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STRENGTH OF ECCENTRICALLY LOADED RIVETED JOINTS

Consider an eccentric loading as in fig. below.

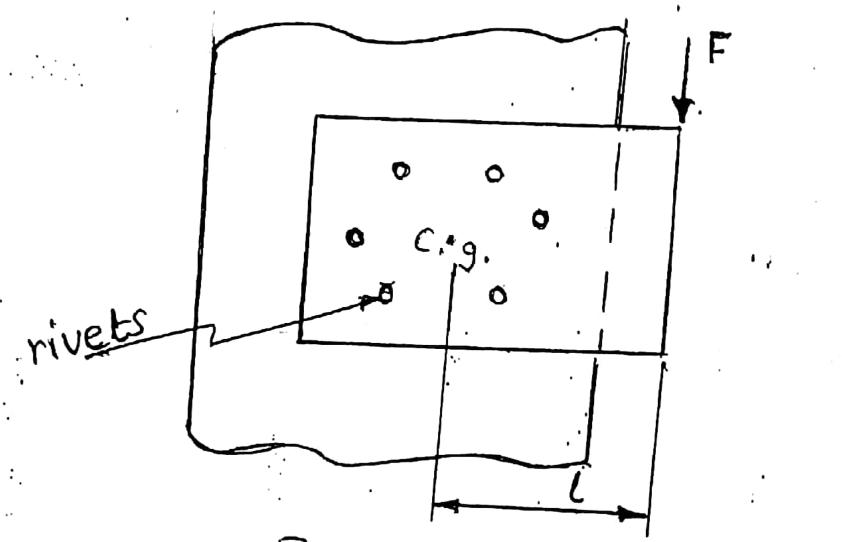


Fig. Eccentric loading

Let the force F act at a distance l from the c.g. (to be determined for a given design) of the rivet group.

Then the resultant loading through the c.g. is as given in fig. below.

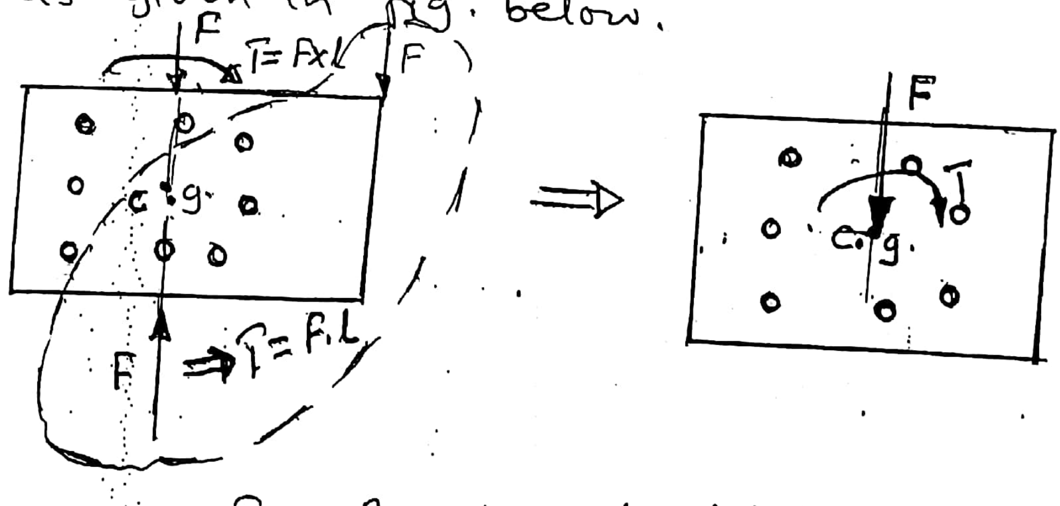


Fig. Resultant load through c.g.

The resultant load therefore is a direct force F and a couple $T = F \times l$.

Now consider the loading on the rivets. This is as given in fig. below.

