INSTRUCTOR'S SOLUTIONS MANUAL

COMPUTER-AIDED MANUFACTURING

THIRD EDITION

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Chapter 1 Introduction to Computer-Aided Manufacturing

Review Questions

1.1. What is computer-aided manufacturing?

Computer Aided Manufacturing (CAM) maybe defined as the effective utilization of computers in manufacturing. There are direct applications such as NC, robotics, PLC, machine monitoring and control, etc. and indirect applications such as MRP, CIM, process planning, scheduling, inventory, shop floor control, manufacturing execution system (MES), etc.

1.2. What are the major developments of CAM technology?

Major developments of CAM technology include but not limited to: NC, Industrial robot, Interactive computer graphics, CNC computer, DNC/FMS, CAD/CAM, PLC, device & cell control, Computer vision, 3-D CAD, solid modeling, factory networking, MAP/TOP, CIM, Concurrent engineering, Intelligent Manufacturing System.

1.3. What is the trend of manufacturing? Describe it in terms of market changes, technological development (both on products, and processes), managerial organization and philosophy shift, and social changes (use brain generation, green movement, and so on).

Trend of manufacturing:

- Rapid changing market place
- Fast development of new technologies
  Vacuum Tubes ->: Transistor -> IC -> VLSI
  Wiring -> thru-hole PCB -> Surface Mount Component
  Quality product -> precision engineering -> nano-engineering
- Fierce competition
- Failing automotive industry, steel mills, …

A "use brain" generation, not willing to learn the trade which requires hand skill.

1.4. List five direct and five indirect applications of computers in manufacturing.

Direct applications: NC machine tool control, FMS control, Material handling system control, Automatic Guided Vehicle, Direct Numerical Control.

Indirect applications: computer aided process planning, computerized shop scheduling, shop floor control, Computer Integrated Manufacturing, manufacturing execution system.

1.5. Discuss how manufacturing impact our standard of living.

Whether we can maintain our standard of living depends on whether we can provide sufficient goods and services to the population. Manufacturing is the meaning to produce goods. Under the free trade movement goods and services are moved freely over the national borders. "Trading" means exchange of goods or services. One must have something others want in order to trade. While a city state may rely on tourism (service) dollars to trade food and goods. A big nation can not afford to specialize on one of the areas such as agriculture, manufacturing, services, etc. to generate enough GDP to trade for other necessities. The nation must compete on all fronts. Without manufacturing, our standard of living will decline.

1.6. In the past four decades we saw manufacturing jobs moving from developed countries to developing countries. Do you believe that manufacturing jobs will always follow the lower cost labors? Why?

The labor intensive and less skilled manufacturing jobs will always follow the lower cost labors. Since the labor cost is a significant part of the total cost. However, knowledge intensive manufacturing jobs will go to where such labors are available.

1.7. CAM is embraced by not only developed countries but also developing countries. Why is CAM important for them?

Although developing countries provide well educated yet inexpensive labors, they still need CAM to improve the productivity and quality. Not all manufacturing tasks can be done by pure human labor. Due to the complexity of the product and quality requirements, most of the industrial products require sophisticated machines to build. It is just impossible to compete by manufacture products by hand.

Chapter 2. Engineering Product Specification

Review Questions:

2.1. What are the five major steps in a design process? Briefly explain each one.

The five major steps in the design process are:

- Conceptualization - This phase represents the emergence of an idea to solve an engineering problem. A need or a requirement triggers this process.
- Synthesis - Based on the concepts generated in the previous stage, the engineer 'synthesizes' a design from base principles.
- Analysis - The design that originated earlier is analyzed for its soundness in this stage. The types of analysis are Mathematical, analysis for strength, Material, etc.
- Evaluation - The design is evaluated in terms of feasibility, cost evaluation. Following evaluation steps (b) and (c) may be repeated again, for instance to insure manufacturability.

Representation - This is the culmination of the design process. A suitable method of representation (CAD models, 2-D drafting, etc.) is chosen to precisely represent the design idea.

2.2. Discuss how a design idea is represented in a designer's mind, that is, in the form of an equation, line drawing, etc.

The designer conceptualizes a part in order to satisfy a specific need. He first visualizes the general shape of the part and the specific features required fulfilling its function. Later he adds manufacturing attributes such as dimensions, tolerances, auxiliary features, etc. But the design in the designers' mind consists of a set of features to satisfy a particular requirement. He may sometimes think in terms of surface equations.

