CHAPTER III

DESCRIPTION OF THE APPARATUS

The main parts of the apparatus were the dynamometer, the strain gauge bridge meter and the lathe.

Dynamometer The dynamometer design is the main purpose of this work.

The dynamometer consists of a cantilever bar which supports the cutting tool and which is mounted in the main body of the apparatus. Cantilever bar is the main part of the dynamometer and was made from a 2 in. Diameter, 7 in. long cylindrical steel bar being devided into 4 sections as shown in the drawing Fig 3.1

Section A was provided as the tool holder, having 3/4" square cross-section.

In order to eliminate torsion effects on the measuring section the tool cutting edges is placed on the centre of the cross section. The carbide tip was clamped by two screws as shown in Fig 3.2 making the changin of tips an easy matter.

Carbide tool tip angles The carbide tip was ground at the angle for hard steel cutting, as shown in Fig 3.3

Section B was provided for joining the tool holder and measuring section rigidly, and to act as the heat sink for heat produced during cutting. This reduces any temperature changes at the strain gauges.

Section C was the measuring section acting as a cantilever beam with 3/4 in. square cross-section and 1 in. length. When a force is acting on the tool tip, the distribution of strain at the measuring sectio is as shown in Fig 3.4

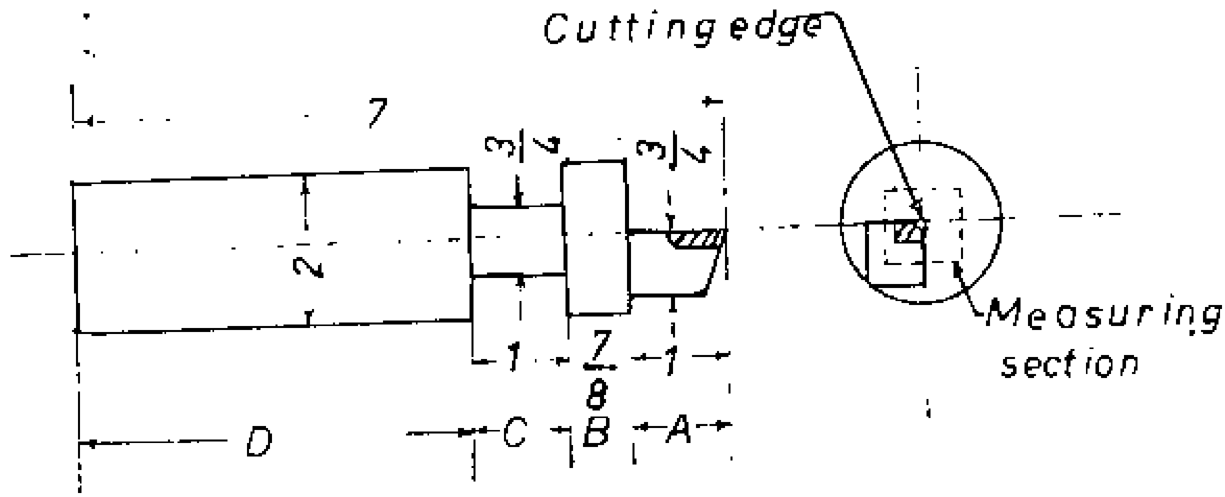

FIG. 3.1
Measuring bar

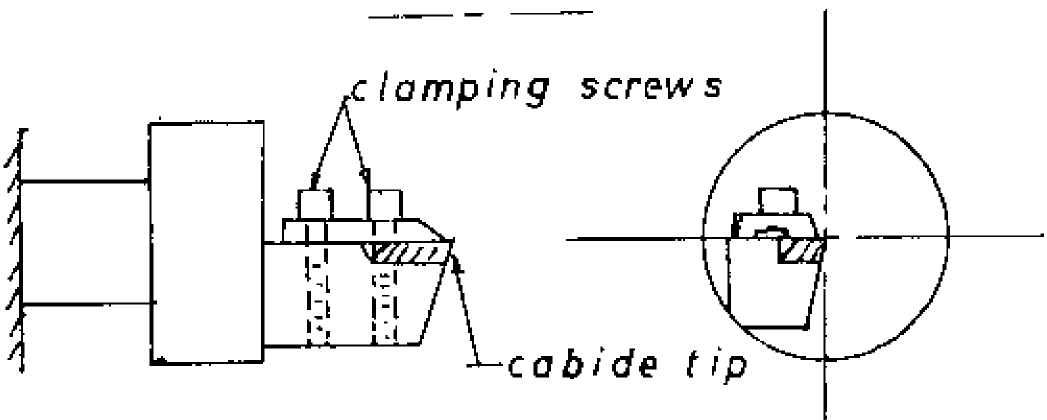

FIG. 3.2 TOOL HOLDER

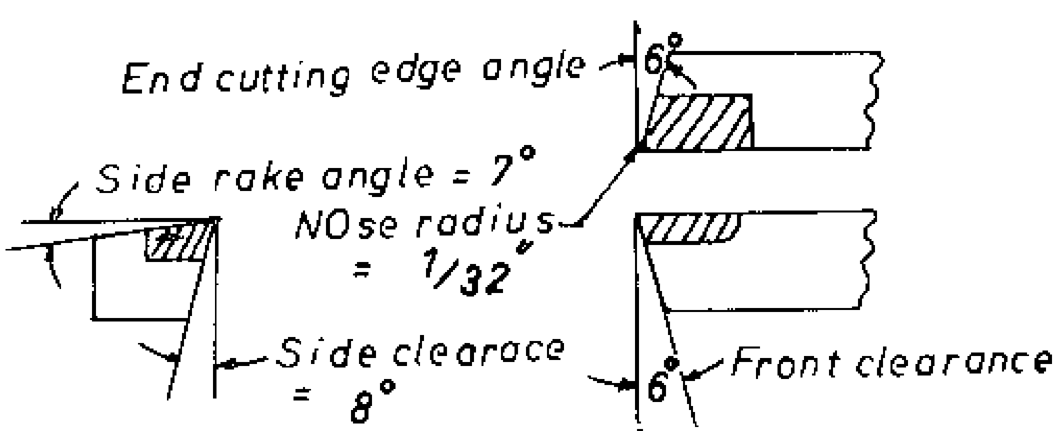

FIG. 3.3 TOOL TIP ANGLES

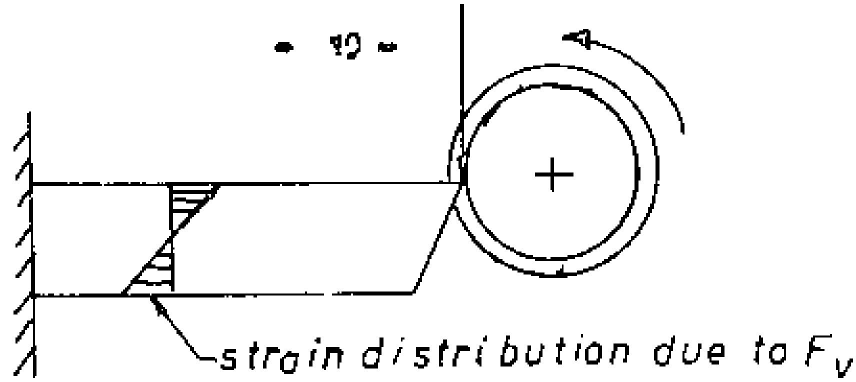

FIG. 3.4

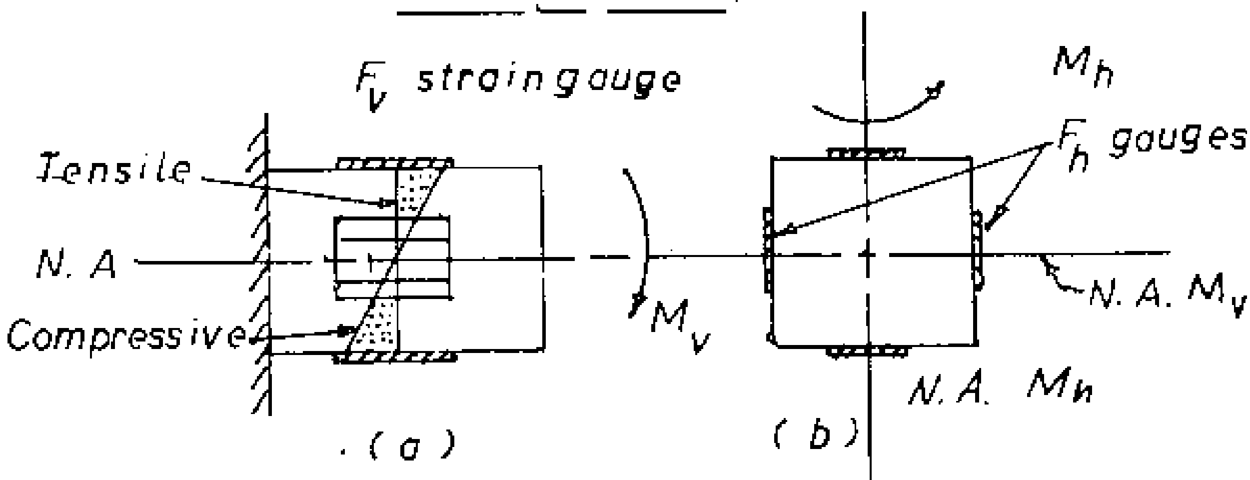

FIG. 3.5 STRAIN GAUGE ATTACHMENT

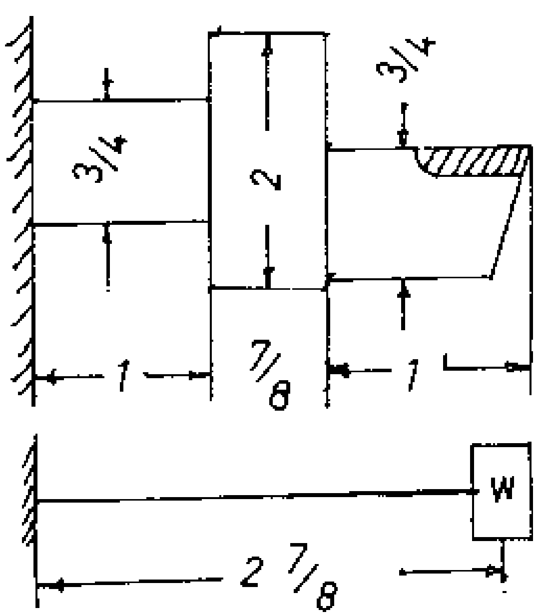

FIG. 3.6 TOOL HOLDER EQUIVALENT SYSTEM

We can measure the strain appearing on the upper and lower surfaces of the measuring section using strain gauges and calibrating in terms of cutting force. Similarly F_t can be measured by measuring the strain on side surface of the measuring bar.

Strain gauge attachment

Four strain gauges used in the designed dynamometer, two of them were used to measure vertical force, and the other two for horizontal force. They were attached on the four surfaces of the measuring section, as shown in Fig. 3.5

The centre lines of the strain gauges were kept on the neutral axes of bending on the surfaces of the measuring section. By this method the cross-coupling of the two component forces is compensated by each strain gauge itself as shown in Fig. 3.5 (a). Strain above the neutral axis is tensile and below is compressive, maximum values above and below the centre line of the strain gauge in Fig. 3.5 (a) being equal and opposite. The shank of the measuring bar, (section D in Fig. 3.1) is 2 in. diam. & 4 1/8 in. long. It was made cylindrical so that the tool side rake could be varied if necessary.

