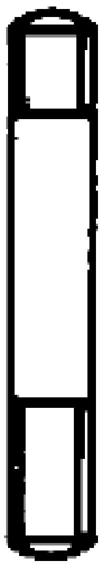
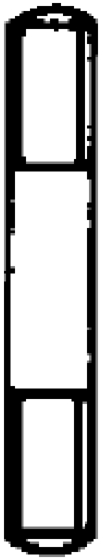
Design for robotic assembly

Introduction

- The slightly asymmetrical threaded stud would not present significant problems in manual handling and insertion
- For automatic handling an expensive vision system would be needed to recognize its orientation.
- If the part were made symmetrical, automatic handling would be simple.



asymmetrical - difficult to orient



symmetrical - easy to orient

Introduction

- If a part can be handled automatically, then it can usually be assembled automatically.

- When we consider design for automation, we will be paying close attention to the design of the parts for ease of automatic feeding and orienting.

Introduction

- In automatic assembly:
  - **Time** taken to complete an assembly does not control the assembly cost.
  - It is the **rate** at which the assembly machine or system cycles.
  - If the total rate (**cost per unit time**) for the machine or system and all the operators is known, the assembly cost can be calculated.

Introduction

- We shall be mainly concerned with:
  1. Cost of all the equipment
  2. Number of operators and technicians
  3. Assembly rate at which the system is designed to operate

- Apportion the cost of product assembly between the individual parts and, for each part; we shall need to know the cost of **feeding and orienting** and the cost of **automatic insertion**.

Design for feeding and orienting

- Feeding cost per part is inversely proportional to required feed rate and proportional to feeder cost.
- For otherwise identical conditions, it would cost twice as much to feed each part to a machine with a 6 s cycle compared with the cost for a machine with a 3 s cycle.
- This illustrates why it is difficult to justify feeding equipment for assembly systems with long cycle times.

Design for feeding and orienting

- The faster the parts are required, the lower the feeding cost.
- This is true only as long as there is no limit on the speed at which a feeder can operate.
- There is an upper limit to the feed rate obtainable from a particular feeder.
- F_m = maximum feed rate

Design for feeding and orienting

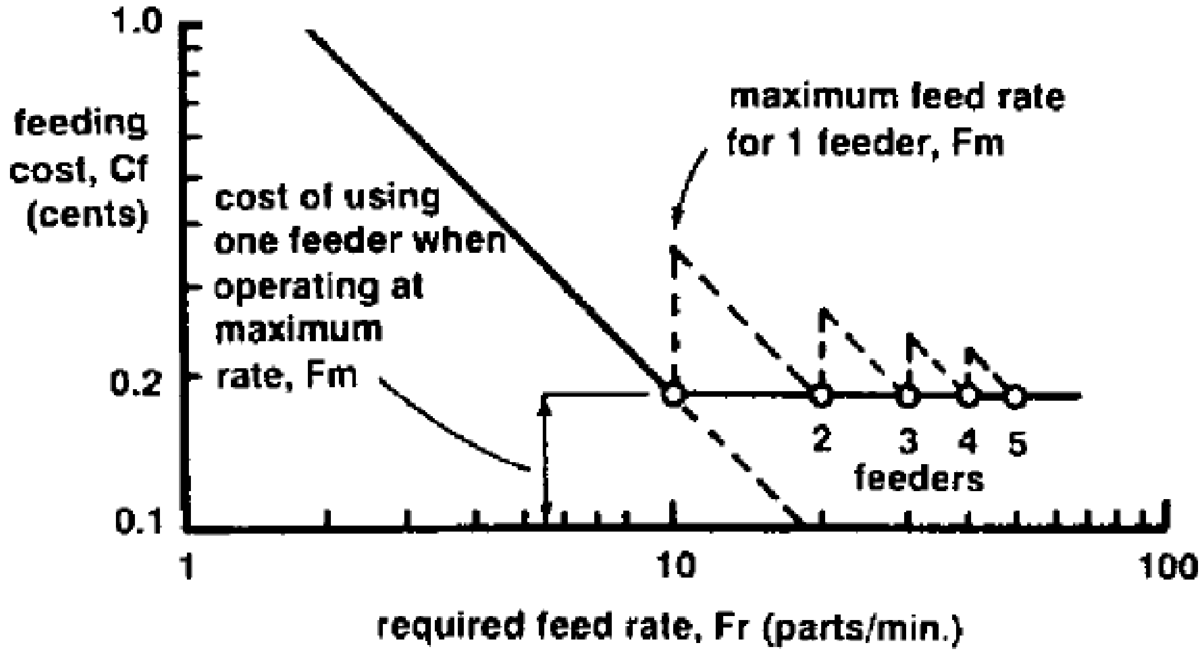
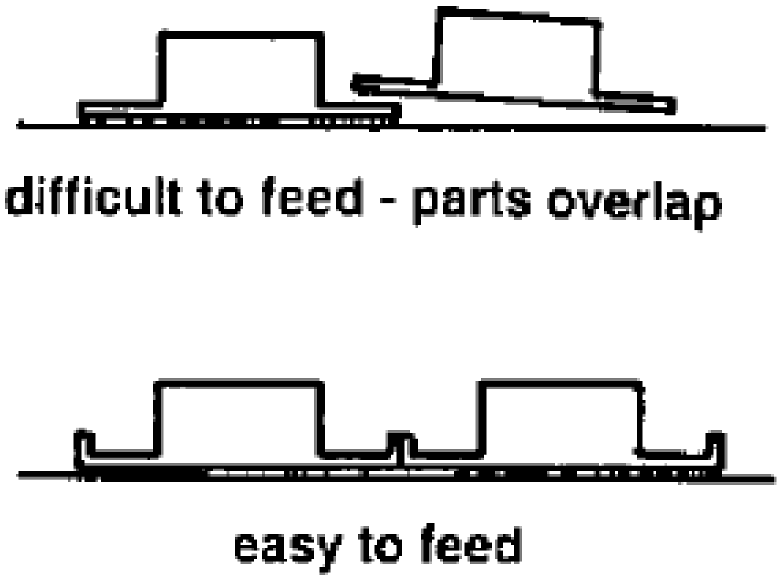


