* Balancing
التوازن

بسبب عدم تساوي الكتله على جانبي العمود الدوار تتولد قوة طارده مركزية واهتزاز مما يؤدي الى انحناء العمود وحماية العمود يجب اضافة كتلة مقدمة في الجانب المعاكس.

Introduction

when we attached mass to arotating shaft, in which produce centrifugal force and vibration, in order to prevent the shaft from this effect, we must attached another mass into the opposite side of the shaft, this prosses is called Balancing.

* Types of balancing
انواع التوازن

I) Balancing of rotating masses توازن الكتل الدواره

II) Balancing of reciprocating masses توازن الكتل الترددية

* I) Balancing of rotating masses

* Casses of of balancing of rotating masses.
حالات توازن الكتل الدواره

* I) Balancing of a single rotating mass by single rotating mass in the same plane.
ا- توازن الكتل الدواره الواحده بكتله دواره واحده تحتويان في مستوى واحد توازن ستاتيكي

case of static balance
حالة التوازن الستاتيكي

In this cass the balancing is done by adding (or cutting) mass into the opposite direction, untill the (Fc) be equal.

∴ The condition of static balance:
شروط التوازن الستاتيكي (الحالة الثابتة)

1) -- $\boxed{\Sigma F = 0}$ → force balance ①

, where | Fc - centrifugal force قوة الطرد المركزي
| ω - rad/s
| W - weight

$$F_{c_1} = F_{c_2}$$

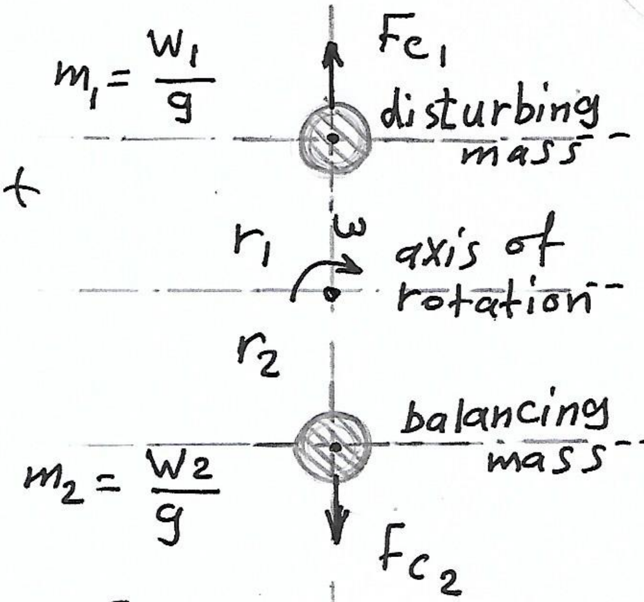
$$m_1 r_1 \omega^2 = m_2 r_2 \omega^2$$

$$\frac{W_1}{g}\omega^2 r_1 = \frac{W_2}{g}\omega^2 r_2$$

$$\boxed{W_1 r_1 = W_2 r_2} \quad \text{--- 1}$$

→ moment balance.

$$\Sigma M = 0 \quad \text{--- 2}$$



ملاحظة (1): شرط التوازن تكون مجموع القوى ومجموع العزوم = 0

ملاحظة (2): لغرض تقليل كتله التوازن، يجب اختيار أكبر نصف قطر للتوازن

II) Balancing of single rotating mass by two masses rotating in different planes.

موازنة كتله دوارة واحدة بكتلتين دوارتين في مستويين مختلفين

هذه الحالة تمثل التوازن الديناميكي، حيث عند الحركة بالإضافة الى القوة تتولد عزوم عند الكراسي

In this case we have dynamic balance, in which produce couple (مزدوج) which tends (يحاول) to turn the shaft in its bearings, there fore for complete balance, we must place two masses in different planes, parallel to the plane of rot-ation.

شروط التوازن الديناميكي هي:

∴ The condition of complete dynamic balance:

1) $\Sigma F = 0$ → static balance.