Natural frequency of the measuring bar

Assume an equivalent system of the measuring bar as a cantilever beam with end weight. (see Fig. 3.6)

$$N = \frac{1}{2\pi}\sqrt{\frac{s\,g}{w}}$$

$$S = \text{stiffness} = \frac{3\,E\,I}{L^3} \quad \text{(for cantilever beam)}$$

$$E = 30 \times 10^6 \text{ lb/in.}^2$$

$$I = \frac{1}{12} ab^3$$

$a = b = 0.75$ in. (width and depth of measuring section)

$$= \frac{1}{12} (0.75)(0.75^3)$$

$$= 0.0263 \text{ in.}^4$$

$L = 2.875$ in. (length of the beam)

$g = 32.2 \text{ ft/sec}^2$

$= 0.28 \text{ lb/in.}^3$ (density of steel)

$$w = 0.28 \left(\frac{33}{140} \times 2 \times 0.75^2 \times \frac{}{4} 2^2\right)$$

$$= 0.873 \text{ lb.}$$

$$N = \frac{1}{2\pi} \sqrt{\frac{3 EI \times g}{L^3 \times w)}}$$

$$= \frac{1}{2\pi} \sqrt{\frac{3 \times 30 \times 10^6 \times 0.0263 \times 12 \times 32.2}{(2.875)^3 \times 0.873}}$$

$$= 1230 \text{ c/s}$$

Stress on the measuring section

The dynamometer was designed for maximum cutting force 100 lbs. and thrust force 50 lbs. (or F_c & F_t)

$R = (100^2+50^2)^{1/2} = 111.83$ lbs

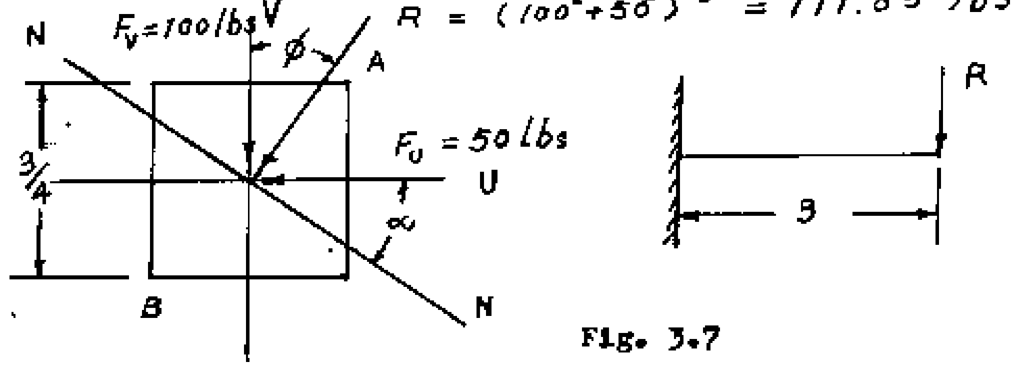

Fig. 3.7

For unsymmetrical bending

$$\sigma = \frac{M_u V}{I_u} + \frac{M_v U}{I_v}$$

$$I_v = I_u = \frac{1}{12} ab^3$$

$$= \frac{1}{12} (0.75)^4 = 0.0263 \text{ in.}^4$$

$$\tan\phi = \frac{50}{100} = \frac{1}{2}$$

$$\tan\alpha = (I_u/I_v) \tan\phi = \frac{1}{2}$$

$$\therefore = 26.6^\circ$$

$$M_u = 100 \times 3$$

$$M_v = 50 \times 3$$

$$\sigma_A = \frac{M_u V_A}{I_u} + \frac{M_v U_A}{I_v}$$

$$= \frac{100 \times 3 \times 0.75}{0.0263 \times 2} + \frac{50 \times 3 \times 0.75}{0.0263 \times 2}$$

$$= 6,420 \text{ psi}$$

yield stress of the steel

= 57,000 psi (by tension test)

$\therefore$ factor of safety $= \frac{57,000}{6,420} = 8.9$

Dynamometer body The dynamometer body consisted of two pieces of steel, between which the measuring bar was clamped using four screws. The whole dynamometer was covered in a case for strain gauge protection, and clamped on the sadle of the lathe by two clamping screws in a similar manner to the tool post of a lathe.