FIG. 5.2 Effect of required feed rate on feeding cost.

Additional feeding difficulties

- If edges of parts are thin, shingling or overlapping can occur during feeding, leading to problems with the use of orienting devices on feeder track



Analysis of an assembly

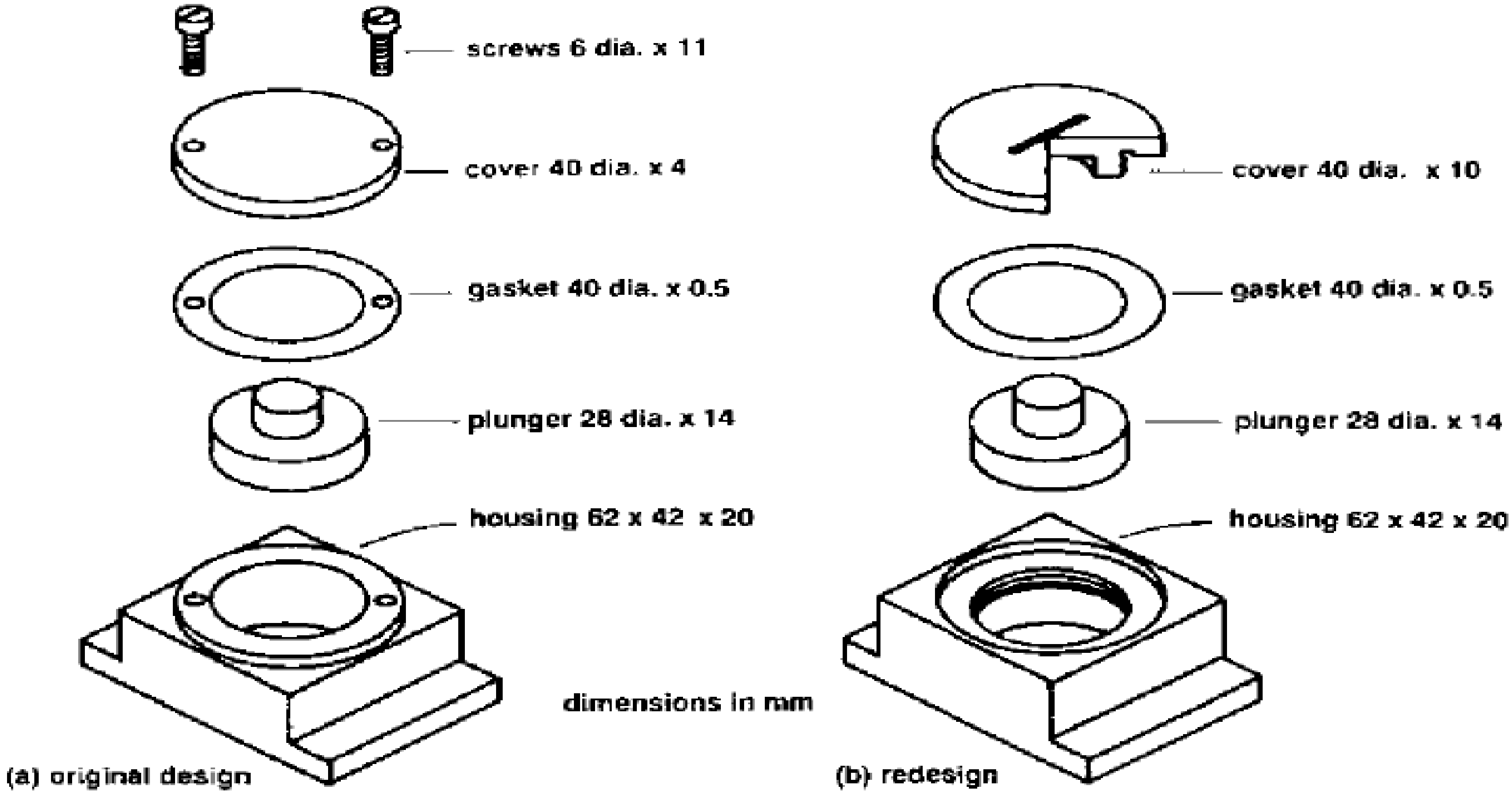


FIG. 5.10 Simple assembly.