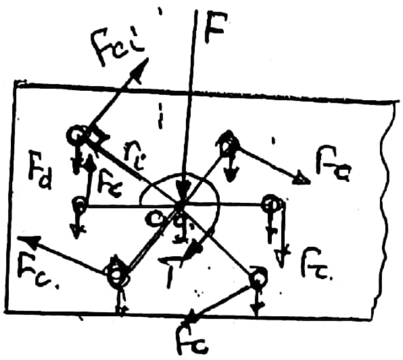


Fig. Loading on rivets.

The component loads on each rivet are $\vec{F_d}$ due to direct load $\vec{F}$ and $\vec{F_{ci}}$ due to couple T. Note that $\vec{F_{ci}}$ is $\perp$ to radius r_i in the direction giving the sense of the couple.

<u>Magnitude of the forces.</u>

$$|\vec{F_d}| = \frac{F}{n}$$ where n = total number of rivets used.

<u>Note:</u> $\vec{F_d}$ is in the direction giving the sense of $\vec{F}$.

$|\vec{F_{ci}}|$ is determined as given in fig. below.

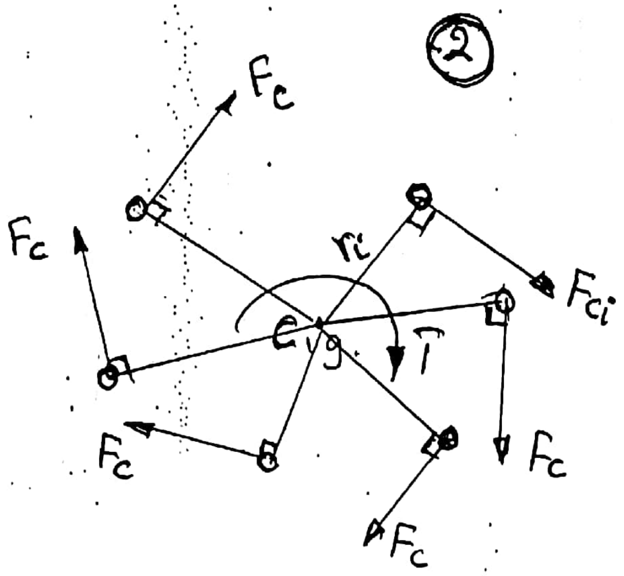


Fig: Loading on rivets due to couple T.

Let: $F_c \propto r$ $\therefore F_{ci} = k\, r_i$

or $k = F_{ci}/r_i$

Now $T = \sum F_{ci} \times r_i$

$\therefore T = k \sum r_i^2$ or $T = \dfrac{F_{ci}}{r_i} \sum r_i^2$

$$\therefore \boxed{|\vec{F}_{ci}| = \frac{T \times r_i}{\sum_{1}^{n} r_i^2}}$$

i.e. magnitude of the force due to couple T on rivet i at a radius r_i from c.g.

<u>Note:</u> $\sum_{1}^{n} r_i^2$ is for all rivets subjected to couple. The rivet at c.g. $F_c = 0$ because $r_i = 0$

<u>Resultant load on rivets</u>

Consider the rivet with component loads $\vec{F}_d$ and $\vec{F}_c$ as given in fig. below.

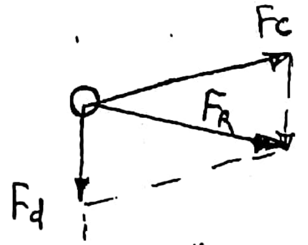
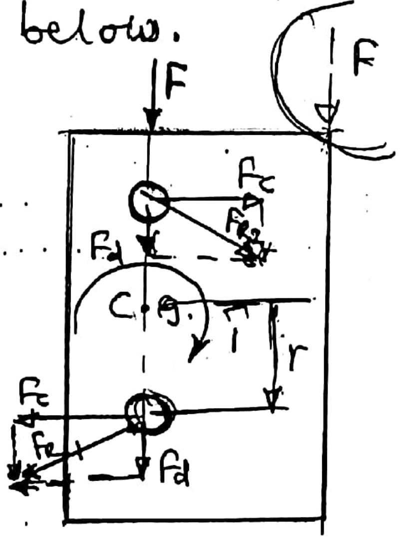


