senior engineer at IBM.

A major project at IBM involved design for assembly evaluation of 1,300 drawings that make up 50 subassemblies. A functional prototype was developed and then analyzed for manufacturability.

"We run the design analysis software on an IBM PC, which requires no programming skills," says Krakinowski. "But if users are not carefully introduced to the system, the results can be somewhat misleading.

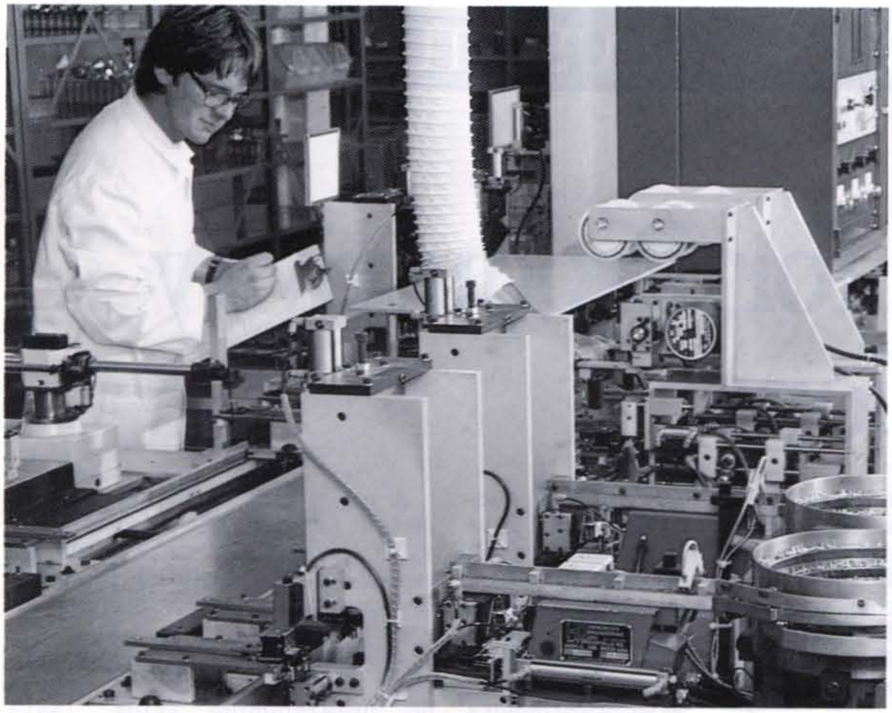
"The terminology is simple, but the meaning of the terms are rigorously defined. For example, the meaning of a term such as 'part is easy to handle' may appear self-evident, but it has a very specific meaning in the context of the analysis system. That is why we use the two-day workshop to introduce users to the subject and give them enough of a working knowledge of the system."

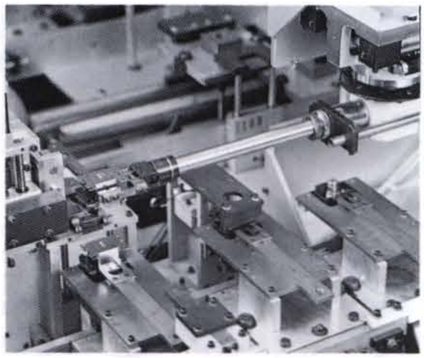
General Electric has been conducting Design for Assembly workshops throughout the company. They have resulted in reduction of parts requirements by an average of 20 percent and cut assembly labor by an average of 40 percent. Handling and inventory costs have also been reduced due to the improved designs.

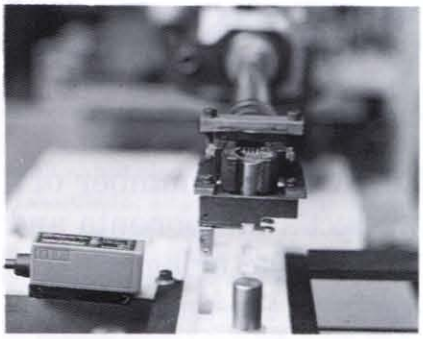
The 2½-day sessions are led by two DFA consultants from GE. The first day explains DFA evaluation and breaks the group of 20 attendees from design engineering, manufacturing and quality personnel into small teams which each analyze two practice assemblies.

On the second day, the small teams analyze their own products. Then on the third day, the teams brainstorm ideas to improve each product's assembly.