Assembled at a rate of 9.6 per minute

Analysis of an assembly

Completed worksheets for automatic assembly analysis of the assemblies

Part or sub or opern No.	No. of repeats	Handling code	Orientation assembly	Relative feeder cost	Max feed rate (parts/min)	Handling difficulty	Handling cost (cents)	Insertion code	Relative work head cost	Insertion difficulty	Insertion/ operation cost (cents)	Total cost (cents)	Figure for min parts	High speed automatic assembly Name of assembly-value Name of part, sub-assembly or operation
ID	RP	HC	OE	CR	FM	DH	CF	IC	WC	DI	CI	CA	NM	
1	1	83100	0.20	1	4.8	12.4	0.40	00	1.0	6.3	0.38	0.69	1	Housing
2	1	02000	0.40	1	21.4	6.3	0.20	02	1.5	0.56	0.56	0.63	1	Plunger
3	1	00840	.*		***.*	**.*	*.**	Manual assembly required				7.13	0	Gasket
4	1	00800	.*	*	***.*	**.*	*.**	Manual assembly required				6.67	1	cover
5	2	21000	0.90	1	122.7	6.3	0.20	39	1.8	11.3	0.68	1.44	0	screw

Analysis of an assembly

Completed worksheets for automatic assembly analysis of the assemblies (Re-Design)

Part or sub or opern No.	No. of repeats	Handling code	Orientation Efficiency	Relative feeder cost	Max feed rate (parts/min)	Handling difficulty	Handling cost (cents)	Insertion code	Relative work head cost	Insertion difficulty	Insertion/ operation cost (cents)	Total cost (cents)	Figure for min parts	High speed automatic assembly Name of assembly-value Name of part, sub-assembly or operation
ID	RP	HC	OE	CR	FM	DH	CF	IC	WC	DI	CI	CA	NM	
1	1	83100	0.20	1	4.8	12.6	0.40	00	1.0	6.3	0.29	0.69	1	Housing
2	1	02000	0.40	1	21.4	6.3	0.20	02	1.5	9.4	0.43	0.63	1	Plunger
3	1	00040	0.70	3	26.3	18.8	0.61	00	1.0	6.3	0.29	0.90	0	Gasket
4	1	02000	0.40	1	15.0	6.3	0.20	38	0.8	5.0	0.23	0.43	1	cover

General rules for product design for automation

The elimination of a part would eliminate:

1. a complete station on an assembly machine-including the parts feeder
2. special work head
3. associated portion of the transfer device

General rules for product design for automation

- Automation can be facilitated by the introduction of guides and chamfers.

- Sharp corners are removed so that the part can be guided into its correct position during assembly leading to:
  1. less control by the placement device
  2. can even eliminate the need for a placement device.

General rules for product design for automation

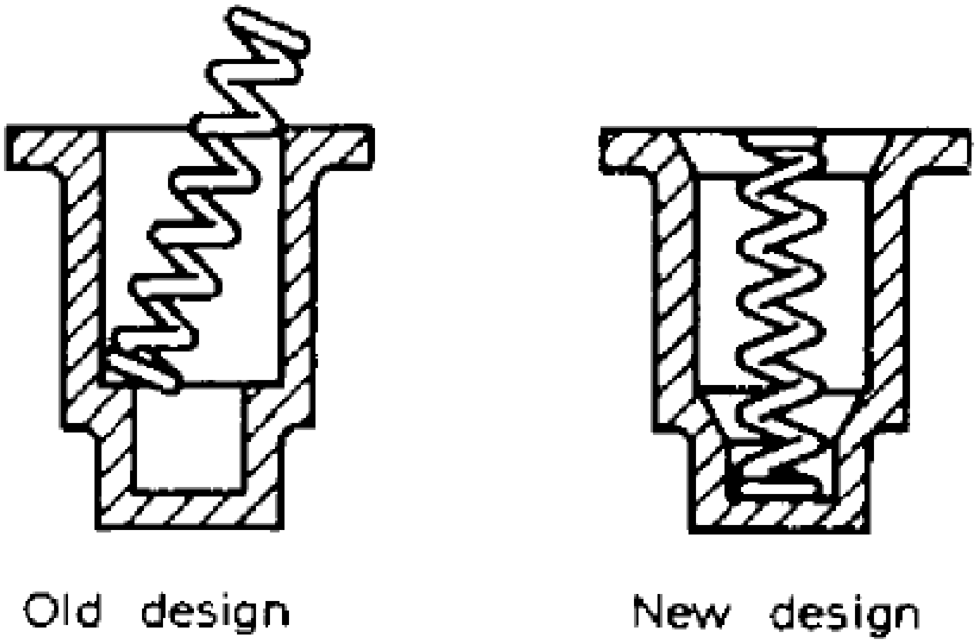


FIG. 5.12 Redesign of part for ease of assembly. (From Ref. 3.)

