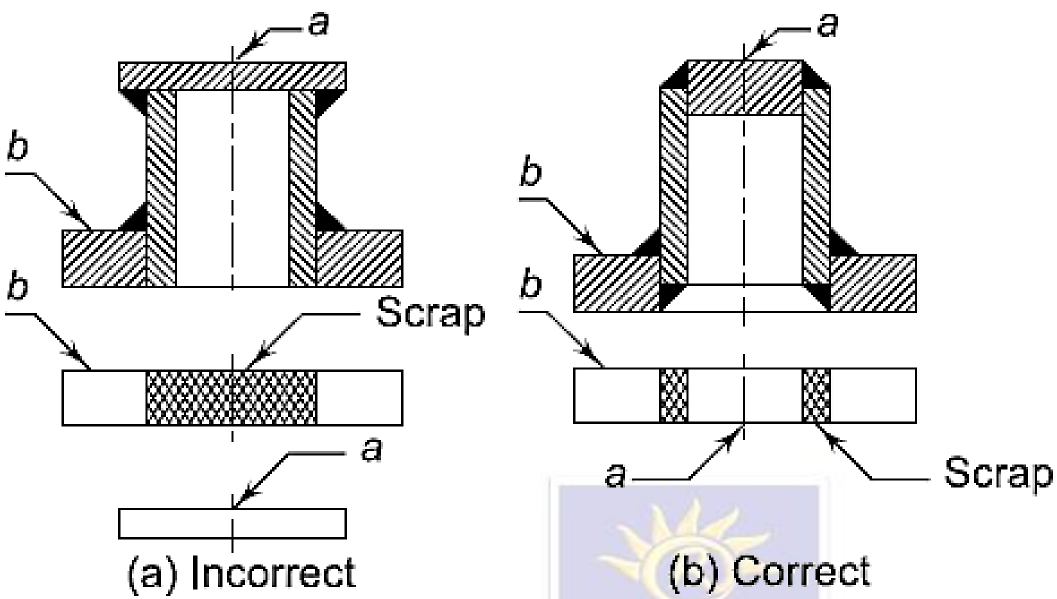

Fig. 3.18 *Reduction of Scrap*

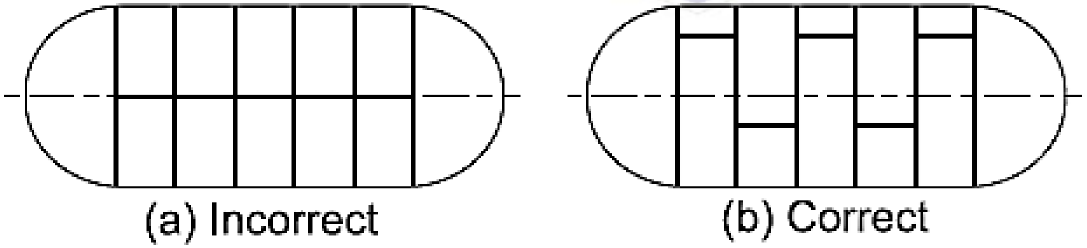

Fig. 3.19 *Avoiding Weld Accumulation*

- DESIGN FOR MANUFACTURE AND ASSEMBLY (DFMA)
- The design effort makes up only about 5% of the total cost of a product. However, it usually determines more than 70% of the manufacturing cost of the product.
- Therefore, at best only 30% of the product's cost can be changed once the design is finalized and drawings are prepared. Using statistical process control or improving manufacturing methods during production stage after the design has been finalised has marginal or little effect on the product's cost.
- The best strategy to lower product cost is to recognise the importance of manufacturing early in the design stage.
- Design for manufacture and assembly are simple guidelines formulated by Bart Huthwaite, Director of Institute for Competitive Design, Rochester, USA3.
- These guidelines, although simple, are used to simplify design, decrease assembly cost, improve product reliability and reduce operation time required to bring a new product into the market. Little technology is required to implement these guidelines. The guidelines are as follows:
- (i) Reduce the Parts Count
- (ii) Use Modular Designs
- (iii) Optimize Part Handling
- (iv) Assemble in the Open
- (v) Do not Fight Gravity
- vi) Design for Part Identity
- (vii) Eliminate Fasteners
- (viii) Design Parts for Simple Assembly
- (ix) Reduce, Simplify and Optimise Manufacturing Process