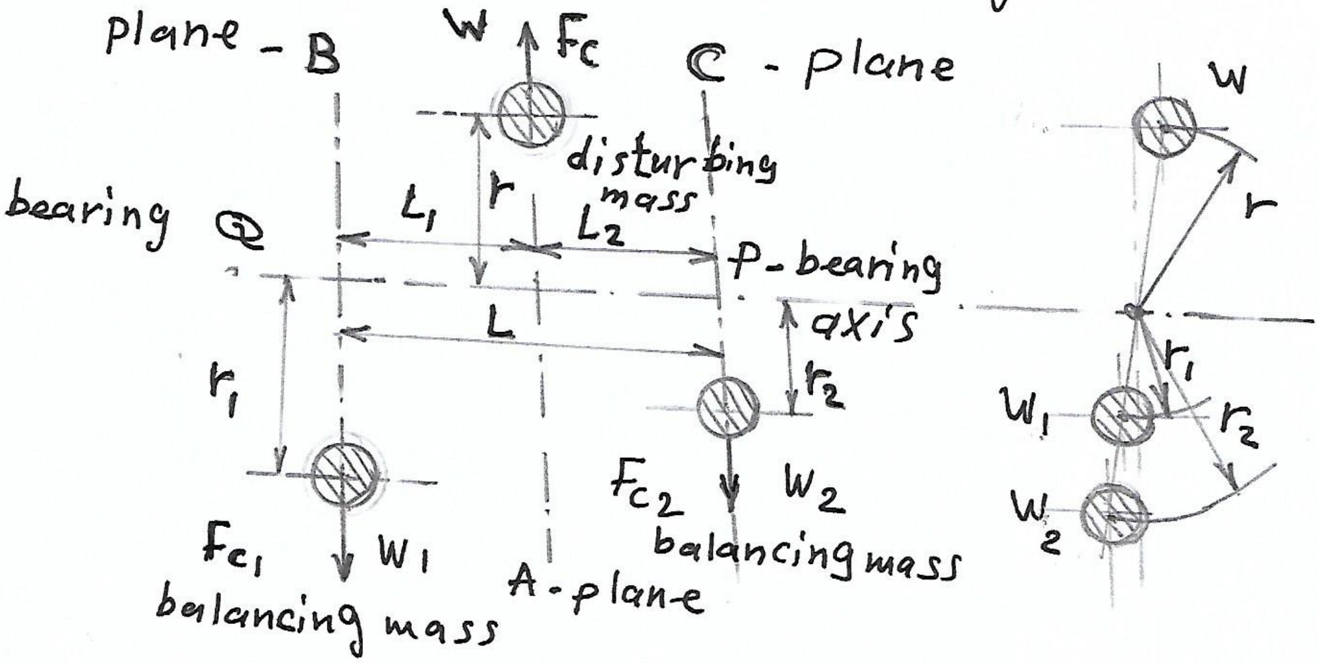
2) $\Sigma M = 0$ → Couple duo to force.

* ways of dynamic balance: طرق التوازن الديناميكي

* There are two ways of attaching of two balancing masses

1) First way when the plane of the distur-bing mass lie between the different

planes of the two balancing masses-



∴ The Condition of complete balance

1) $\Sigma f = 0$

$\therefore F_c = F_{c1} + F_{c2}$

$\therefore \frac{W}{g}\omega^2 r = \frac{W_1}{g}\omega^2 r_1 + \frac{W_2}{g}\omega^2 r_2$

$\therefore \boxed{W r = W_1 r_1 + W_2 r_2}$ ---- ① → static balance.

2) $\Sigma M = 0$

In order to find the magnitude of balancing force (dynamic force in bearing Q) in plane B, we must take:

$\Sigma M_P = 0$

$\therefore -F_{c1} * L + F_c * L_2 = 0$

$\therefore F_{c1} * L = F_c * L_2$

$\frac{W_1}{g}\omega^2 r_1 L = \frac{W}{g}\omega^2 r L_2$

$\therefore \boxed{W_1 r_1 = \frac{W r L_2}{L}}$ ---- ②

similary for plane (C).