2.4. What are the methods used in diameter inspection?

The simplest method is the use of a micrometer screw gauge (for od), and Vernier's calipers (for id as well as for od). More precise measurements may be taken using sophisticated measurement techniques. In mass production, the fastest methods include the use of plug gauges.

2.5 Why is it that 100 percent inspection seldom ensures that a shipment of parts will be 100 percent to specifications?

If the inspection devices are 100 percent accurate and the person operating the devices never makes mistake, with 100 inspection the parts will be 100 percent to the specifications. However, the above assumption is not always false.

2.6 For what reasons is it advisable to control the surface roughness of a part?

It is for working surface. Working surfaces are those for items such as bearings, pistons, and gear teeth, for which optimum performance may require control of the surface characteristics. Non-working surfaces are sometimes controlled for aesthetical purposes.

2.7 What is meant by the root-mean-square deviation?

Root-mean-square is a calculated value representing the surface roughness. It is calculated by the square root of the mean value of squared surface deviation heights from the center line.

$$rms = \sqrt{\frac{\sum_{i=1}^{n} y_i^2}{n}}$$

2.8 What is the value of 1 μin?

One micro inch is one one millionth an inch. Or, it can be written as 0.000,001 inch.

2.9 Give the sequence in ascending order based on surface roughness of the following processes: cold rolled, die cast, plaster cast, hot rolled, and cold drawn.

Consult to a manufacturing processes textbook, the following order can be found:

Die cast

Plaster cast

Cold rolled

Cold drawn

Hot rolled

2.10 What do we mean by statistical quality control?

Statistical quality control is an analytical tool that can be used to evaluate machines, materials, and processes by observing performance and performance trends in variation so that comparisons and reductions may be made to control the desired quality level.

2.11 Define standard deviation.

The standard deviation can be defined as the root-mean-square deviation, in that it is the square root of the mean of the squares of the deviations.

2.12 What is a normal distribution?

Normal distributions are a family of distributions that have the same general shape. They are symmetric with scores more concentrated in the middle than in the tails. Normal distributions are sometimes described as bell shaped. They differ in how spread out they are. The area under each curve is the same. The height of a normal distribution can be specified mathematically in terms of two parameters: the mean (μ) and the standard deviation (σ).

The height (ordinate) of a normal curve is defined as: $\frac{1}{\sqrt{2\pi\sigma^2}} e^{-(x-\mu)^2/2\sigma^2}$ where μ is the mean and σ is the standard deviation,

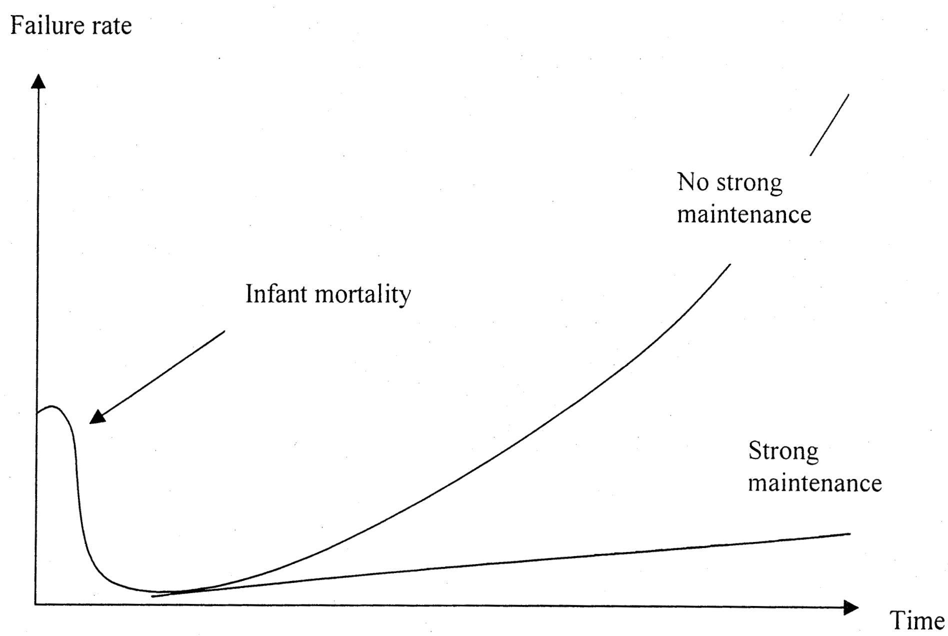
2.13 Why is it desirable to plot the "range" of successive samples?

