CHAPTER 1

Introduction

As compared to former times, today’s products are designed and optimized under completely different rules, with the main focus being on vital questions such as shortages of raw materials, total energy content and the environment-friendly disposal or reuse of a product.

Intelligent lightweight constructions can only be obtained by consistently using a material mix of steel, light metal and plastics. The development of new materials with diverse applications puts additional challenges on processing technology. This is particularly so when different materials have to be joined to make components which retain their individual beneficial properties in the composite product. This raises the question: Which joining technique to use?

The joining technique used should be able to join these different materials in such a way that their individual specific properties are retained.
1.1 Traditional Joining techniques and their Limitations

Traditional joining techniques have their well-known limitations. Mechanical techniques such as riveting or bolting have the following disadvantages:

- It is necessary to drill holes in the work pieces that are being joined which damages and hence weakens the materials.
- High stress around the holes as force transfer takes place at points which results in stress concentration.
- Prone to loosening, weakening, rusting, increases noise source.
- Increased weight and cost.

With thermal techniques such as welding, brazing, soldering have the following disadvantages -

- The specific properties of the material alter within the heat affected zone.
- Joint is permanent and hence dismantling is not possible.

1.2 Adhesive Bonding

In such situation Adhesive bonding is only the competitive joining technique which is rapidly gaining acceptance amongst major manufacturers because of specific advantages over conventional mechanical fastening techniques and it is anticipated that adhesive bonding technology will assume an even more important role in industry in the future for the following four key reasons.

1.2.1 Adhesive Bonding – Future Technology for Industry

1. Adhesive bonding technology can be used to bond virtually any desired combination of materials with each other, creating long-lasting bonds.
2. The use of Adhesive bonding technology in production processes in general allows the material properties of the substrates to be retained: Compared to welding and soldering/brazing, the bonding process requires relatively little or no heat input. No damage occurs, unlike when rivets or screws are used.
3. In product manufacture, the two aforementioned considerations enable the specific material properties of substrates to be optimally utilised in
components. This allows new construction methods to be employed.

4. It is also possible to use bonding technology to introduce customised additional properties into the component via the actual joining.

![Adhesive Bonding – Future Technology for Industry](image)

**Fig. 1.2** : Adhesive Bonding – Future Technology for Industry

### 1.2.2 Limitations of Adhesive Joining technique

However, adhesive joining is not without its disadvantages. Separation of adhesively joined surfaces is difficult and thus adhesive joints are not preferred for components that need to be regularly changed or serviced.

Monitoring of the health of adhesive joints is difficult and field repairs of adhesive joints may require specialised equipment. Adhesives are sensitive to environmental changes and their performance may degrade over time as they are subjected to varying moisture and temperature conditions. However, the advantages of adhesive joining make it an attractive choice and adhesive joints are being increasingly used in structural applications.

### 1.3 Applications of Adhesive Bonding

#### 1.3.1 Automotive Applications

In modern cars materials are used in a so-called multi-material design. In these
concepts lightweight materials like aluminium and magnesium alloys, fibre reinforced plastics and high strength steels are used where they fulfil the purpose best. For different reasons it is not possible to weld the mixed materials so that mechanical joining and adhesive bonding have to be used.

Fig. 1.3 : Automotive Applications

1.3.2 Aerospace Applications

The aircraft manufacturing industry provided the key technology impulse for modern bonding technology. The basic need for weight saving was the driving force for new design and construction methods. In modern Airbus aircraft, for example, about 30% of all components are joined using bonding technology.

1.3.3 Medical Applications

Adhesives are today employed in diverse areas of medicine, replacing traditional methods with friendlier processes. For example stitches can be avoided by applying special cyanoacrylate adhesives to quickly close skin wounds. An advantage here is that the whole wound can be covered, so largely suppressing secondary bleeding and the risk of infection. The use of methacrylate based
adhesives has been a great success in orthopedics for anchoring hip socket implants to the bone as shown in fig. (1.4).