General rules for product design for automation

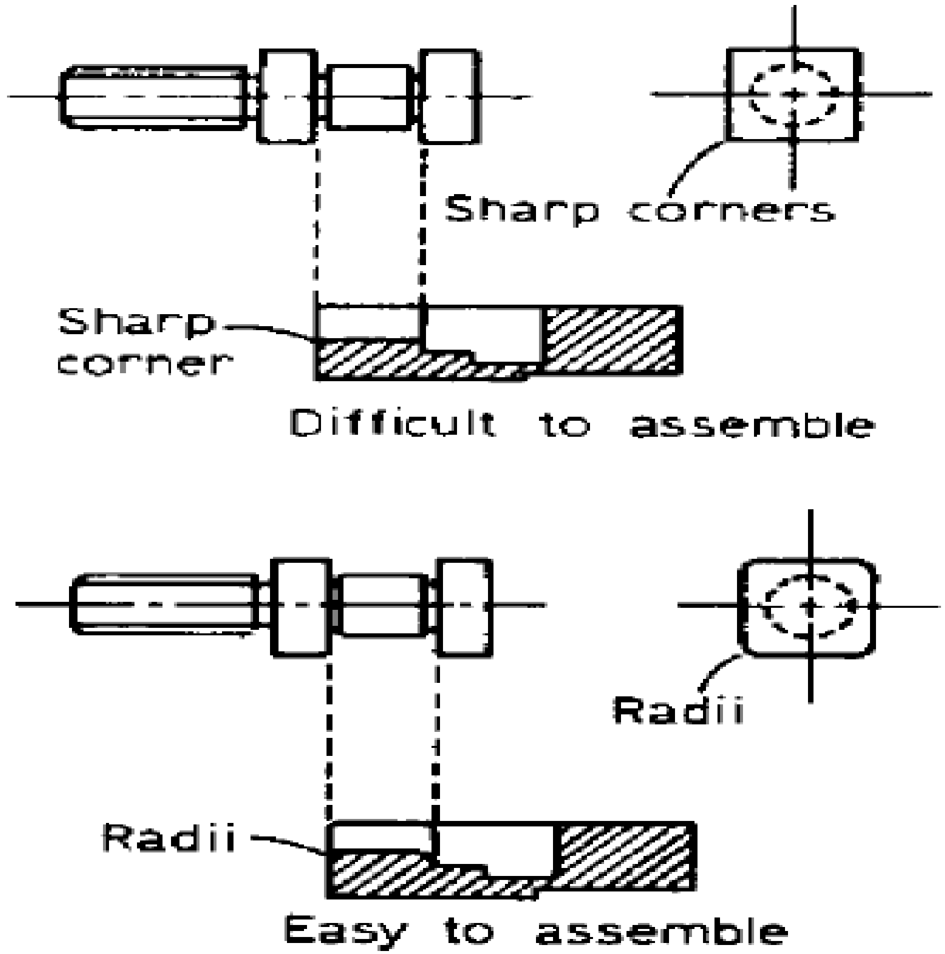


FIG. 5.13 Redesign to assist assembly. (From Ref. 4.)

General rules for product design for automation

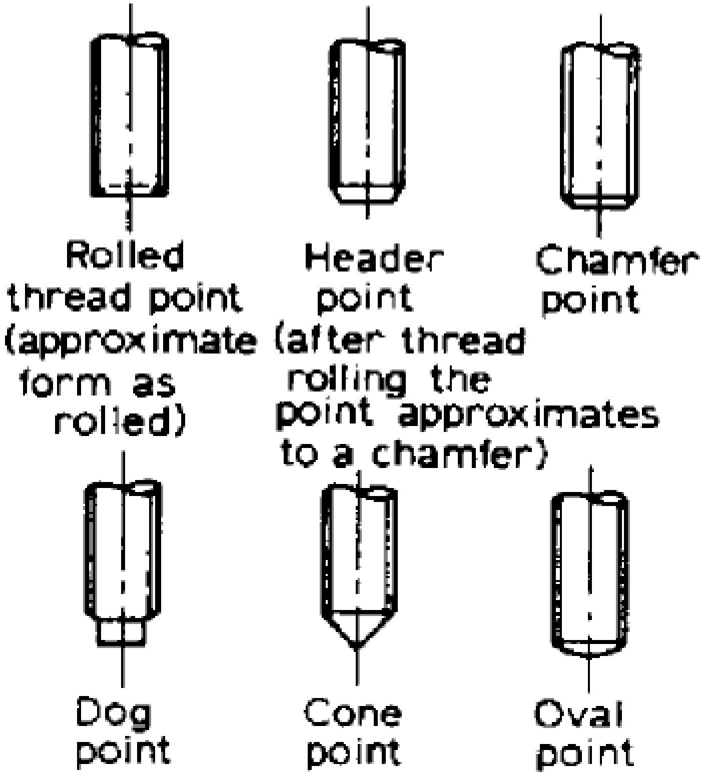


FIG. 5.14 Various forms of screw points. (From Ref. 4.)

- Screws that tend to centralize themselves in the hole give the best results in automatic assembly:
  1. **Rolled thread point:** very poor location; will not centralize without positive control on the outside diameter of the screws.
  2. **Header point:** only slightly better than (1) if of correct shape.
  3. **Chamfer point:** reasonable to locate.
  4. **Dog point:** reasonable to locate
  5. **Cone point:** very good to locate.
  6. **Oval point:** very good to locate.

General rules for product design for automation

Assembly from above:

•Allow for assembly in sandwich or layer fashion, each part being placed on top of previous one.

– Gravity can be used to assist in feeding and placing of parts.