The range of successive samples provides a view of how precise is the process. While the sample mean shows the trend of process shift. The range change will provide a signal to the operator that the process is running less stable.

2.14 Why do chance failures plot as an approximate straight line when failure rate is plotted against time?

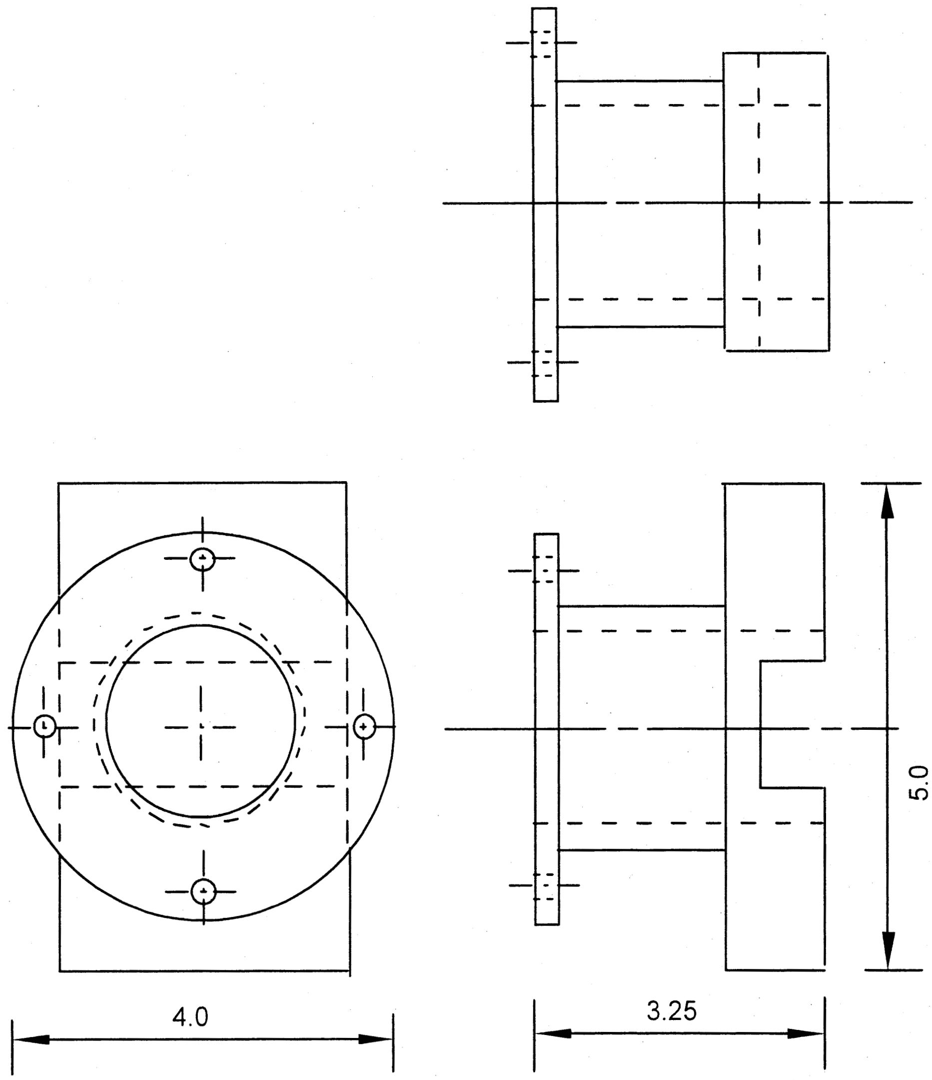
There are four types of failures: Infant mortality, chance failures, abuse or misuse, and wear-out. Infant mortality always happens at the early stage and not a function of time. Chance failure is a failure due to random event, again not a function of time. Abuse or misuse failure is due to poor operation policy, not a function of time. Wear-out failure is the only one correlated to the time. Since failure rate does have a component of time, it is plotted against time. Chance failures not being a function of time, the plot should approximate straight line when plotted against time.

2.15 Show graphically the effect of a strong maintenance and preventive maintenance program on the relation between failure rate and time.