At Black & Decker, the Boothroyd Dewhurst design for assembly technique has been used extensively. One product which has used it is a specially designed, high-strength flashlight for firefighters called the Sun Lance.







Designing automated manufacturing *for the Type 91 relay at Hamilton Standard Controls in Logansport, Ind. resulted in a substantial reduction of direct labor. In the photo at the upper right is shown robotic assembly of the magnetic subassembly and terminal block subassembly. In the photo at bottom right is robotic assembly of the movable contacts and actuator to the terminal block assembly. Shown in the large photo at left is final assembly riveting of the terminal block and magnetic subassembly. Behind the feeder bowls, terminals are soldered.*

Sequential stacking *motions are used for this Whirlpool vacuum cleaner motor assembly (the enclosure of which is shown being inserted on the line). The assembly consists of the electronic controls, four screws, a mounting bracket, the seal and then the motor.*

The number of parts on the flashlight were reduced from 30 to 10 and the number of manufacturing processes dropped from 16 to five. Assembly time was reduced by 60 percent. Among the techniques used besides design for assembly techniques were eliminating adhesive bonding and soldering.

Hamilton Standard Controls, a unit of United Technologies, has also designed many of its products for productivity using the Boothroyd Dewhurst approach. Besides their electronic controls, the company has also used design for productivity in the manufacture of two relays.

Direct labor on the Type 91 relay was substantially reduced by designing it for automation. There was no net reduction in parts or assembly operations, but some of the metal fabrication processes were changed so they were more consistent. The use of feeder bowls, pick and place machines, and automated testing resulted in the labor reduction. Within

Xerox, IBM, GE, Whirlpool and Black & Decker have used design for productivity extensively.

four months, the line was running at 70 to 80 percent of its rated output.

The Type 134 relay was designed using the knowledge the company had gained by redesigning the Type 91 production line. The cover and base of the 134 relay snaps together instead of using screws, and fly winding equipment, which is new to the company, will be used to wind wire on the relay's bobbin.

The standard winding method which had been in use involved putting the relay's bobbin on an arbor and rotating it at high speed. But since the 134 relay has terminals which are long relative to most relay bobbins, there was the possibility that the centrifugal force of rotating the bobbin would throw the terminals out of place. But with the fly winding equipment, this mishap won't be possible because the bobbin will be stationary and the flyer will rotate the wire around it.

The company also has a proprietary way of maintaining the critical dimension between the magnet core and the pivot point of the armature. A patent is being applied for it.

Designing vacuum cleaners

When designing its new vacuum cleaner line, Whirlpool used several design for productivity methods including the Boothroyd Dewhurst method. One method used was classifying parts by their material properties and designing them to be multifunctional.

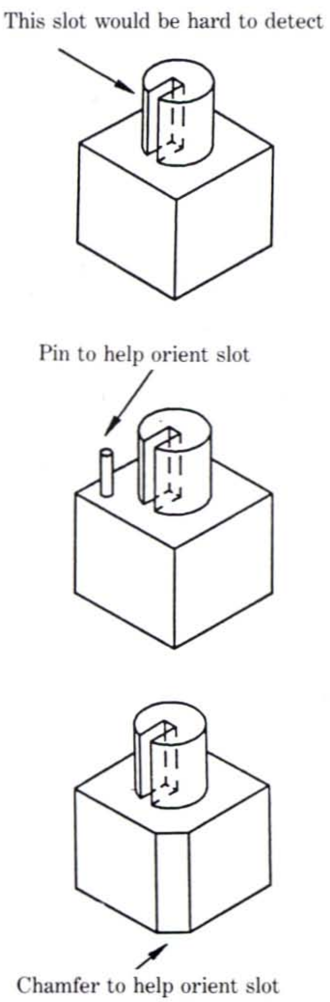
An example of this is the wraparound bumper on the canister vacuum cleaner. It serves not only as a bumper, but as a seal for the dust bag cover.

The motor mount, which is made of an injection moldable thermoplastic rubber, also serves as a vibrational dampening mount and as a seal to separate the two vacuum chambers of the machine.