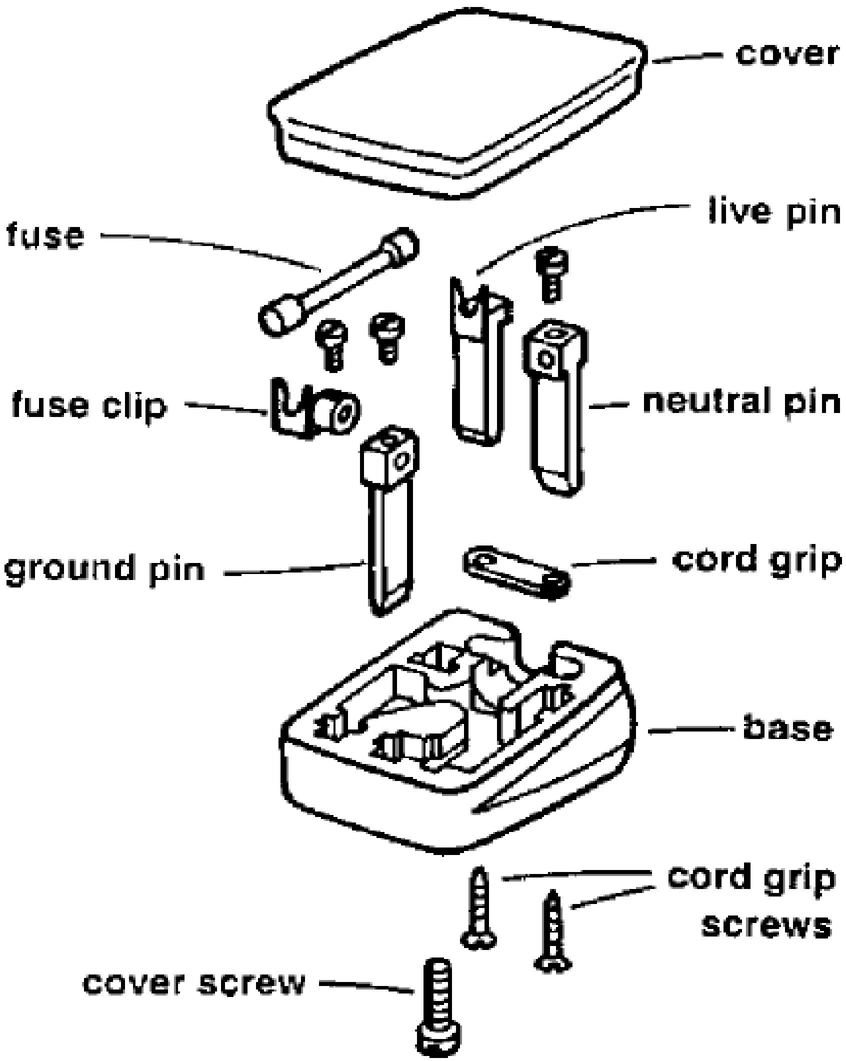
•Work heads and feeding devices above the assembly station:

– They will be accessible in event of a fault due to feeding of a defective part.

•Assembly assist in the problem of keeping parts in their correct positions during the machine index period, when dynamic forces in the horizontal plane might tend to displace them.

– With proper product design using self-locating parts, force due to gravity should be sufficient to hold the part until it is fastened or secured.

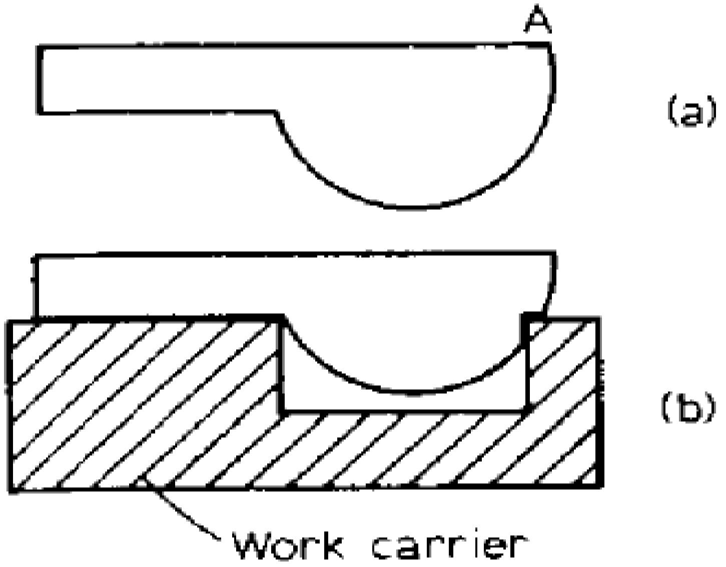
General rules for product design for automation



- **Assembly from above is not possible**:
- divide assembly into subassemblies.
- **Fig. 5.15:**
- Difficult to position and drive the two cord grip screws from below.
- The two screws, cord grip, and plug base could be treated as a subassembly dealt with prior to main machine assembly.