Review Problems

2.1 Prepare a three-view drawing in third angle projection of the part shown in Figure 2.36.

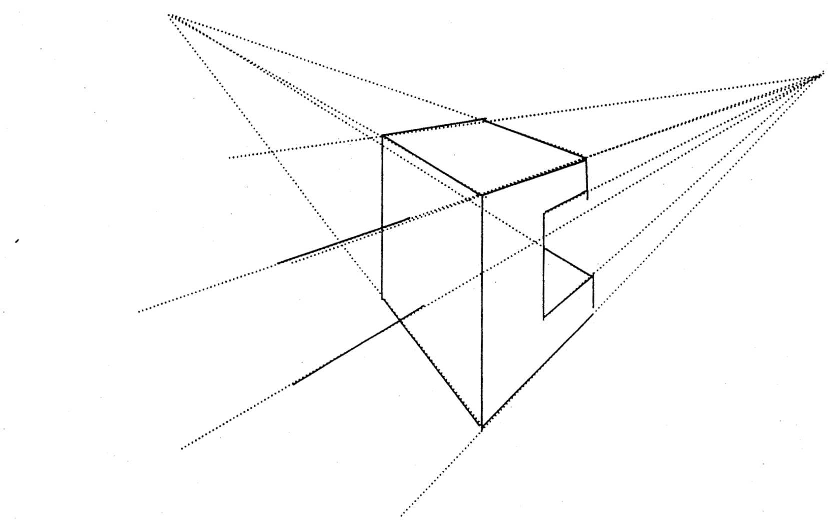


2.2 Prepare an orthographic projection drawing of the part shown in Figure 2.36.

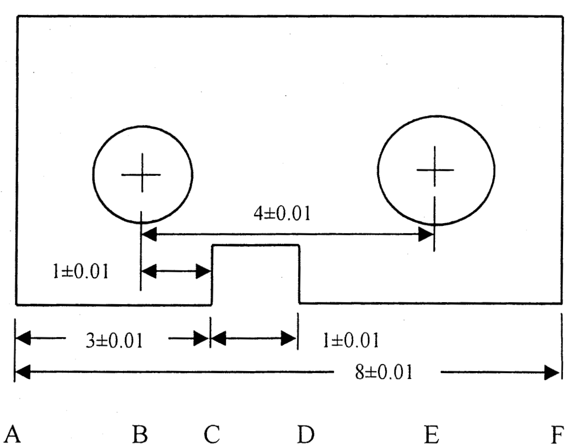
Figure 2.29 is already an orthographic project drawing. Ask students to do it on a CAD system.

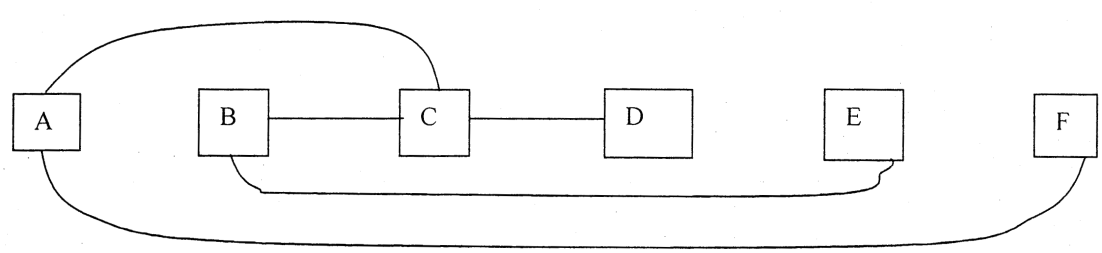
2.3 Prepare a two-point perspective projection drawing of the part shown in Figure 2.36.

A two-point perspective projection drawing should look like (partial drawing shown below):



2.4 Prepare a tolerance graph for the following part drawing. Only dimensions along the X coordinate are shown and considered in the problem. Is there any cycle or disconnect node?





There is no cycle neither disconnected nodes.