Strain gauge bridge

The strain gauge bridge used in the experiment was "Tinsley bridge type 5580"

Range of bridge

Suitable for strain gauges 50 to 2000 ohms

Gauge factors 1.8 to 4.5 in steps of .01

Strain measurement:-

0 to ± 1% readable to .001% (10 units of microstrain)

0 to ± 0.1% readable to .0005% (5 units of microstrain)

Limit of error:-

± 0.5% of reading or 5 units of microstrain, whichever is the greater

Sensitivity:-

Detector sensitivity sufficient to balance to one unit of microstrain using 100 ohm gauges

External Circuits:-

Suitable for single gauge with dummy gauge, 2 active gauge and 4 active gauge bridges

Bridge Supply

Self-contained square wave oscillator operating at 1000 cycles (the use of a square wave oscillator eliminates the effect of lead capacitance and also parasitic EMFs which generally arise in DC circuits due to differences in temperature). (Tinsley bridge operation instruction book)

The bridge circuit

The bridge circuit used in the dynamometer was a two active arm bridge as shown in Fig. 3.8 The strain gauges were "Tinsley" strain gauges, type 20 B, gauge factor 1.87, gauge resistance 123 ohms.

The advantage of the two active arm bridge are a doubled amplitude of signal to the bridge galvanometer and automatic temperature compensation, as mentioned in the chapter II

Lathe

The lathe used in these experiments was a "town woodhouse" of 3 h.p. capacity.