$\Sigma M_Q = 0$ $\rightarrow + F_{c_2} \cdot L + F_c \cdot L_1 = 0$

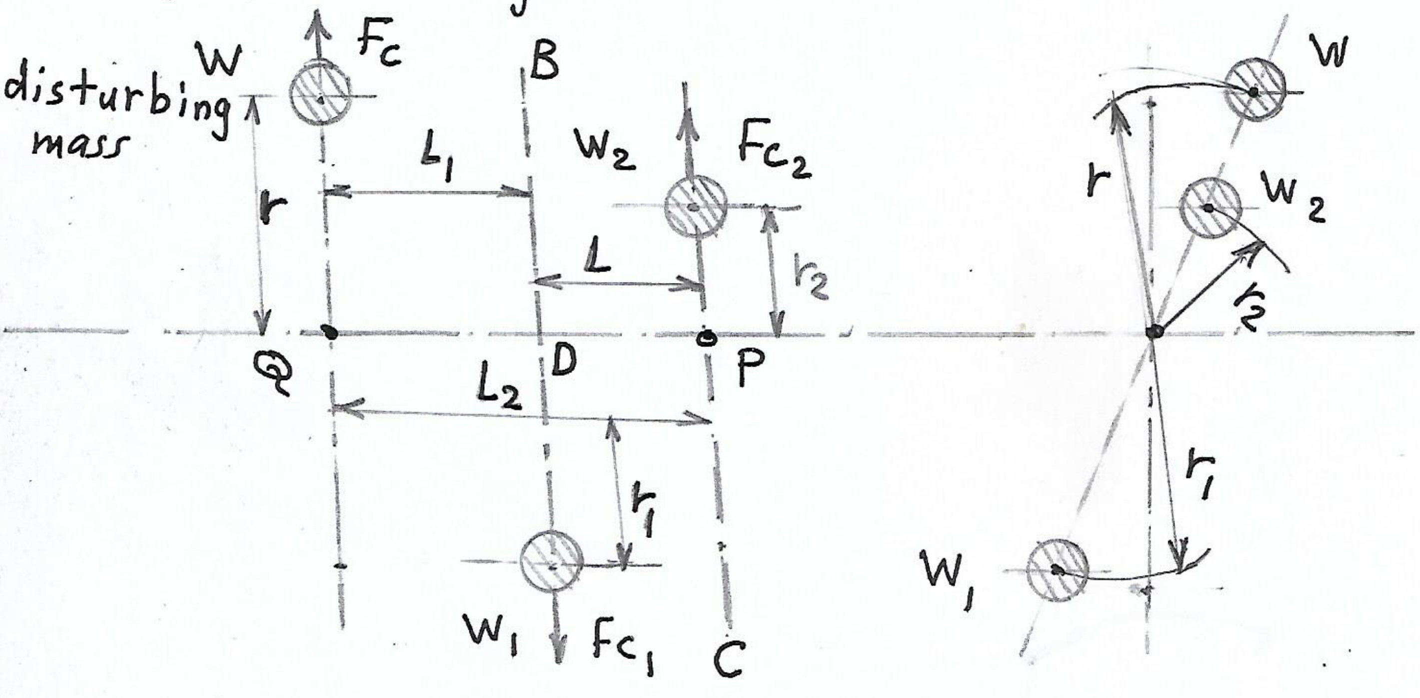
$\therefore F_{c_2} * L = F_c * L_1$

$\frac{W_2}{g} \omega^2 r_2 L = \frac{W}{g} \omega^2 r L_1$

$$\boxed{W_2 r_2 = \frac{W r L_1}{L}} \quad --- (3)$$

$\therefore$ equations (1), (2), (3) $\rightarrow$ represent condition of Complet dynamic balance.

2) The second way when the plane of the disturbing mass lies on one end of the planes of balancing masses



$\therefore$ The condition of the Complete balance be:

1) $\Sigma f = 0$

$\therefore F_c + F_{c_2} = F_{c_1}$

$\therefore \boxed{W r + W_2 r_2 = W_1 r_1} \quad --- (1) \Rightarrow$ static balance.

