CHAPTER 2

THEORETICAL CONSIDERATION

This chapter presents the related theoretical considerations comprising Pareto analysis, check sheet, brainstorming, Quality functional deployment and machine design.

2.1 Pareto analysis

According to Staker (1995) ,Pareto Analysis is the Method of identifying the vital few causes (typically 20%) which cause 80% of the problem. The method was invented by Vilfredo Pareto (1848-1923), an Italian economist and sociologist. He discovered that 80 percent of the wealth in Italy was held by only 20 percent of the population, hence the 80/20 rule.

In addition Pareto Analysis can be use as follows:

- Use it when selecting the most important things on which to focus, thus differentiating between the 'vital few' and the 'trivial many'
- Use it after improving a process, to show the relative change in a measured item.
- Use it when sorting a set of measurements, to emphasize their relative sizes visually.
- Use it. rather than a Bar Chart or Pie Chart to show the relative priority of a set of numeric measurements.

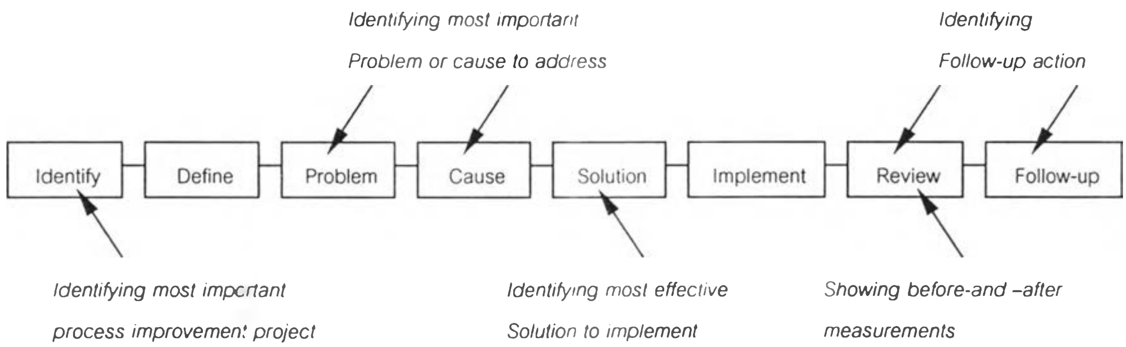


Figure 2.1 Possible uses in improvement project framework

Pareto was given a set of recurring problems, it is unlikely that each problem will occur the same number of times in any one period. In fact, it is common that a few problems will occur far more often than the rest put together. This unequal distribution occurs in many situations and can be used to single out the 'vital few' from the 'trivial many'.

The Pareto Chart is simply a Bar Chart in which the bars sorted into size order, with the highest bar on the left, as in figure 2.2.

Item measured	Measure or count
Item 1	12
Item 2	2
Item 3	32
Item 4	4
Item 5	19
Item 6	9
Item7	1

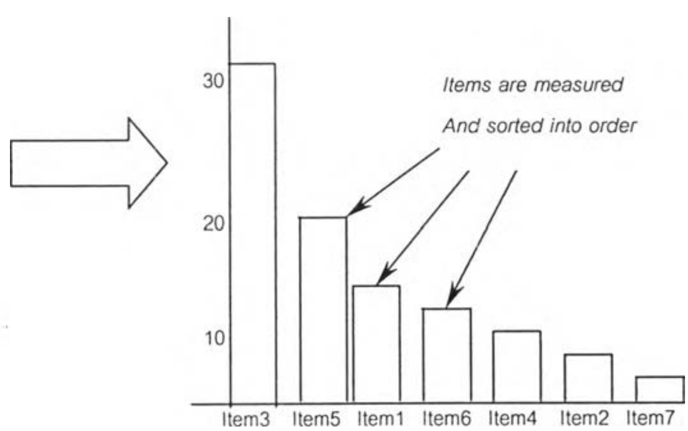


Figure 2.2 Pareto Chart

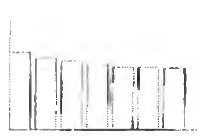
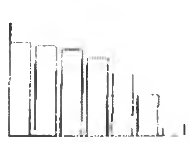
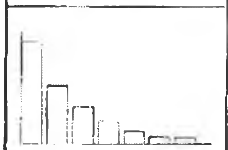
This not only shows the absolute priority of each bar, through its position in the chart, but also its relative priority, through its height as compared with the other bars.