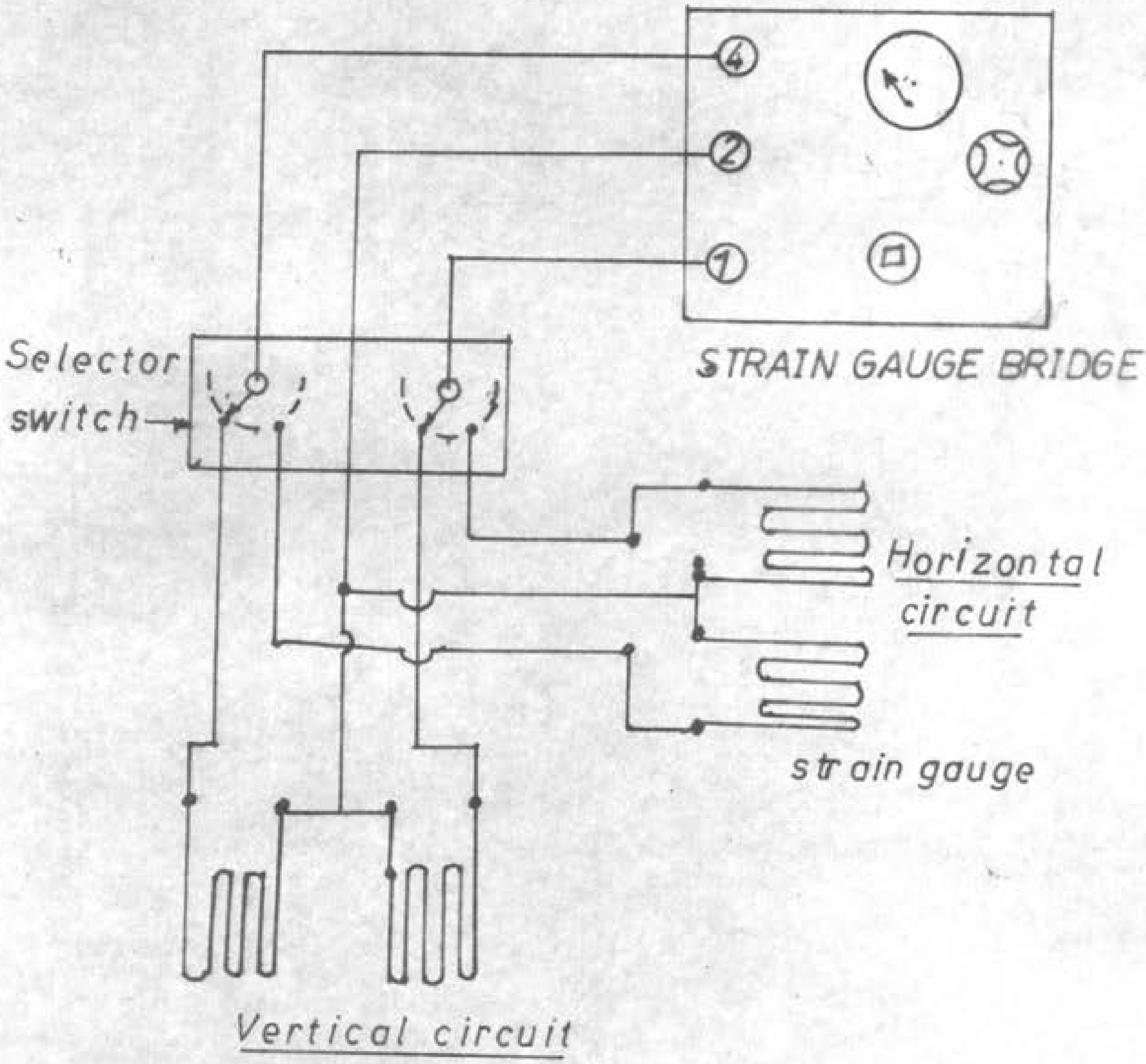

FIG. 3. 8 STRAIN GAUGE BRIDGE CIRCUIT

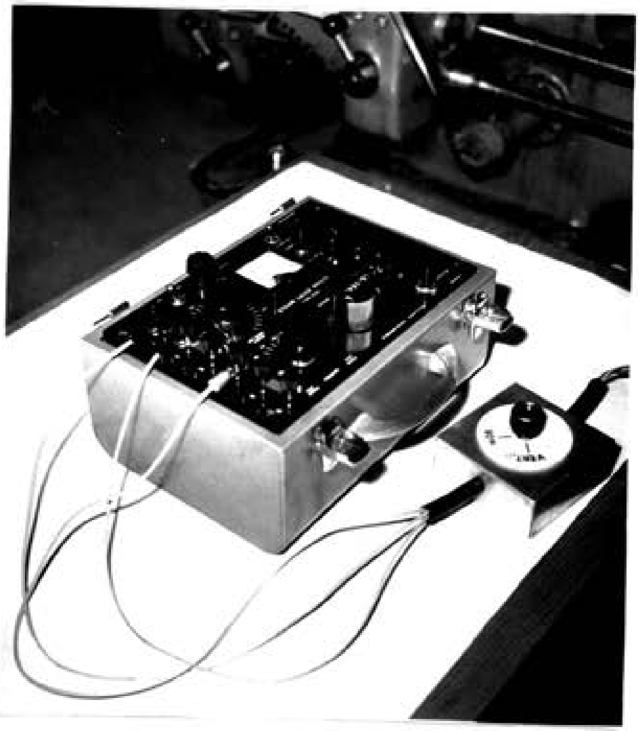

Fig. 3.9 strain gauge bridge & selector switch

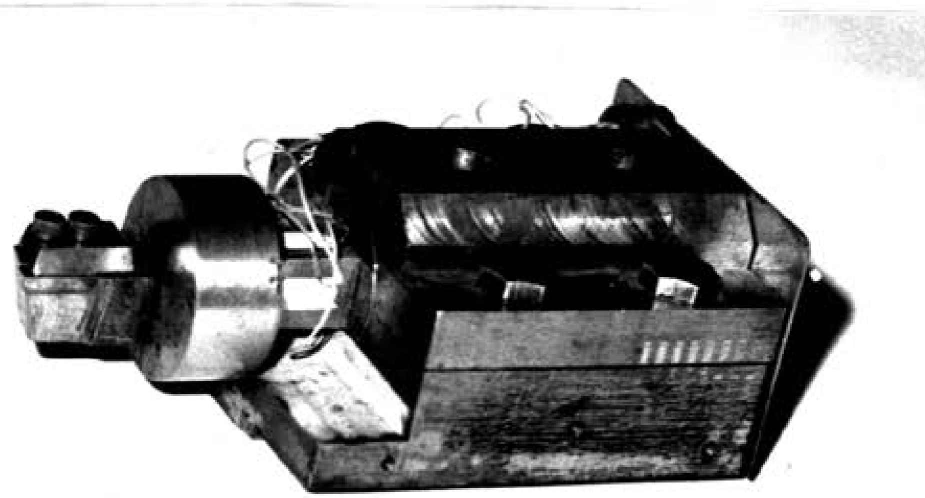

Fig. 3.10 Dynamometer showing inside