2) $\Sigma M_P = 0$

$\therefore W_1 r_1 L = W r L_2$

$$\therefore \boxed{W_1 r_1 = \frac{W r L_2}{L}} \quad \text{---} (2)$$

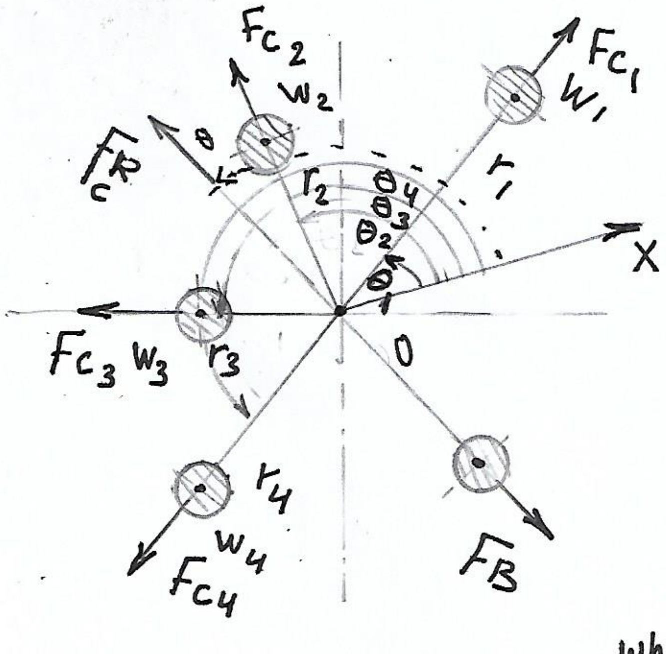
$\Sigma M_D = 0$

$\therefore W_2 r_2 L = W r L_1$

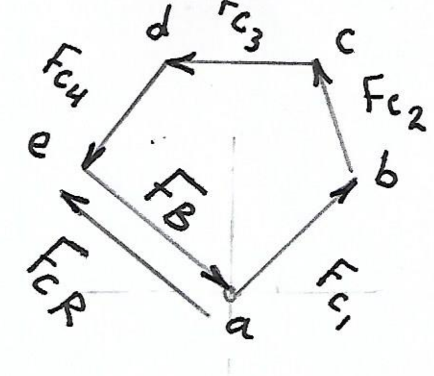
$$\therefore \boxed{W_2 r_2 = \frac{W r L_1}{L}} \quad \text{---} (3)$$

III) Balancing of several masses rotating in the same plane ; توازن مجموعة كتل تدور في مستوى واحد

Let we have any number of masses for example four masses, with weights (W_1, W_2, W_3, W_4), angles ($\theta_1, \theta_2, \theta_3, \theta_4$), radius ($r_1, r_2, r_3, r_4$) rotates in one plane about axis $ox \perp$ to the plane at o.



Fig(a)



Fig(b)

where $ea = F_B$, $ae = F_{cR}$

* The magnitude and position of the balancing mass may be found by two methods:

* 1) Analytical Method: الطريقة التحليلية

Is done by resolving the centrifugal forces horizontally and vertically, then we determine the resultant:

$$\Sigma R_H = W_1 r_1 \cos\theta_1 + W_2 r_2 \cos\theta_2 + \cdots$$

$$\Sigma R_V = W_1 r_1 \sin\theta_1 + W_2 r_2 \sin\theta_2 + \cdots$$

→ ∴ The magnitude of the resultant Centrifugal Force make angle θ with horizontal.

$$F_{CR} = \sqrt{(\Sigma R_H)^2 + (\Sigma R_V)^2} \quad \cdots (1)$$

$$\tan\theta = \frac{\Sigma R_V}{\Sigma R_H} \quad \cdots (2)$$

∴ The balancing force = Resultant C-force and in opposite direction, and the weight of the balancing force be:

$$F_{CR} = F_B = \frac{W}{g}\omega^2 r \quad \cdots (3)$$

* 2) Graphical Method: الطريقة البيانية

يمكن الحصول على قيمة واتجاه كتلة التوازن باتباع الخطوات التالية:

The magnitude and position of balancing mass may be obtained as follow:

١- ارسم مخطط الإزاحة لموقع كل كتلة

1) Draw space diagram with the positions of all masses Fig (a).

٢- اوجد قوة الطرد المركزي او العزم لكل كتلة.

2- Find C-force for each mass (F_C) or ther torque (Wr) (product of mass * radius).

with | weights W_1, W_2, W_3, W_4
| radius r_1, r_2, r_3, r_4
angles $\theta_1, \theta_2, \theta_3, \theta_4$

and let the system (shaft) be balanced by two masses rotating in the planes L, M with | weight W_L, W_M
| radius r_L, r_M
angles θ_L, θ_M

∴ For Complete balance, we must determine the magnitude and direction of the balancing masses as follow:

1- Draw the linear and angular position of all the masses, as in Fig(a), Fig(b), and transverse all the planes into reference plane, which is $\perp$ to the axis of rotation Like (L), so the distance of all planes at left of R.P (−) and at right (+)