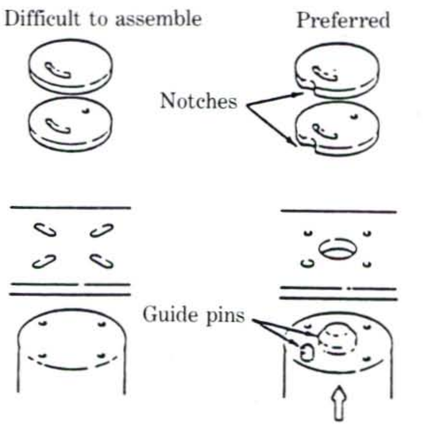
Another productivity method was to classify parts by production tooling processes by incorporating more features into one mold. The number of parts and molds were reduced in several locations of the canister vacuum cleaner.

A new swivel caster design reduced the number of parts from 20 to four. The base of the canister includes the support for the rear wheels and is retained by snap catches. The front handle on the base also serves as a bumper support, and the base includes the cord reel support.

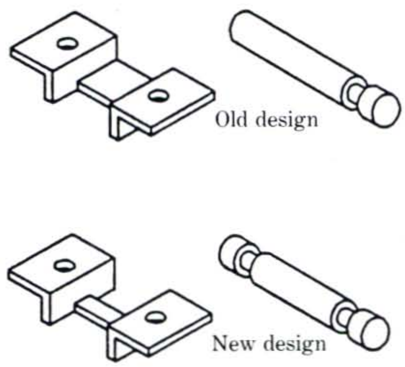
The net benefit of these sophisticated tooling ideas was that the molds



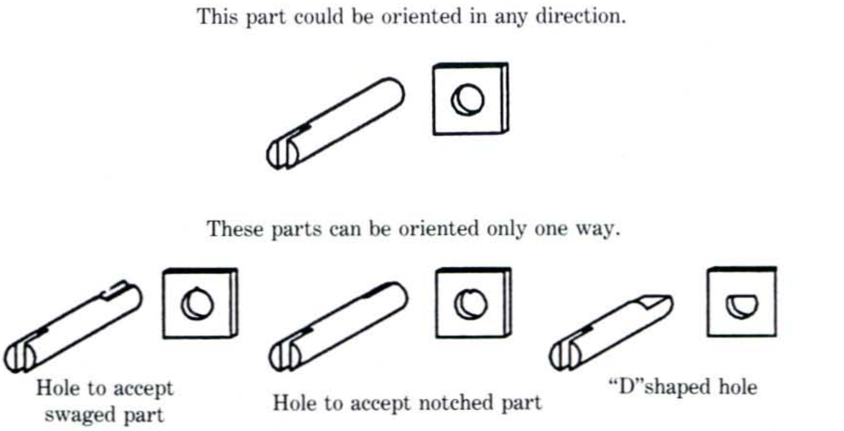
External features *can be added to orient parts.*