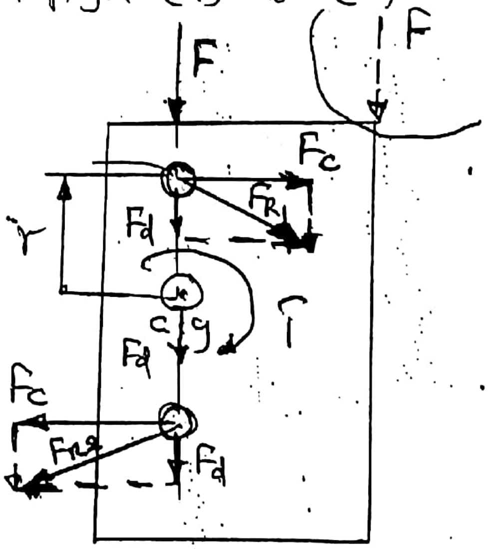
Fig: Rivet with component loads showing the resultant.

$\therefore$ The resultant $\vec{F_R} = \vec{F_d} + \vec{F_c}$

That is the resultant $\vec{F_R}$ can be determined in magnitude and direction vectorially. The resultant is the one to be considered for the strength of the rivet in shear and bearing. Also the strength of the plate in bearing..

Consider simple cases in figs. (a) to (d) below.