As the Pareto Chart is often used for decision making, it is an important part of building a Pareto Chart to identify the right item to measure and show on the chart, as different measures may well result in the bars be ordered quite differently.

In a stable process, the order of the bars may be expected to remain constant. Thus, if the order of the bars changes with successive measurements, this may indicate an unstable process (or an insufficient number of measurements). Improvements (i.e. changes in the process) will often result in the order of the bars changing. If the improvements are maintained, the new bar order will remain stable.

Pareto Charts may have different overall "shapes" as shown in Table 2.1. The 'spiky' Pareto Chart is the most useful, as it enables an easy selection of items to carry forwards for further action.

Table 2.1 Shapes of Pareto Chart

Shape of chart	Description	Interpretation
	Plateau	All bars are of comparable height. No clear selection of items.
	Convex	A number of bars on the left are of similar height. It is easier to reject those on the right than select from those on the left.
	Concave or spiky	One or two bars are significantly higher than the rest (often making up 80% or more of the total). This is the ideal shape for selecting the vital few items for further action.

2.2 Check sheet

According to Staker (1995), check sheet use for manually collect data in a reliable, organized way which can use as follows.

- Use it when data is to be recorded manually, to ensure the data is accurately recorded and is easy to use later, either for direct interpretation or for transcription, for example into a computer.
- Use it when the recording involves counting, classifying, checking or locating.
- Use it when it is useful to check each measurement as it is recorded, for example that it is within normal bounds.
- Use it when it is useful to see the distribution of measures as they are built up. (Staker, 1995)

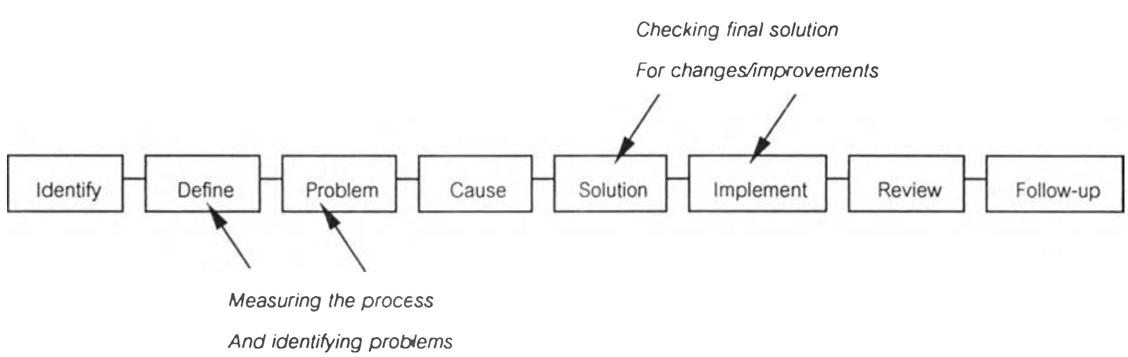


Figure 2.3 Possible uses in improvement project framework

Source : Staker (1995)

If data is collected in a disorganized way, it is likely to end up as a jumble of numbers on a convenient scrap of paper, where the numbers are easily misunderstood and the paper may be lost. By collecting it in an organized way, fewer mistakes are likely in the collection, transcription, understanding and storage of the data.

A Check Sheet is simply a sheet of paper-organized to simplify and standardize manual data collection and to ease interpretation of results. The simplification is characterized by the use of checks or marks to record events, rather than recording these as numbers or text, as in Fig. 2.4. This enables one Check Sheet to contain a large number of recorded data points.

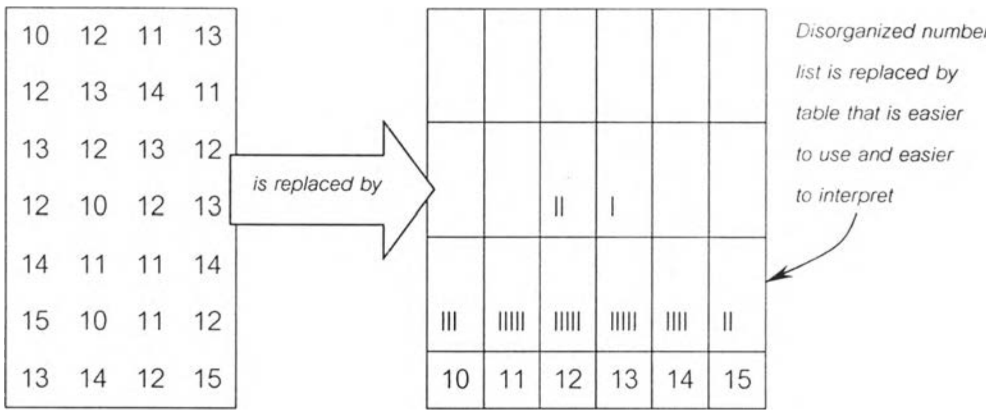


Figure 2.4 Simplifying and standardizing manual data recording

Source: Staker (1995)