General rules for product design for automation

- Have a base part on which assembly can be built.
  - Must have features to be suitable for quick and accurate location on the work carrier.
- **Figure 5.16a:**
  - If a force were applied at *A*, part would rotate unless adequate clamping was provided.
  - To ensure that a base part is stable, Arrange that its center of gravity be contained within flat horizontal surfaces.
- **Fig. 5.16b:** A small ledge machined into part



Design for feeding and orienting

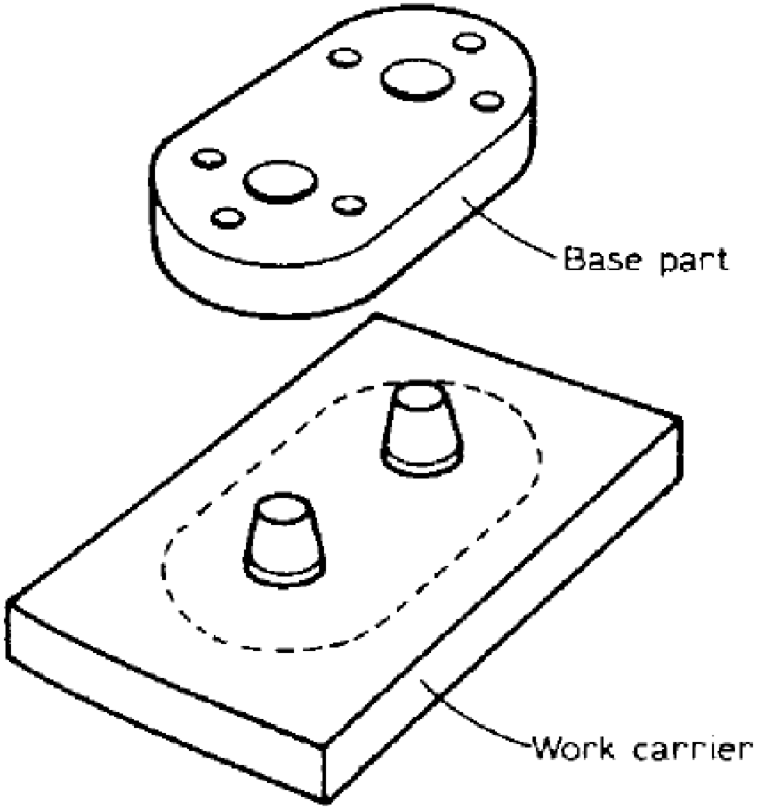


FIG. 5.17 The use of tapered pegs to facilitate assembly

- **Fig. 5.17:** Location of base part in the horizontal plane is often achieved by tapered dowel pins mounted in the work carrier to provide guidance

Design for feeding and orienting

- Most versatile parts feeder is the **vibratory bowl feeder**.
- Three basic design principles:

1. Avoid designing parts that will tangle, nest, or shingle.
2. Make the parts symmetrical.
3. If parts cannot be made symmetrical, avoid slight asymmetry or asymmetry resulting from small or non-geometrical features.