2.5 Continue Problem 2.4, what are inferred distances between D-E, E-F, C-E?

$d_{DE} = -d_{DC} - d_{CB} + d_{BE} = -1 - 1 + 4 = 2$

$d_{EF} = -d_{EB} + d_{BC} - d_{CA} + d_{AF} = -4 + 1 - 3 + 8 = 2$

$d_{CE} = -d_{CB} + d_{BE} = -1 + 4 = 3$

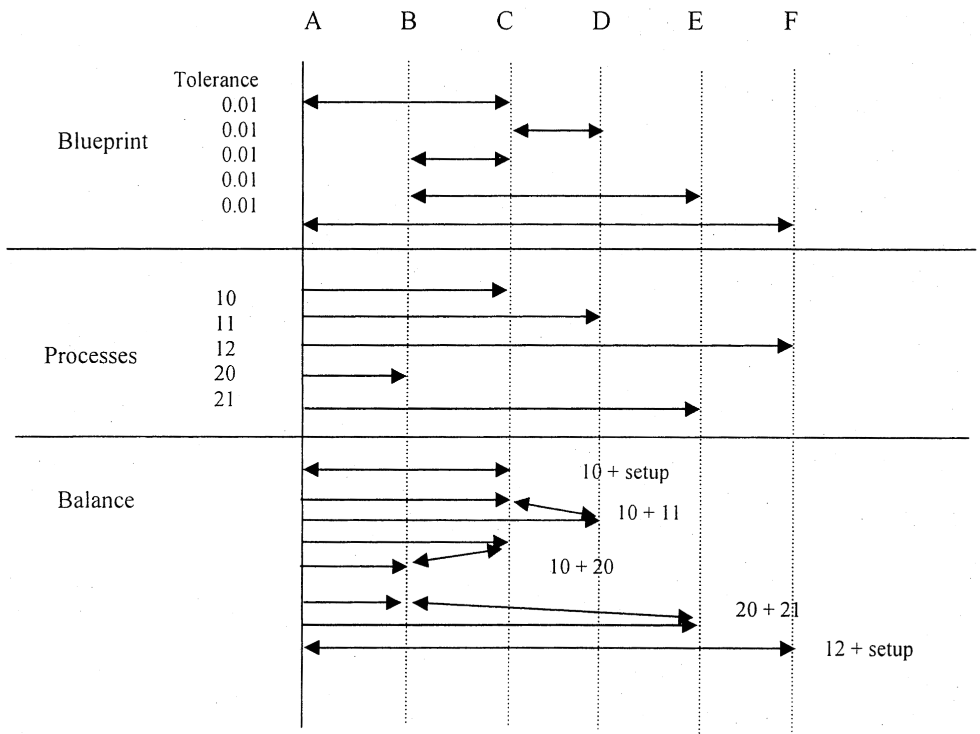
2.6 Continue Problem 2.4, what are inferred tolerances between D-E, E-F, C-E?

$t_{DE} = t_{DC}+t_{CB}+t_{BE} = \pm0.01\pm0.01\pm0.01 = \pm0.03$

$t_{EF} = +t_{EB} + t_{BC} + t_{CA} + t_{AF} = \pm0.01\pm0.01\pm0.01\pm0.01 = \pm0.04$

$t_{CE} = t_{CB} + t_{BE} = \pm0.01\pm0.01 = \pm0.02$

2.7 The process plan for the part in Figure 2-37 has only one setup using A as reference. Surfaces C, D, F, and holes B and E are machined under the same setup. The setup error is 0.001. The process error for C, D, and F is 0.002. The location process error for B and E is 0.003. Prepare a tolerance chart to verify whether the specifications can be produced successfully.



$$t_{AC}^{M} = t_{10}^{P} + setup = 0.002 + 0.001 = 0.003$$
$$t_{CD}^{M} = t_{10}^{P} + t_{11}^{P} = 0.002 + 0.002 = 0.004$$
$$t_{BC}^{M} = t_{10}^{P} + t_{20}^{P} = 0.002 + 0.003 = 0.005$$
$$t_{BE}^{M} = t_{20}^{P} + t_{21}^{P} = 0.003 + 0.003 = 0.006$$
$$t_{AF}^{M} = t_{12}^{P} + setup = 0.002 + 0.001 = 0.003$$

2.8 The weights of ceramic compacts were taken at random and recorded as follows:

Specimen weights, kg				
1.24	1.31	1.29	1.34	1.26
1.32	1.41	1.37	1.28	1.31

1.40	1.34	1.29	1.32	1.30
1.31	1.26	1.28	1.34	1.31
1.25	1.29	1.34	1.31	1.32

Calculate the mean and standard deviation of the samples. Assume that the mean and standard deviation of the samples is representative of the population. Find the upper and lower control limits and plot an x control chart. Is the process in statistical control? Explain why.