There are three main uses of Check Sheets. Firstly, they can be used to count items, either as a simply count of different items, such as defects, or to show the distribution of a set of measurements. Simple counts may be displayed as a Pareto Chart, whilst distribution may be displayed as a Histogram. When counting items, the Check Sheet also is useful as the overall picture is built up in front of your eyes as you add individual items. Secondly, they may be used to show the physical location of something, such as defects on a manufactured item. This is useful for finding significant bunching of measurements, which may then help to find problems. Lastly, they may be used to help to prompt for an action and consequently be ticked to certify that a particular action has been carried out.

In interpreting and analyzing Check Sheets, identified problems may be broken down further by using the other information on the sheets about the circumstances where the measurements were made. A danger in interpretation is in not having or using this information and making assumptions that localized problems are more widespread than they are. For example, a defect log from a single product line may be wrongly generalized to cover all product lines.

2.3 Brainstorming

According to Armstrong (1994), Brainstorming is a sample technique that can be used to encourage group creativity. It is a formal approach used to help a group generate as many ideas as possible in as short a time as necessary on a chosen subject. Maximum benefit will be gained by adopting formal guidelines based upon three main features.

- Cross-fertilization- this happens when two or more people have part of an idea which on its own may seem irrelevant but when all are brought together a useful original idea is generated.
- Suspending judgment – this is crucial; the brainstorming session is purely for generation of ideas, not evaluation. Suspending judgment help to avoid looking in on one particular area of ideas, thus exhausting opportunities to explore all the possibilities. No idea should be considered ridiculous. It is part of the chairman's role to prevent participants from making comments such as, 'That would never work because…' or 'We've done it before '.
- Formality of setting- particularly at the early stages, this help to remove some of the tension that people may feel, which makes them hesitant to suggest ideas. As people become for familiar with the technique and more use to expressing ideas, the setting has less of an influence.

  In striving to meet these requirements, certain guidelines should be followed and it is the role of the chairman to ensure this happens. These rules are as follows:
- Define the central issue and make sure everyone agree upon it.
- Ever one should be allowed and encouraged to contribute; no one person should dominate.
- Every idea should be recorded in the words of the speaker.
- Never criticize ideas.
- Make no attempt to evaluate ideas.
- Don't develop ideas at length or get involved in lengthy discussions.

- The session should run for a set time or until all ideas have been exhausted, whichever is the shorter.

Great enjoyment and feeling of contributing can be gained from brainstorming, particularly when an idea is found that would not have come from an individual member of the team alone.

The underlying gold of brainstorming is the number of ideas generated, not the quality.

2.4 Quality functional deployment

Quality Functional Deployment is a planning process used to identify customer wants, needs, and expectations and incorporate them into the product development cycle. Theories are developed as to how these priorities can be incorporated into future product design/development.

QFD (Quality Function Deployment) was introduced thirty years ago in Japan as a quality system concentrated on delivering products and services that satisfy customers efficiently. It becomes more and more popular methodology to crunch customer needs to be design requirements, product/part characteristics, and manufacturing operations systematically. By doing this, we can be sure that we are working precisely on what customer wants throughout the company then our product would be success in the market.

The QFD methodology has to be done by a cross-functional team of company because it concerns the most part of company since marketing people through production people. Market research will initially provide the significant information to QFD, which are customer voices or customer requirements.