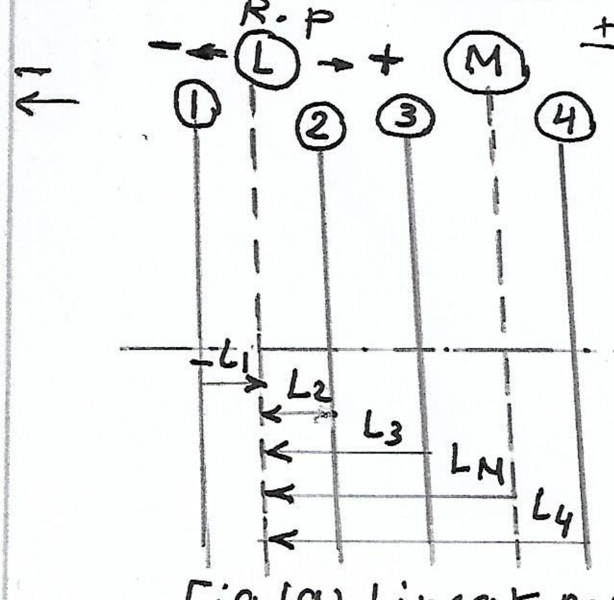
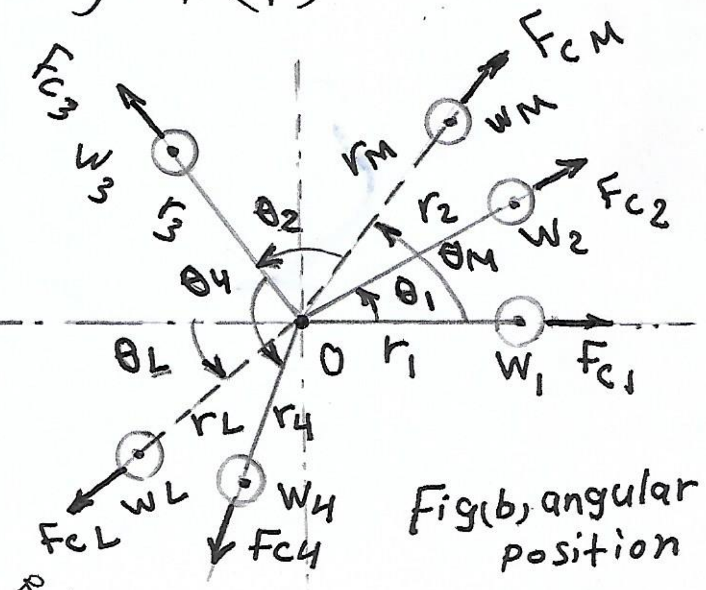


Fig (a) Linear position



Fig(b) angular position

R-P

2- Tabulate the date, as in table (2)

1	2	3	4	5	6
Plans	Weights $W(N)$	radius $r(mm)$	Centrifugal Force $\frac{\omega^2}{g} W \cdot r (N \cdot M)$	distance from R.P $L(m)$	Couple $\frac{\omega^2}{g} W \cdot r \cdot L (N \cdot m^2)$
1	W_1	r_1	$W_1 r_1$	$-L_1$	$-W_1 r_1 L_1$
L (R.P)	W_L	r_L	$W_L r_L$	0	0
2	W_2	r_2	$W_2 r_2$	L_2	$W_2 r_2 L_2$
3	W_3	r_3	$W_3 r_3$	L_3	$W_3 r_3 L_3$
M	W_M	r_M	$W_M r_M$	L_M	$W_M r_M L_M$
4	W_4	r_4	$W_4 r_4$	L_4	$W_4 r_4 L_4$

3- representation (تمثيل) of Couple vectors, as Follow.

Vector Couple of W_1 is C_1 which is $\perp$ on W_1 From o to the paper. by same way draw with magnitude C_1, C_2, C_3, C_4 --- $-W_1 r_1 L_1, W_2 r_2 L_2$, --- as in fig (c).