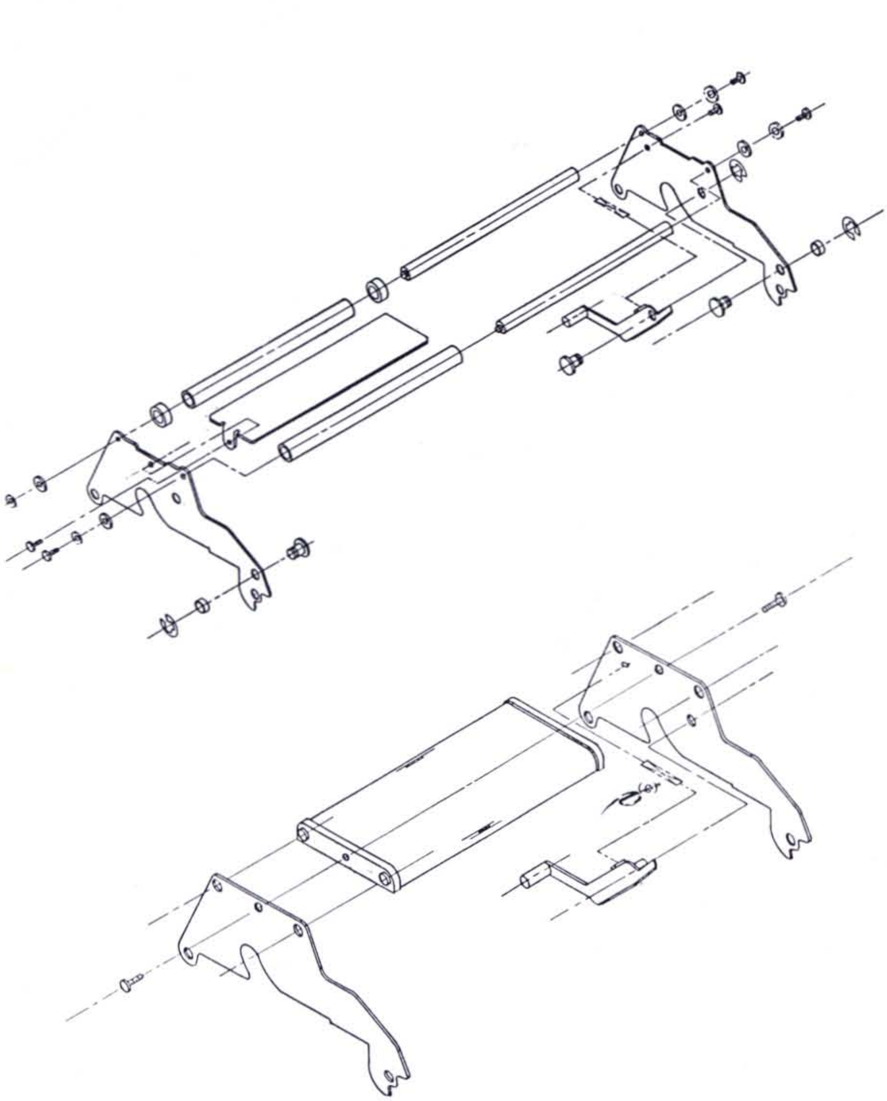
Self-fixturing *of parts with notches or guide pins can ease assembly.*



The parts *in the lower row were redesigned for symmetry so the possible number of orientations was kept low.*



If parts *can't be designed symmetrically, their asymmetry should be increased so they can be oriented only one way.*



***The redesign** on the bottom was one of three done by NCR Corp. for a paper guide assembly in a teller machine. It reduces the total number of parts for the assembly from the 33 shown on top to seven.*

are pieces of fixed automation—they reduce the number of assembly operations.

The third productivity method used was to design the product for assembly efficiency. Linear motion is used extensively in the assembly of the vacuum cleaner. For example, the motor was designed to use straight line assembly motions.

Included in the motor assembly is one of the electronic controls, four screws, a mounting bracket, the seal and then the motor. These components are all assembled in a sequential stacking operation where the net benefit results from a simplified and more efficient assembly method.

DFA rules

The basic principles of Design for Assembly relate to two areas: the ease of component handling and assembly of a product or subassembly; and whether the minimum number of parts have been used for a product or subassembly.

The criteria Boothroyd and Dewhurst established for the minimum number of parts test was:

- Does the part move relative to its mating part during operation or service?
- Do the parts have to be of different materials?
- Do the parts have to be disassembled during assembly or service?

The assembly efficiency is then calculated by dividing the theoretical minimum assembly time by the estimated assembly time. The theoretical minimum assembly time is assigned by the Boothroyd Dewhurst method according to the product. The time value is for ideal parts and is standard for all parts.

The estimated assembly time is a theoretical minimum assembly time plus time penalties for problems in handling and inserting assembly parts. If a part is eliminated, the assembly time for that part is zero.

A general rule of designing for assembly is to avoid fasteners, especially non-standard ones. But when they are necessary, the same type of fastener should be used. If washers are necessary, they should be attached to a bolt or screw ("captured") rather than separate. Also, tapped holes should be avoided and self-threading fasteners substituted.

In manufacturing, "pancake" assembly, in which parts are layered on top of each other along the Z axis, can be used not only to simplify assembly motion, but also to reduce the number of fasteners. To provide compliance or "give" in part assembly, so accuracy errors can be forgiven, chamfered or beveled part edges are helpful.

Simple mechanical processes should be used in manufacturing when possible. Difficult ones such as welding or brazing, soldering, and certain adhesives should be avoided.

Nesting a part in an indentation in the work surface which matches its contour can eliminate clamping the part down during assembly. Cables which must be connected, as on a loudspeaker, should have connectors attached to them so the cable end can be located. Electronic components should not be connected to a circuit board with cables, but rather mounted on a slave circuit board and the slave board inserted into the main circuit board.

Other design for assembly ideas are shown in the accompanying diagrams. □