Design for robotic assembly
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.
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.
• 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.
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.

\[ F_m = \text{maximum feed rate} \]
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.

- Difficult to feed - parts overlap
- Easy to feed
Analysis of an assembly

Assembled at a rate of 9.6 per minute
### Analysis of an assembly

**Completed worksheets for automatic assembly analysis of the assemblies**

<table>
<thead>
<tr>
<th>ID</th>
<th>Part or sub or opern No.</th>
<th>No. of repeat s</th>
<th>Handling code</th>
<th>Orientation assembly</th>
<th>Relative feeder cost</th>
<th>Max feed rate (parts/min)</th>
<th>Handling difficulty</th>
<th>Handling cost (cents)</th>
<th>Insertion code</th>
<th>Relative work head cost</th>
<th>Insertion difficulty</th>
<th>Insertion/operation cost (cents)</th>
<th>Total cost (cents)</th>
<th>Figure for min parts</th>
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<td>*<em>.</em></td>
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<td>Manual assembly required</td>
<td></td>
<td></td>
<td>7.13</td>
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### Analysis of an assembly

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

<table>
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<th>Part or sub or opern No.</th>
<th>No. of repeats</th>
<th>Handling code</th>
<th>Orientation Efficiency</th>
<th>Relative feeder cost</th>
<th>Max feed rate (parts/min)</th>
<th>Handling difficulty</th>
<th>Handling cost (cents)</th>
<th>Insertion code</th>
<th>Relative work head cost</th>
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<th>Figure for min parts</th>
<th>Name of assembly-value</th>
<th>Name of part, sub-assembly or operation</th>
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<td>0.43</td>
<td>1</td>
<td>Gasket</td>
<td>cover</td>
</tr>
</tbody>
</table>
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.
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.)
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.

**FIG. 5.14** Various forms of screw points. (From Ref. 4.)
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.
• **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.
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**: Location of base part in the horizontal plane is often achieved by tapered dowel pins mounted in the work carrier to provide guidance.

**FIG. 5.17** The use of tapered pegs to facilitate assembly
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

Parts will nest

Rib in part will stop nesting

Straight slot will tangle

Crank slot will not tangle

Open-ended spring will tangle

Closed-ended spring will tangle only under pressure

Open spring-lock washer will tangle

Closed spring-lock washer will tangle only under pressure

FIG. 5.18 Examples of redesign to prevent nesting or tangling. (From Ref. 5.)
Design for feeding and orienting

- 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.

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

![Diagram](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.
### Single-Station One-Arm System

| 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                           |
| 0                                           | 1                                           |
| 2                                           | 3                                           |

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

**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.
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.
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
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.
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.