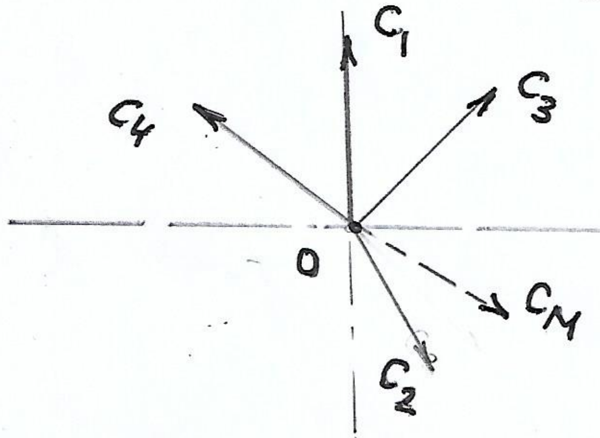


Fig (c) Vector Couple

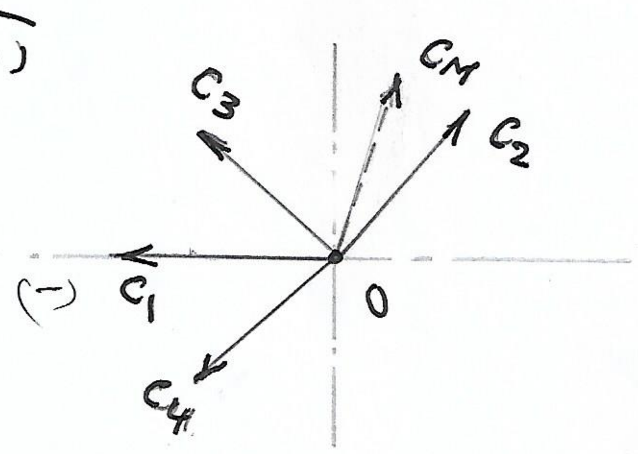


Fig (d) vector couple direction

by turning the vector Couple 90 Counter clock wise became the vector Couple and the Centrifugal force in the Same direction as in Fig (d). unless the vector C_1 in opposite direction as in table (2).

4- Drawing of Couple polygon, From column (6) table (2).

by taking pol and suitable Scale, ~~and~~ draw all the Couple vectors with Same magnitude, direction and Sense fig(e).

assume $1\ N.m^2 = 1$ mm Scale.

where:

$C_M = do = W_M r_M L_M$

∴ from Couple polygon we Can determine the magnitude and dire-ction of mass W_M as Follow:

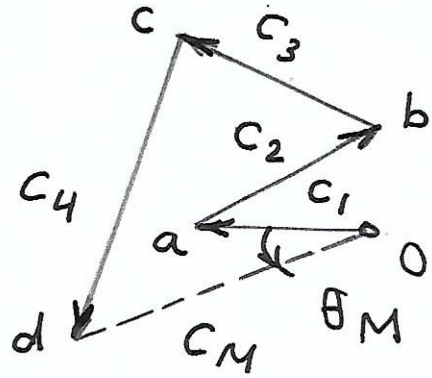


Fig (e) Couple polygon

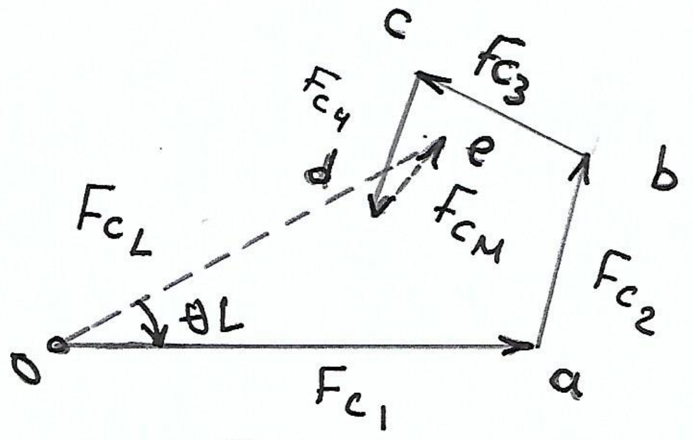
$$W_M = \frac{do\ (N.m^2)}{r_M L_M\ (m^2)} \quad \text{---} ① \quad \text{where } \boxed{C_L = 0}$$

$\theta_M \Rightarrow$ angle of inclination

From o draw Line // and = to do and inclined with C_1 at angle θ_M

5) Drawing of Centrifugal force polygon: From column (4) table (2) as in fig (F).

By taking pol and suitable scale draw all Fc with Same magnitude and direction.



Fig(f) Force polygon.

where vector $eo = F_{c_L} = W_L r_L$

$\therefore$ From C-force polygon we can determine the magnitude and dire-ction of mass M_L as follow:

- mag-d $W_L = \dfrac{eo\ (N.m)\ \text{from scale}}{r_L\ (m)}$ --- (2)

- direction θ_L = measure between F_{cL} and Line F_{c_1} in the same direction.