There are several different approaches to QFD, which are

- The four-phase approach uses QFD Matrix to convert customer requirements into product characteristics. The product characteristics will be converted through another QFD Matrix into part characteristics. By doing the same way, part characteristics will be converted into process characteristics that will be finally converted into production control.
- The matrix of matrices approach, developed by GOAL/QPC, is used to address a wide variety of development issues. It identifies specific matrices which should be used to address specific development issues.
- The International TechneGroup, Inc. (ITI) QFD approach for Concurrent Product/Manufacturing Process Development was developed to support ITI's work in helping corporations to implement Concurrent Engineering practices. It involves evaluating the wants and needs from all different types of customers. It also integrates the principles of concept selection to help development teams to objectively evaluate alternatives.
- There are many other approaches that can make QFD success in different ways. It depends on how good we can adapt the idea for the particular situation.

It can obviously be seen that any approaches of QFD use matrix table, or what we call "House of quality matrix" as a basic tools to figure out relationship between customer needs and product features. Affinity diagram or tree diagram are widely used to group all the customer requirements and product features before putting in a house of quality.

The House of Quality is a matrix table that cross-functional team of company uses to create a QFD process. QFD methodology requires that the team ask specific questions about customer needs, competitors, and how their organization will meet the challenges of providing products that delight the customer.

Steps to House of Quality

Step 1: Customer Requirements – "Voice of the Customer"

- Determining the market segments to identify the customer
- Gathering customer requirements of product or service by cross-functional team
- Organizing and evaluating data by using simple quality tools, such as affinity diagrams

Step 2: Regulatory Requirements

- Documenting requirement of regulatory standards, if needed be

Step 3: Customer Important Ratings

- Ranking the importance of customer requirements

Step 4: Customer Rating of the Competition

- Identifying sale opportunities, goals for continuous improvement, customer complaints, ECT

Step 5: Technical Descriptor – "Voice of the Engineer"

- Determining product specifications that can be measured and benchmarked against the competition

Step 6: Direction of Improvement

- Determining the direction of improvement for each function

Step 7: Relationship Matrix

- Determining the relationship between customer requirements and company capabilities by using the question "What is the strength of the relationship between technical function and customer requirements?"
- Using indicator as Weak-1, Moderate-3, or Strong-9

Step 8: Technical Analysis of Competitor Products

- Comparing competitor products to our product
- Determining specific value for the technical functions

Step 9: Target Values for Technical Functions

- Establishing target values for technical functions

Step 10: Correlation Matrix

- Examining impact among each single technical function
- Documenting any strong negat ve relationships
- Taking actions to eliminate physical contradictions

Step 11: Absolute Importance

- Calculating the absolute important of each technical function
- Getting eventually the technical aspects of product or service matters the most to customer

According to the 11 steps above, the structure of House of Quality can be grouped into 5 major parts as shown in Figure 2.5.

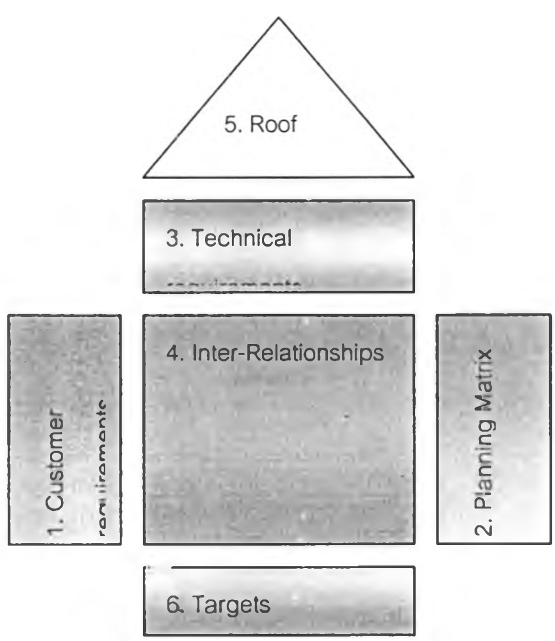


Figure 2.5: The struc ure of House of Quality

We could assume somehow that house of quality is design oriented and serves as a valuable resource for designer. It could be also a communications device between marketing people and engineers. For marketing people, it represents the voice of customer, which can be adapted into several issues for market analysis or competitive analysis. For engineers, it can provide information converted from customer requirements, which give them the punctual direction to design product or service. As a result, we could be able to reduce the timing of development stage in product life cycle. Furthermore, the product or service has high possibility to success in the market.

As described in the approach of QFD, the four-phase approach uses house of quality to crunch the input for the next phase starting from customer requirement through manufacturing process. Obviously the QFD is a method to do design product or service systematically throughout the development stage.