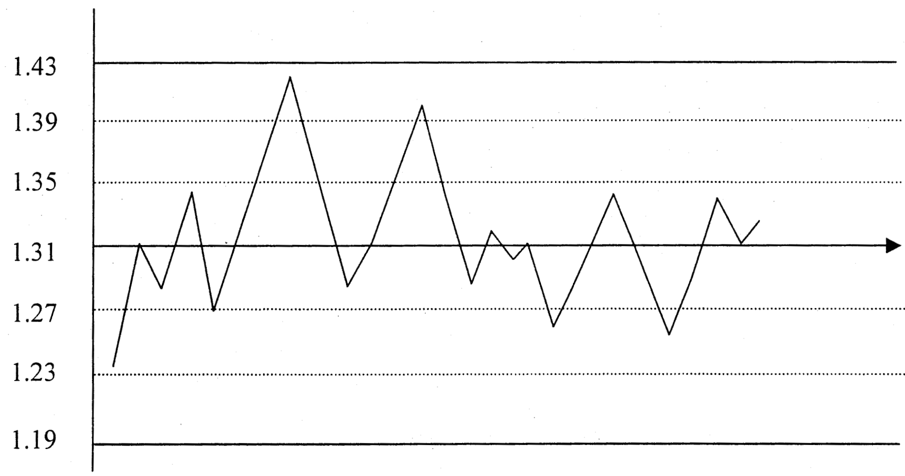
Average = 1.31

Standard Deviation = 0.04

Upper control limit = 1.31 + 3 x 0.04 = 1.43

Lower control limit = 1.31 – 3 x 0.04 = 1.19

All of the samples are within the control limit. There is no up or down trend observed.



2.9 Given a process in statistical control with a population mean of 5.000 in and a population standard deviation of 0.001 in., determine (a) the natural tolerance limits of the process and (b) if the specification limits are 5.001 ± 0.002 in., what percentage of the product is defective, assuming that the process output deviations are normally distributed?

a. The natural tolerance limits are set at 3 σ that is 0.003 in.

5.000"±0.003"

b. 5.001" ± 0.002" then the upper specification limit is 5.003" and the lower specification limit is 4.999".

Pr (x>5.003) = 1-Φ((5.003-5.000)/0.001)=1-Φ(3)=0.00135

Use the Excel function "=1-NORMSDIST(3)"

Pr(x<4.999) = Φ((4.999-5.000)/0.001)=Φ(-1)=0.158655

Use the Excel function "=NORMSDIST(-1)"

Total defects = Pr(x>5.003)+Pr(x<4.999) = 0.00135+0.158655=0.16 = 16%

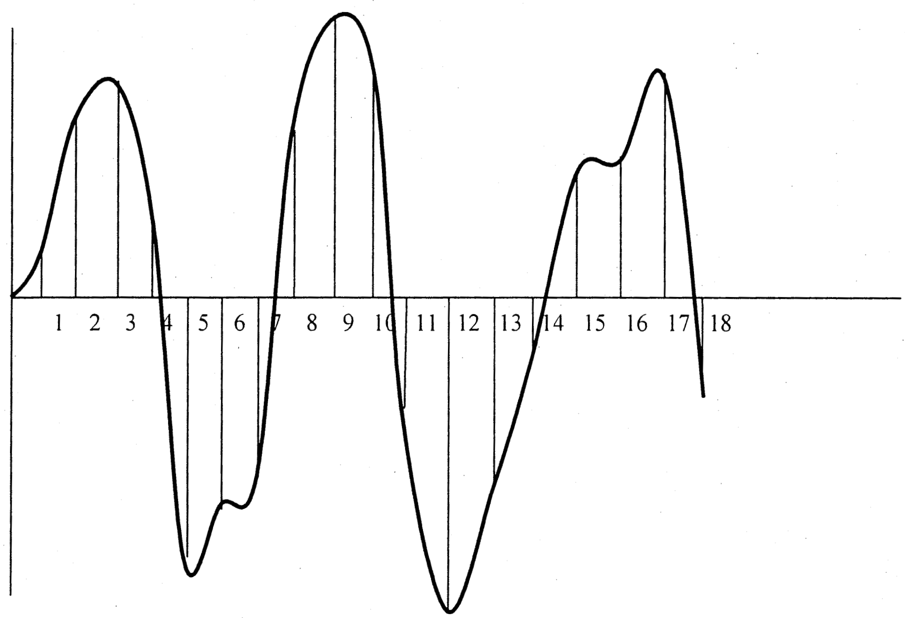
2.10 Given a process with a population mean of 10.00 and a population standard deviation of 1, what can be said about the interval 10 ± 2 if the distribution is normal?