Design for feeding and orienting

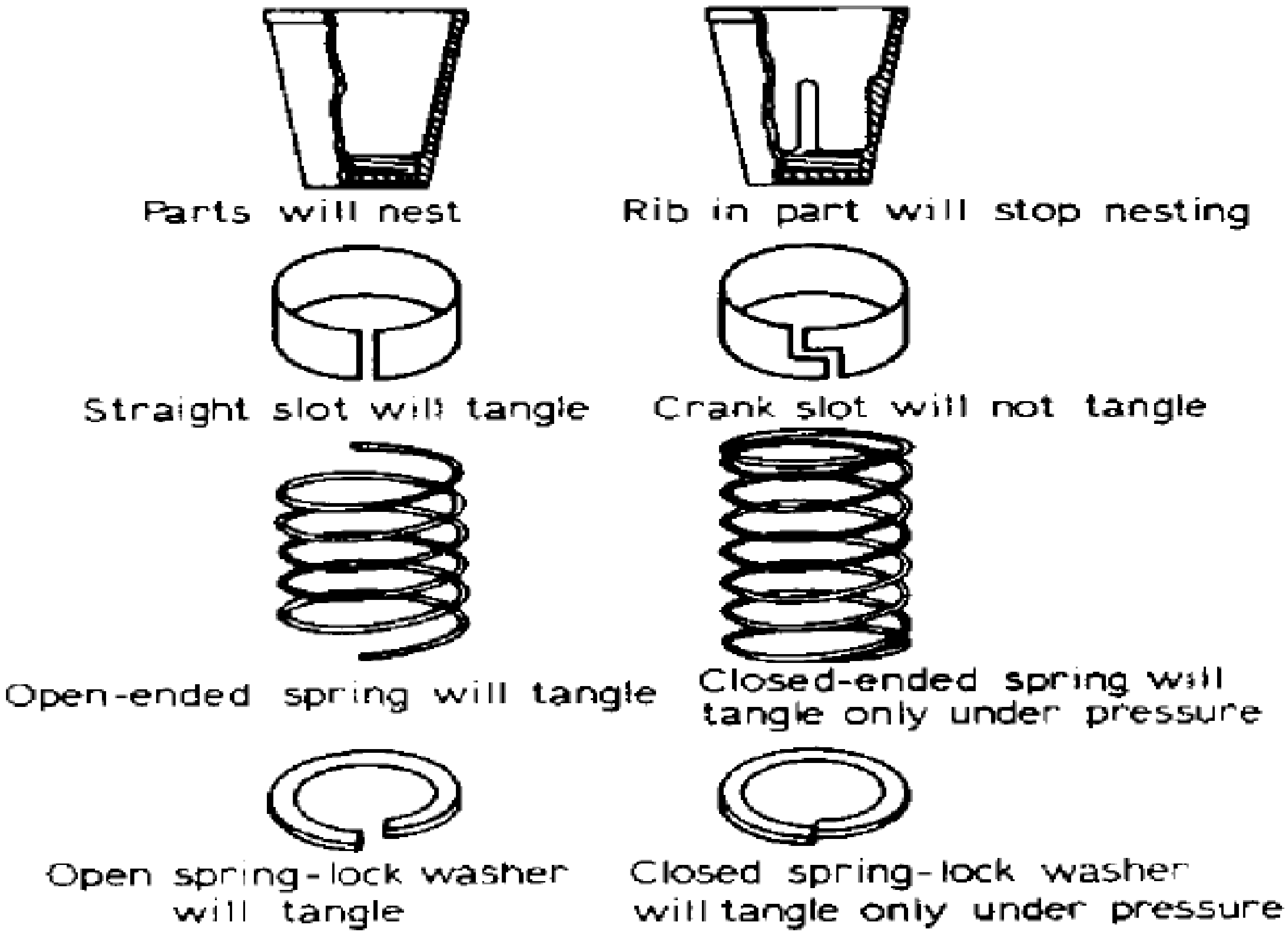


FIG. 5.18 Examples of redesign to prevent nesting or tangling. (From Ref. 5.)

Design for feeding and orienting

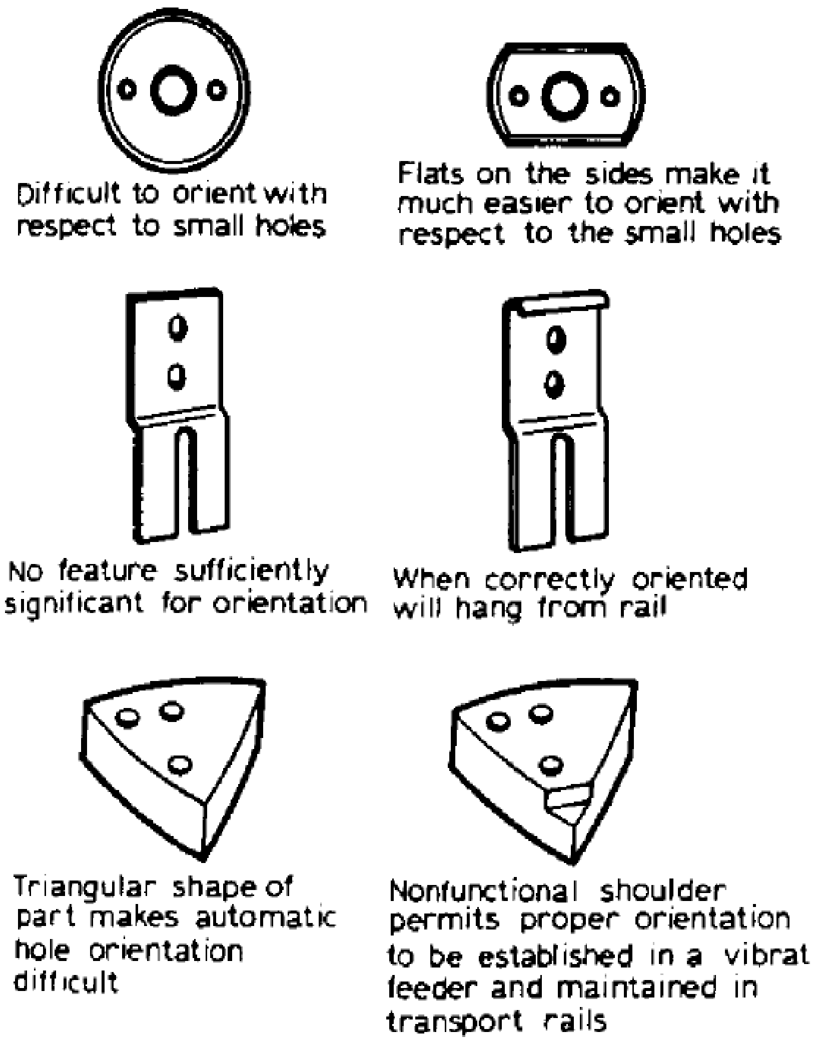
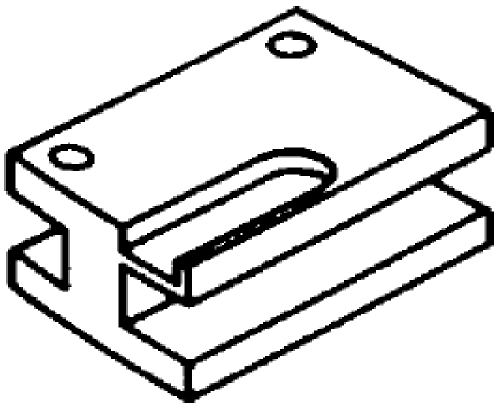


FIG. 5.19 Provision of asymmetrical features to assist in orientation. (From Ref. 5.)