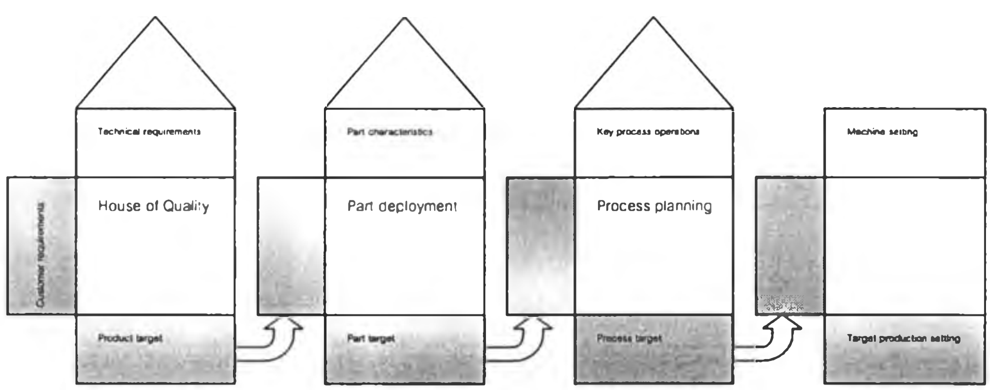


Figure 2.6 : The four-phase approach of QFD

2.5 Machine design

2.5.1 Shear and Moment Diagrams.

Beams are important structural members used in Web Cutting System. The design is often based upon the ability to resist bending stress. According to Hibbeler [1997], he had stated about beam sign convention as follow.

" Beam Sign Convention. Before presenting a method for determining shear and moment as functions of *x* and later plotting these functions (shear and moment diagrams) it is first necessary to establish a *sign convention* so as to define " positive " and " negative" internal shear force and bending moment. [This is analogous to assigning coordinate direction *x* positive to the right and *y* positive upward when plotting a function $y= f(x)$.] Although the choice of a sign convention is arbitrary, here we will use the one often used in engineering practice and shown in Figure 2.7. The positive directions require the distributed load to act downward on the beam; the internal shear force to cause a clockwise rotation of the beam segment on which it acts; and the internal moment to cause compression in the top fibers of the segment, or to bend the segment so that it holds water.

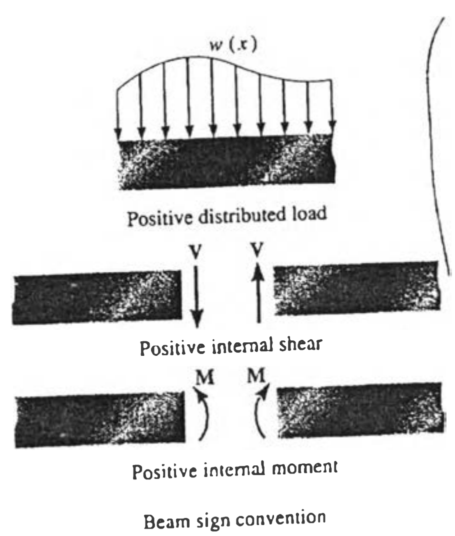


Figure 2.7 Beam sign convention

The following procedure provides the method for determining the shear and moment functions and constructing the shear and moment diagrams for a beam.

Support Reactions. Draw a free-body diagram of the beam and determine all the support reactions. Resolve the force into components acting perpendicular and parallel to the beam's axis.

Shear and Moment Functions. Select position coordinates x such that each coordinate extends into a region of the beam located *between* concentrated forces, or discontinuities of distributed loading. The *origin* for each coordinate can be established at any suitable point, but usually it is at the beam's left end. Section the beam perpendicular to its axis at each position x and draw the free-body diagram of one of two segments. Make sure that V and M are shown acting in their *positive sense*, in accordance with the sign conventions given in Figure 2.7. Use the equilibrium equation $\sum F_y = 0$ to determine V as a function of x. The internal moment M as a function of x is obtained by summing moments at the beam's cut section, $\sum M = 0$.

Once established, the results for V and M can be *checked* using the results of Eq.2.5.2, i.e., $V=dM/dx$ and $-w= dV/dx$.

Shear and Moment Diagrams. Plot the shear function (V versus x) and the moment function (M versus x). If numerical value of the functions describing V and M are *positive*, the values are plotted above the x axis, whereas negative values are plotted below the axis. Generally it is convenient to show the shear and moment diagram directly below the free-body diagram of the beam.