Lecture Machine Design-Design against Static Load

- MODES OF FAILURE
- A static load is defi ned as a force, which is gradually applied to a mechanical component and which does not change its magnitude or direction with respect to time. It was discussed in Chapter 2 that engineering materials are classifi ed into two groups—ductile and brittle materials. A ductile material is one which has a relatively large tensile strain before fracture takes place. On the other hand, a brittle material has a relatively small tensile strain before fracture. A tensile strain of 5% is considered to be the dividing line between brittle and ductile materials. Structural steels and aluminium are ductile materials, while cast iron is an example of a brittle material. A mechanical component may fail, that is, may be unable to perform its function satisfactorily, as a result of any one of the following three modes of failure1:
- (i) failure by elastic defl ection;
- (ii) failure by general yielding; and
- iii) failure by fracture.
- FACTOR OF SAFETY
- While designing a component, it is necessary to
- provide suffi cient reserve strength in case of an
- accident. This is achieved by taking a suitable
- factor of safety (fs).
- The factor of safety is defi ned as

$$(fs) = \frac{\text{failure stress}}{\text{allowable stress}}$$

$$(fs) = \frac{\text{failure load}}{\text{working load}}$$

- The allowable stress is the stress value, which is used in design to determine the dimensions of the component. It is considered as a stress, which the designer expects will not be exceeded under normal operating conditions. For ductile materials, the allowable stress s is obtained by the following relationship:

$$\sigma = \frac{S_{yt}}{(fs)} \qquad (4.1)$$

For brittle materials, the relationship is,

$$\sigma = \frac{S_{ut}}{(fs)} \qquad (4.2)$$

- where Syt and Sut are the yield strength and the ultimate tensile strength of the material respectively.
- There are a number of factors which are diffi cult to evaluate accurately in design analysis. Some of the factors are as follows:
- (i) Uncertainty in the magnitude of external
- force acting on the component
- (ii) Variations in the properties of materials like yield strength or ultimate strength
- (iii) Variations in the dimensions of the component due to imperfect workmanship

- In addition to these factors, the number of assumptions made in design analysis, in order to simplify the calculations, may not be exactly valid in working conditions. The factor of safety ensures against these uncertainties and unknown conditions. The magnitude of factor of safety depends upon the following factors:
- (i) Effect of Failure Sometimes, the failure of a machine element involves only a little inconvenience or loss of time, e.g., failure of the ball bearing in a gearbox. On the other hand, in some cases, there is substantial fi nancial loss or danger to the human life, e.g., failure of the valve in a pressure vessel. The factor of safety is high in applications where failure of a machine part may result in serious accidents.
- (ii) Type of Load The factor of safety is low when the external force acting on the machine element is static, i.e., a load which does not vary in magnitude or direction with respect to time. On the other hand, a higher factor of safety is selected when the machine element is subjected to impact load. This is due to the fact that impact load is suddenly applied to the machine component, usually at high velocities.
- (iii) Degree of Accuracy in Force Analysis When the forces acting on the machine component are precisely determined, a low factor of safety can be selected. On the contrary, a higher factor of safety is necessary when the machine component is subjected to a force whose magnitude or direction is uncertain and unpredictable.
- (iv) Material of Component When the component is made of a homogeneous ductile material like steel, yield strength is the criterion of failure. The factor of safety is usually small in such cases. On the other hand, a cast iron component has nonhomogeneous structure and a higher factor of safety based on ultimate tensile strength is chosen.
- (v) Reliability of Component In certain applications like continuous process equipment, power stations or defense equipment, high safety increases with increasing reliability.
- (vi) Cost of Component As the factor of safety increases, dimensions of the component, material requirement and cost increase. The factor of safety is low for cheap machine parts.
- (vii) Testing of Machine Element A low factor of safety can be chosen when the machine component can be tested under actual conditions of service and operation. A higher factor of safety is necessary, when it is not possible to test the machine part or where there is deviation between test conditions and actual service conditions.
- (viii) Service Conditions When the machine element is likely to operate in corrosive atmosphere or high temperature environment, a higher factor of safety is necessary.
- (ix) Quality of Manufacture When the quality of manufacture is high, variations in dimensions of the machine component are less and a low factor of safety can be selected. Conversely, a higher factor of safety is required to compensate for poor manufacturing quality.