(a) $|\vec{F_d}| = \frac{F}{2}$

$|\vec{F_{R1}}| = |\vec{F_{R2}}|$

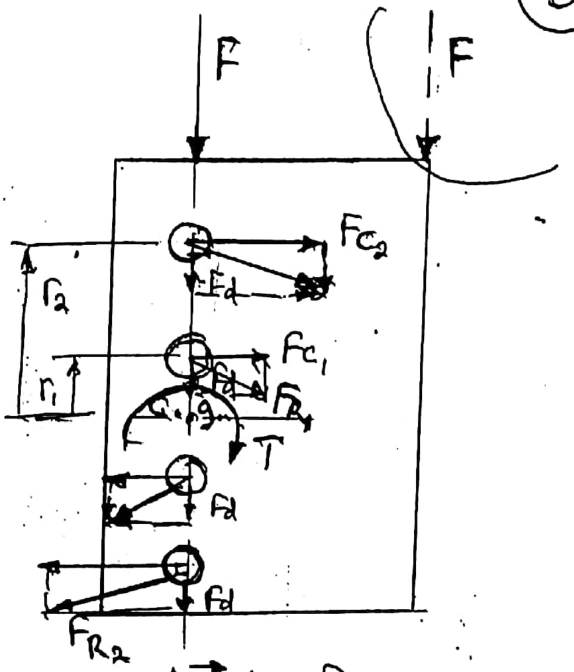
$= \sqrt{F_d^2 + F_c^2}$

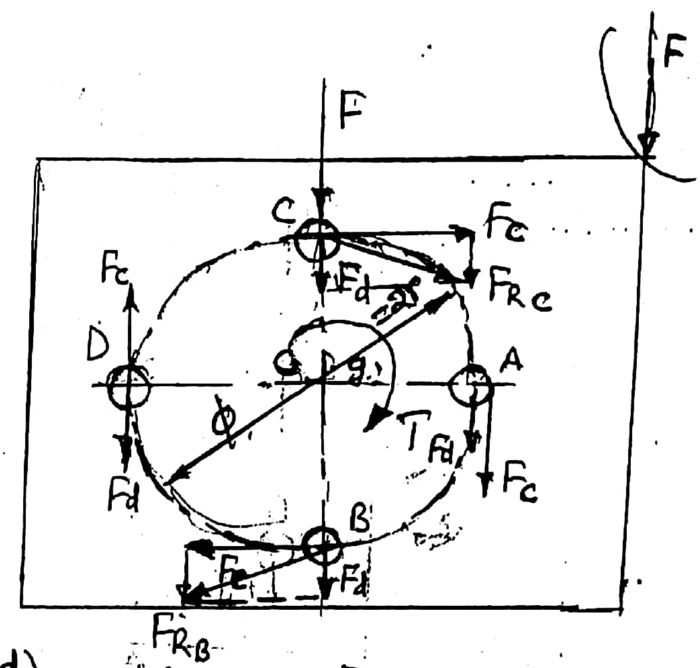
$F_c = \frac{Tr}{2r^2} = \frac{T}{2r}$

(b) $|\vec{F_{c_1}}| = |\vec{F_{c_2}}| = \frac{Tr}{2r^2} = \frac{T}{2r}$

$F_d = F/3$

$|\vec{F_{R1}}| = |\vec{F_{R2}}| = \sqrt{F_d^2 + F_c^2}$





(c) $|\vec{F_d}| = \dfrac{F}{4}$

$$F_{c_1} = \frac{T \times r_1}{\sum r_i^2}$$

$$F_{c_2} = \frac{T \times r_2}{\sum r_i^2}$$

$$\sum r_i^2 = 2r_1^2 + 2r_2^2$$

$$|\vec{F_R}| = \sqrt{F_d^2 + F_c^2}$$

max. at outer rivets.

(d) $|\vec{F_d}| = \dfrac{F}{4}$

$$|\vec{F_c}| = \frac{Tr}{\sum r_i^2}, \quad \sum r_i^2 = 4r^2$$

$$|\vec{F_{R_A}}| = F_d + F_c$$

$$|\vec{F_{R_D}}| = F_c - F_d$$

$$|\vec{F_{RC}}| = |\vec{F_{R_B}}| = \sqrt{F_d^2 + F_c^2}$$

Fig. Simple cases for resultant rivet load.

Now consider a more general case (Fig. below).

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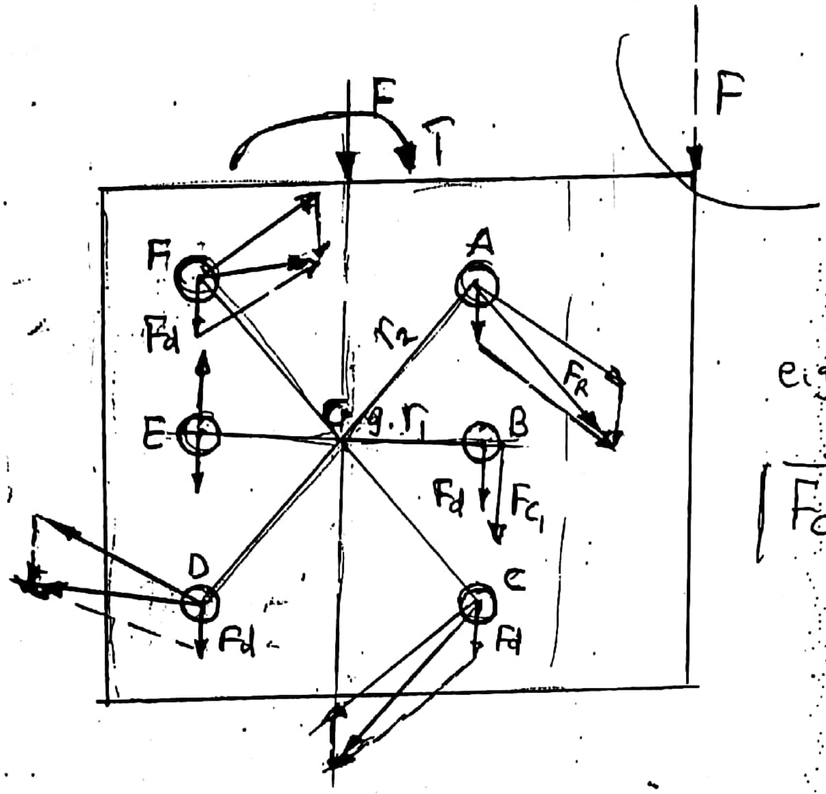