One can say that the process is at 2-sigma quality level. If the process is used to produce the product with the 10 ± 2 interval, the defect rate would be:

$Pr(x>12)+Pr(x<8)=1-\Phi((12-10)/1)+\Phi((8-10)/1)=1-\Phi(2)+\Phi(-2)=0.046=4.6\%$

2.11 Determine the surface roughness values of the partial surface trace given in the table below in terms of the maximum peak to valley roughness, the arithmetic average, AA, and the root-mean-square, rms.

Point	Deviations from mean µin.	Point	Deviations from mean µin.
1	4	10	20
2	15	11	10
3	18	12	23
4	8	13	15
5	20	14	3
6	17	15	8
7	15	16	10
8	17	17	20
9	24	18	5



$$R_a = \frac{\sum_{i=1}^{n} y_i}{n}$$

Ra=(4+15+18+8+20+17+15+17+24+20+10+23+15+3+8+10+20+5)/18=14

$$rms = \sqrt{\frac{\sum_{i=1}^{n} y_i^2}{n}}$$

rms=sqrt(($4^2+15^2+\ldots+5^2$)/18)=15.38

2.12 On an interference fit the basic size of a hole is 3.5000in. The interference between the shaft and the hole must be at least 0.0015 in. The tolerance on the shaft and the hole is 0.0009 in. using the basic hole system and unilateral tolerances. Divide the tolerances on each item into three groups so that the small shafts mate with the small holes, the medium shafts mate with the medium holes, etc. Thereby there will be as nearly uniform as possible interference between the mating parts. This procedure is called selective assembly and is used when more precise metal fits are needed than can be obtained by conventional interchangeable manufacture. Hole diameter is $3.5000^{+0.0000}_{-0.0009}$ and the shaft diameter is $3.5015^{+0.0009}_{-0.0000}$. Do an experiment by randomly assemble hole and shaft within each of the three groups. What is the average interference for the entire batch? Now try to assemble without dividing them into groups. What is the average interference now?

Produced Holes:

3.5000	3.4991	3.4999	3.4992	3.4995
3.4992	3.4991	3.4993	3.5000	3.4998
3.4997	3.4992	3.4995	3.4999	3.4994
3.4993	3.4998	3.4991	3.4992	3.4998
3.4997	3.4991	3.5000	3.4991	3.4994

Produced Shaft:

3.5020	3.5015	3.5021	3.5023	3.5024
3.5023	3.5021	3.5024	3.5016	3.5019
3.5019	3.5022	3.5020	3.5022	3.5016
3.5020	3.5018	3.5017	3.5021	3.5020
3.5016	3.5017	3.5019	3.5018	3.5023

Without grouping:

The shaft size – the hole size:

0.002	0.0024	0.0022	0.0031	0.0029
0.0031	0.003	0.0031	0.0016	0.0021
0.0022	0.003	0.0025	0.0023	0.0022
0.0027	0.002	0.0026	0.0029	0.0022
0.0019	0.0026	0.0019	0.0027	0.0029

Average interference = 0.002484
Std dev = 0.000445
Min = 0.0016
Max = 0.0031

Grouping: (by sorting both holes and shafts)
Group 1:

Hole	3.4991	3.4991	3.4991	3.4991	3.4991	3.4992	3.4992	3.4992
Shaft	3.5015	3.5016	3.5016	3.5016	3.5017	3.5017	3.5018	3.5018
Diff	0.0024	0.0025	0.0025	0.0025	0.0026	0.0025	0.0026	0.0026

Group 2:

Hole	3.4992	3.4993	3.4993	3.4994	3.4994	3.4995	3.4995	3.4997
Shaft	3.5019	3.5019	3.5019	3.502	3.502	3.502	3.502	3.5021
Diff	0.0027	0.0026	0.0026	0.0026	0.0026	0.0025	0.0025	0.0024

Group 3:

3.4997	3.4998	3.4998	3.4998	3.4999	3.4999	3.5	3.5	3.5
3.5021	3.5021	3.5022	3.5022	3.5023	3.5023	3.5023	3.5024	3.5024
0.0024	0.0023	0.0024	0.0024	0.0024	0.0024	0.0023	0.0024	0.0024

Average = 0.002484
Std dev = 0.000107
Min = 0.0023
Max = 0.0027

What shown here is a more consistent interference between shafts and holes.