2.5.2 Graphical Method for Constructing Shear and Moment Diagrams.

In case where a beam is subjected to *several* concentrated forces, couples, and distributed loads, determining V and M as function of x and then plotting these equations can become quite tedious. In this section a sampler method for constructing the shear and moment diagram is discussed-a method based on two differential relation that exist among distributed load, shear, and moment.

Regions of Distributed Load. For purposes of generality, consider the beam shown in Figure 2.8*a*, which is subjected to an arbitrary distributed load $w=w(x)$ and a series of concentrated force and couple moments. A free-body diagram for a small segment of the beam, having the length Δx , is shown in Figure 2.8b. Since this segment has been chosen at a position x along the beam where there is no concentrated force or cople moment, the result to be obtained will *not* apply at these point of concentrated loading.

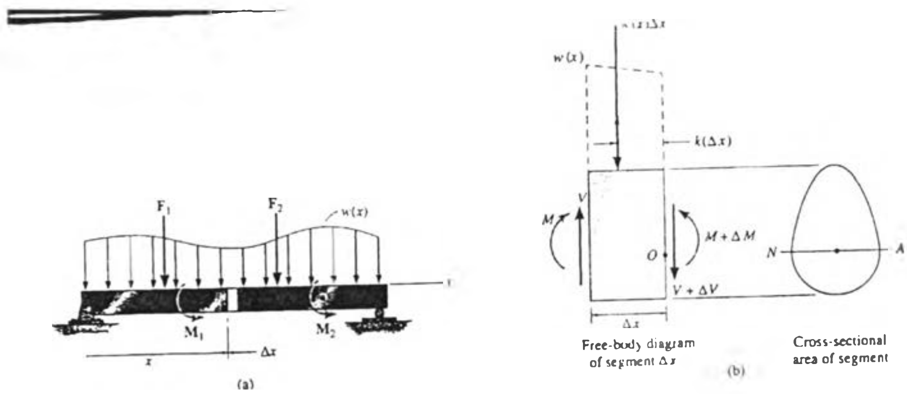


Figure 2.8 : Regions of Distributed Load

Notice that all the loading shown on the segment act in their positive directions according to the established sign convention, Figure 2.7. Also, both the internal resultant shear and moment, acting on the right face of the segment, must be increased by a small finite amount in order to keep the segment in equilibrium. The distributed load has been replaced by a resultant force *w(x)* Δx that acts at a fractional distance $k(\Delta x)$ from the right end, where 0<k<1(for example, if *w(x)* is *uniform*, $k = \frac{1}{2}$). Applying the two equations of equilibrium to the segment, we have

$$+\uparrow \sum F_y = 0; \qquad V - x(x)\Delta x - (V + \Delta V) = 0$$

$$\Delta V = -w(x)\Delta x$$

$$\circlearrowright + \sum M_o = 0; \qquad -V\Delta x - M + w(x)\Delta x[k(\Delta x)] + (M + \Delta M) = 0$$

$$\Delta M = V\Delta x - w(x)k(x)^2$$

Dividing by Δx and taking the limit as $\Delta x \rightarrow 0$, the above two equations become

$$\frac{dV}{dx} = -w(x)$$

slope of	= -distributed
shear diagram	load intensity
at each point	at each point

(2.5.1)

$$\frac{dM}{dx} = V$$

slope of	= shear
moment diagram	at each
at each point	point

(2.5.2)

2.5.3 Torsional Deformation of a Circular Shaft

Torque is moment that tends to twist a member about its longitudinal axis. Its effect is of primary concern in the design of axles or drive shafts used in vehicles and machinery

The Torsion Formula. It a shaft subjected to an external torque, then for equilibrium an internal torque must also be developan equation on the cross section of a circular shaft or tube.

It thematerial is linear-elastic, then Hooke's law applies, $\tau = G\gamma$, And consequently a *linear variationin shear strain,* leads to a corresponding *linear variation in shear stress* along any radial line on the cross section. Hence, like the shear-strain variation, for a solid shaft, τ will vary from zero at the shaft's longitudinal axis to a maximum value, τ_{max}, at its outer surface. This variation is shown in Figure 2.9 on the front facesof aselected number of elements, located at an intermediate radial position ρ andat the outer radius c. Due to the proportionality of triangles, or by using Hooke's law ($\tau = G\gamma$) and [$\gamma = (\rho/c)\gamma_{max}$], wecan write

$$\tau = \left(\frac{\rho}{c}\right)\tau_{\max} \qquad (2.5.3)$$

This equation expresses the shear-stress distribution as a function as function of the radial position ρ of the element; in other words, it defines the stress distribution in terms of the geometry of the shaft. Using it, we will now apply the condition requires the torque produced by the stress distribution over the T at the section, which holds the shaft in equilibrium.