e.g. $|\vec{F_d}| = \frac{F}{6}$

$$|\vec{F_{ci}}| = \frac{T \times r_i}{\sum r_i^2}$$

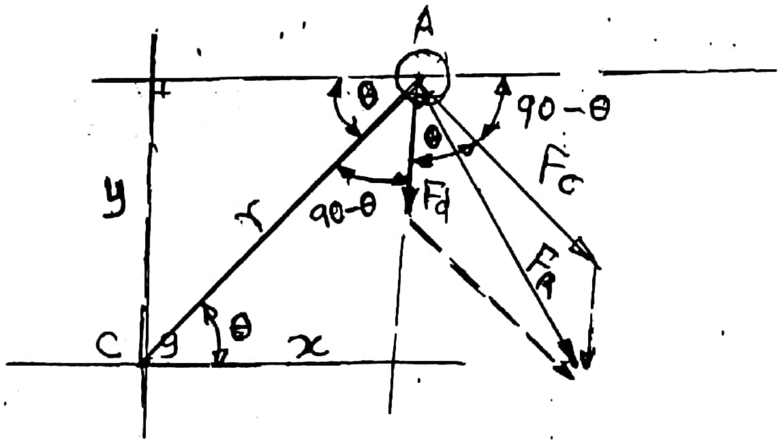
Fig. A more general case

$|\vec{F_{RB}}| = F_{c_1} + F_d$, $|\vec{F_{RE}}| = F_{c_1} - F_d$ no problem.

$|\vec{F_{RA}}| = |\vec{F_{RC}}|$ and $|\vec{F_{RD}}| = |\vec{F_{RF}}|$

Apart from rivet B, critically loaded rivets may also be A and C.

To get the resultant $\vec{F_{RA}}$ proceed as follows



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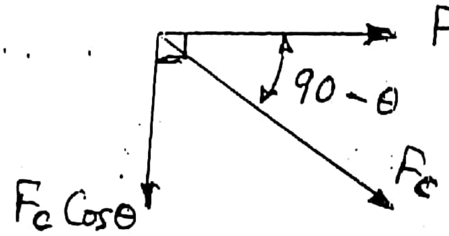
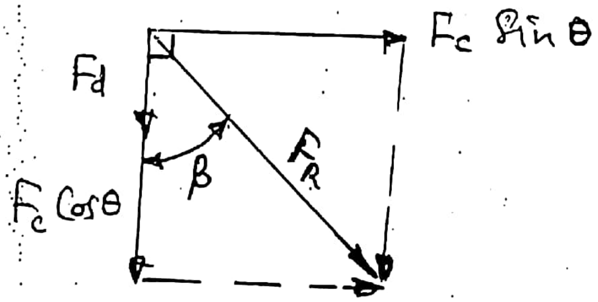
1. Calculate $|\vec{F_c}|$ and $|\vec{F_d}|$ as usual.

2. $\tan\theta = \frac{y}{x}$ or $\underline{\theta = \tan^{-1}\frac{y}{x}}$

3. Components of $\vec{F_c}$ are as given below



4. The resultant $\vec{F_R}$ will be given by the resultant components as given below.



$$\therefore |\vec{F_R}| = \sqrt{(F_c \sin\theta)^2 + (F_d + F_c\cos\theta)^2}$$

$$= \sqrt{\underline{F_c^2 \sin^2\theta} + F_d^2 + \underline{F_c^2\cos^2\theta} + 2F_dF_c\cos\theta}$$

$$\therefore |\vec{F_R}| = \sqrt{F_c^2 + F_d^2 + 2F_dF_c\cos\theta}$$

Direction of $\vec{F_R}$ is $\beta = \tan^{-1}\left(\frac{F_c\sin\theta}{F_d + F_c\cos\theta}\right)$ with $\vec{F_d}$