- STRESS–STRAIN RELATIONSHIP
- When a mechanical component is subjected to an external static force, a resisting force is set up within the component. The internal resisting force per unit area of the component is called stress. The stresses are called tensile when the fi bres of the component tend to elongate due to the external force. On the other hand, when the fi bres tend to shorten due to the external force, the stresses are called compressive stresses. A tension rod subjected to an external force P is shown in Fig. 4.1. The tensile stress is given by, $\sigma_t = \frac{P}{A}$

$$= (10^6)\left(\frac{N}{m^2}\right) = (10^6)\frac{N}{[10^3 mm]^2} = 1 N/mm^2$$

Therefore, two units (N/mm^2) and (MPa) are same. In this book, the unit (N/mm^2) is used. However, it can be replaced by (MPa) without any conversion factor.

The strain is deformation per unit length. It given by

$$\varepsilon = \frac{\delta}{l} \qquad (4.4)$$

where,

ε = strain (mm/mm)
δ = elongation of the tension rod (mm)
l = original length of the rod (mm)

According to Hooke's law, the stress is directly proportional to the strain within elastic limit. Therefore,

$$\sigma_t \propto \varepsilon$$

or $$\sigma_t = E\,\varepsilon \qquad (4.5)$$

where E is the constant of proportionality known as *Young's modulus* or *modulus of elasticity* (in N/mm^2 or MPa).

For carbon steels, $E = 207\,000$ N/mm^2
For grey cast iron, $E = 100\,000$ N/mm^2

Substituting Eqs (4.3) and (4.4) in Eq. (4.5),

$$\delta = \frac{Pl}{AE} \qquad (4.6)$$

A component subjected to a compressive force is shown in Fig. 4.2. The compressive stress σ_c is given by,

$$\sigma_c = \frac{P}{A} \qquad (4.7)$$

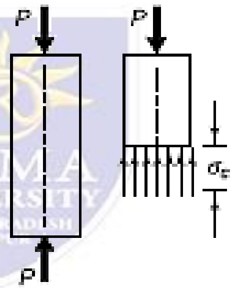

Fig. 4.2 *Compressive Stress*

The following assumptions are made in the analysis of stress and strain:

(i) The material is homogeneous.
(ii) The load is gradually applied.
(iii) The line of action of force *P* passes through the geometric axis of the cross-section.
(iv) The cross-section is uniform.
(v) There is no stress concentration.

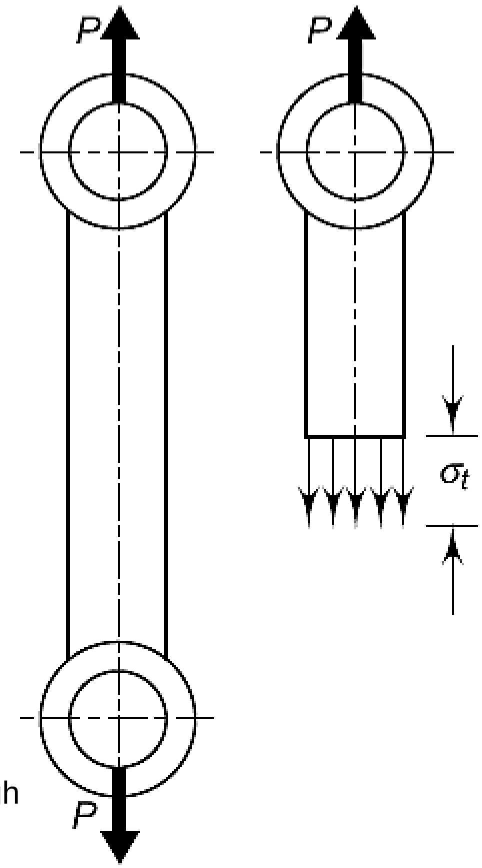

Fig. 4.1 *Tensile Stress*