1.3.4 Other Applications

Sport

Bonded bicycle frames, kayaks, rowing boats, rows, pole vault poles, golf clubs, tennis rackets etc.

Oil and gas industry

Oil tanks reconstructions, corrosion resistant barriers, repair of pipelines, pipeline strengthening etc.

Adhesive manufacturers offer more than 250,000 different products for the most diverse applications and these products are customised for virtually every purpose. From which it is clear that adhesive bonding technology offers far more than today’s applications, and has enormous future potential.

1.4 The Need

The increased application of adhesive bonding was accompanied by development of mathematical and numerical methods to analyse or predict the
behaviour of joints, but at present also this is still an open problem.

An important aspect in the use of adhesive joints in structural applications is the ability to predict their performance at the design stage. For successful industrial application of adhesive joints, reliable and easy to use methods of designing adhesive joints are required. Such methods would not only provide confidence in the use of adhesives, but would also enable improved joint designs.

Thus a need exists for the development of solution that can simulate field conditions and predict performance of adhesive joints. This predictive model would also provide opportunity to explore different design alternatives which may contribute towards design optimization. As the cost of adhesive joints is also comparable to the traditional joining methods it is required to design adhesive joints in an optimum way. For optimum design of adhesive joint, complete knowledge of stress distribution and the parameters affecting stress distribution in adhesive joint is necessary.

Both adhesion and cohesion play their part in maximizing the strength of a bond. Just as with a chain, the weakest link in a bonded joint determines what loads the joint can be subjected to. Furthermore, the adhesive strength is in general sufficiently high. This is the case when the natural strength of the adhesive, and not the adhesion, is the limiting factor. The cohesive properties of an adhesive are already determined by the manufacturer. Now it is up to users to try and attain these by proper designing of the joint and curing under optimum conditions.

![Adhesion – Cohesion Chain](image)

Fig. 1.5 : Adhesion – Cohesion Chain


1.5 Motivation for the work

The fixing of cylindrical components subjected to torque is a common requirement in Industrial manufacture. In recent years, adhesives, especially anaerobic adhesives, have found many applications that range across many industries replacing traditional methods. Some typical cylindrical joints are shaft to shaft, Gear to Shaft, Rotor to Shaft, Bearing into Housing, Tube into Casting, Cylinder Liner into Engine Block, Pulley to Shaft, Fan to Shaft, Trunnions into Rollers and Bushings into Housings etc.

![Joint Surface](image)

Adhesive joints have been previously been designed empirically. Now a day's data is available to design adhesive joints in an optimum manner. For optimum design of adhesive joint, complete knowledge of stress distribution and the parameters affecting stress distribution in adhesive joint is necessary.

Deciding the failure criteria for the adhesive joint is a task which is more challenging than the calculation of stress distribution in adhesive layer along the bond length. Different failure criteria’s have been proposed by different researchers, but there is no accordance about the best one or which criteria to use in which conditions. The criteria could be based on stress, deformations, fracture mechanics or cohesive zone model approach.
There are two basic mathematical approaches for the analysis of adhesively bonded joints: Closed-form analysis (Analytical methods) and Numerical methods (i.e. FE Analysis).

### 1.6 Objectives of the work

- The present work aims at the development of analytical model for adhesively bonded cylindrical joint subjected to torsion loading for determination of stresses in adhesive layer along the bond length.

- Analytically investigate the effect of variation of geometrical parameters like bond length, bond clearance, polar moment of inertia of adherends and material parameter like modulus of rigidity of adherends and adhesive on the torque transmission capability of the joint.

- Validate the results obtained from analytical methods by conducting physical tests using different shaft materials and adhesives.

- Obtain the solution to the problem through numerical technique like Finite Element Analysis. Compare the results obtained from FEA with experimental values of failure torque for reasonable validity.

- Obtain analytical solution for optimum values of geometrical parameters like bond length and bond clearance for maximum torque transmission capability of cylindrical adhesive joint.

- Obtain analytical solution for determination of profile of cylindrical adhesive joint having uniform torsional strength and hence maximum torque transmission capability.