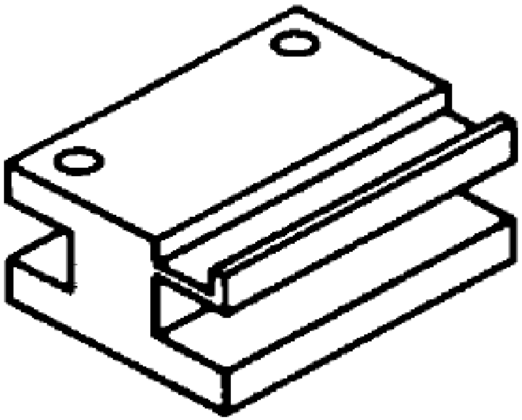
- deliberately add **asymmetrical features** for the purpose of orienting.
- The features that require alignment are difficult to utilize in an orienting device, so corresponding external features are deliberately added.

Design for feeding and orienting

- **FIG 5.20a:** a part that would be difficult to handle
- **FIG 5.20b:** redesigned part, which could be fed and oriented in a vibratory bowl feeder at a high rate.



(a)
Very difficult to orient



(b)
Possible to orient

FIG. 5.20 Less obvious example of a design change to simplify feeding and orienting.

Design for feeding and orienting

- Parts that are easy to handle automatically will also be easy to handle manually.
- Very small parts or complicated shapes formed from thin strips are difficult to handle in an automatic environment.
  - Manufacture the parts on the assembly machine or to separate them from the strip at the moment of assembly.

Summary of design rules for automatic assembly

Rules for Product Design

1. Minimize number of parts
2. Ensure that product has a suitable base part on which to build the assembly
3. Ensure that base part has features that enable it to be readily located in a stable position in the horizontal plane.
4. Design product so that it can be built up in **layers**, each part being assembled from above and positively located so that there is no tendency for it to move under the action of horizontal forces during the machine index period.
5. Provide chamfers or tapers that help to guide and position parts in the correct position.
6. Avoid expensive and time-consuming fastening operations, such as screw fastening, soldering, and so on.

Summary of design rules for automatic assembly

Rules for the Design of Parts

1. Avoid projections, holes, or slots that cause tangling with identical parts when placed in bulk in the feeder.
2. Attempt to make the parts symmetrical
3. If symmetry cannot be achieved, exaggerate asymmetrical features to facilitate orienting or, alternatively, provide corresponding asymmetrical features that can be used to orient the parts.

Product design for robot assembly

AR	TP
AG	TG

Single-Station One-Arm System

TP - relative affective basic operation time
AR - relative robot cost
AG - relative additional gripper or tool cost
TG - relative time penality for gripper or tool change

		part can be gripped & inserted using standard gripper or gripper used for previous part			
		no holding down		part requires temporary holding or clamping	
		self-aligning	not easy to align	self-aligning	not easy to align
part added but not finally secured		0	1	2	3
using motion along or about the vertical axis	0	1.0 1.0 0 0	1.0 1.07 0 0	1.0 1.0 1.0 0	1.0 1.07 1.0 0
using motion along or about a non-vertical axis	1	1.5 1.0 0 0	1.5 1.07 0 0	1.5 1.0 1.0 0	1.5 1.07 1.0 0
involving motion along or about more than one axis	2	1.5 1.8 0 0	1.5 1.9 0 0	1.5 1.8 1.0 0	1.5 1.9 1.0 0

FIG. 5.21 Portion of classification system and database for a single-station one-arm robot assembly system. (From Ref. 2.)

Summary of Design Rules for Robot Assembly

1. Reduce part count

2. Include features such as leads, lips, chamfers, etc., to make parts self-aligning in assembly.

3. Ensure that parts which are not secured immediately on insertion are self-locating in the assembly.

4. Design parts so that they can all be gripped and inserted using the same robot gripper.
   - Each change to a special gripper and then back to standard gripper is approximately equal to two assembly operations.

Summary of Design Rules for Robot Assembly

5. Design products so that they can be assembled in layer fashion from directly above.

6. Avoid the need for reorienting the partial assembly or for manipulating previously assembled parts.
   – These operations increase robot assembly cycle time without adding value to assembly.
   – If the partial assembly has to be turned to a different resting aspect during assembly process, then this will usually result in increased work fixture cost and the need to use a more expensive 6 DOF robot arm.

Summary of Design Rules for Robot Assembly

7. Design parts that can be easily handled from bulk. Avoid parts that
   – Nest or tangle in bulk
   – Are flexible
   – Have thin or tapered edges that can overlap or "shingle" as they move along a conveyor or feed track
   – Are so delicate or fragile that recirculation in a feeder would cause damage
   – Are sticky or magnetic so that a force comparable to the weight of the part is required for separation
   – Are abrasive and will wear the surfaces of automatic handling systems
   – Are light so that air resistance will create conveying problems

Summary of Design Rules for Robot Assembly

8. If parts are to be presented using automatic feeders, then ensure that they can be oriented using simple tooling.

9. If parts are to be presented using automatic feeders, then ensure that they can be delivered in an orientation from which they can be gripped and inserted without any manipulation.

Summary of Design Rules for Robot Assembly

10. If parts are to be presented in magazines or part trays, then ensure that they have a stable resting aspect from which they can be gripped and inserted without any manipulation by the robot.
    - If the production conditions are appropriate, the use of robots holds advantages over the use of special purpose work heads and some design rules can be relaxed.
    - For example, a robot can be programmed to acquire parts presented in an array—such as in a pallet or part tray which has been loaded manually, thus avoiding many of the problems arising with automatic feeding from bulk.