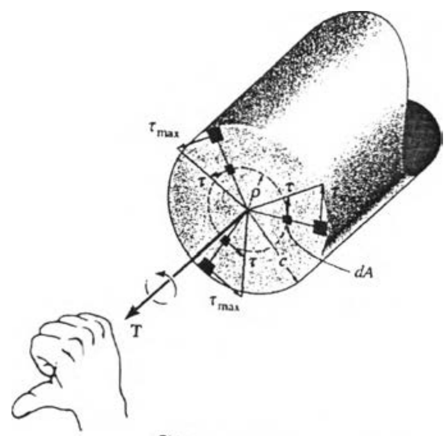


Figure 2.9 : Shear stress varies linearly along each line of the cross section

Figure 2.9 Specifically, each element of area *dA*, located at ρ, is subjected to a force of $dF = \tau\, dA$. The torque produced by this force is $dT = \rho(\tau\, dA)$. We therefore have for the entire cross section

$$T = \int_A \rho(\tau dA) = \int_A \rho\left(\frac{\rho}{c}\right)\tau_{\max} dA \qquad (2.5.4)$$

Since τ_{max}/c is constant,

$$T = \frac{\tau_{\max}}{c}\int_A \rho^2 dA \qquad (2.5.5)$$

The integral in this equation depends only on the geometry of the shaft. It represents the polar moment of inertia of the shafts cross-sectional area computed about the shafts longitudinal axis. We will symbolize its value as J, and therefore the above equation can be written in a more compact form, namely,

$$\tau_{max} = \frac{Tc}{J} \qquad (2.5.6)$$

Where

τ_{max}= the maximum shear stess in the shaft, which occurs at the outter surface

T = the resultant internal torque acting at the cross section. Its value is determined From the method of sections and the equation of moment equilibrium applied about the shaft,s longitudinal axis

J = the polar moment of inertia of the cross-sectional area

c = the outer radius of the shaft

Using Eqs. 2.5.3 and 2.5.6, the shear stress at the intermediate distance ρ can be determined from a similar equation:

$$\tau = \frac{T\rho}{J} \qquad (2.5.7)$$

Either of the above two equations is often referred to as the torsion formula. Recall that it is used only if the shaft is circular and the material is homogeneous and behaves in a linear-elastic manner, since the derivation is based on the fact that the shear stress is proportional to the shear strain.

Tubular shaft. It a shaft has a tubular cross section, with inner radius c_i and outer radius c_o, then we can determine its polar moment of inertia by subtracting J for a shaft of radial c_i from that determined for a shaft of radius of radius c_o. The result is

$$J = \frac{\pi}{2}\left(c_c^{4} - c_i^{4}\right) \qquad (2.5.8)$$

Like the solid shaft, the shear stress distributed over the tube, s cross-sectional area varies linearity along any radial line, Figure 2.10a. Furthermore, the shear stress varies along an axial plane in this same manner, Figure 2.10b. Examples of the shear stress acting on

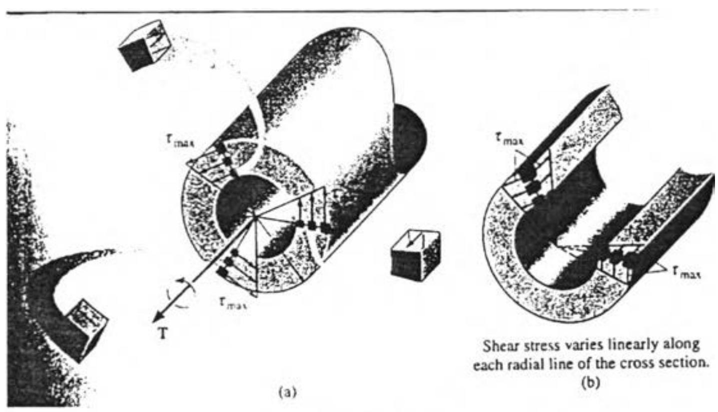


Figure 2.10 Shear stress