Machine Dynamics

Chapter 3b：Classic Dynamics

Department of
Mechanical Engineering
National Taiwan University

Tseng-Ti Fu
Room 503-5
Email: ttfu@ntu.edu.tw

工程評估實驗室

Graphical dynamics

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Graphical dynamics

- The approach

1) May also called the force component method.

2) Use the concept of “center of ” to simplify the analysis.

3) reduce a system into a system. (in a planar system)

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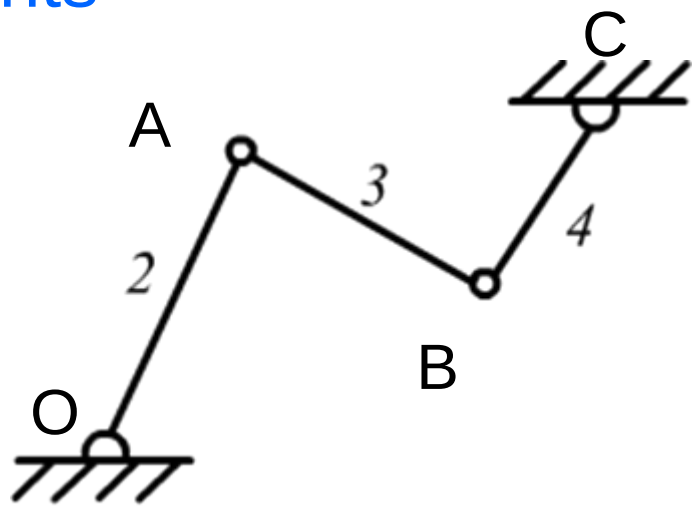
Graphical dynamics (cont.)

- The method:

a) Case 1: if there are 3 points

For a 4-bar linkage, separate link 3 from the linkage into a free body diagram



Known quantities：

1) acceleration of link joints

2) angular acceleration of link 3

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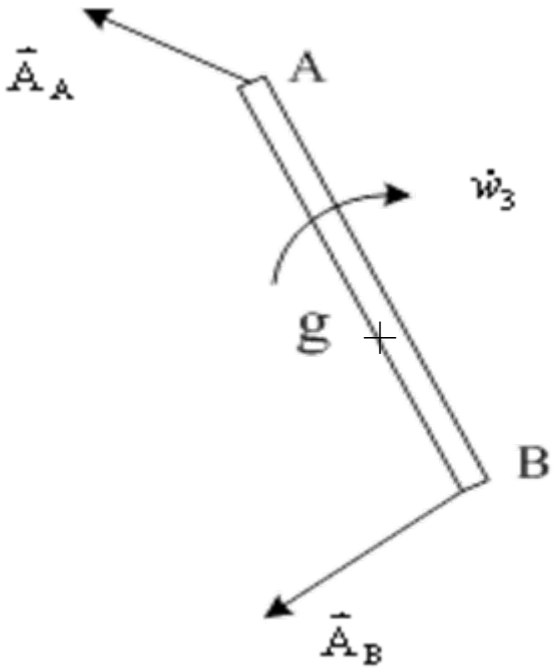
Graphical dynamics (cont.)

The acceleration of center of gravity by the relative acceleration method:

$$\vec{A}_g = \vec{A}_A + \vec{A}_{g/A} = \vec{A}_A +$$



component component

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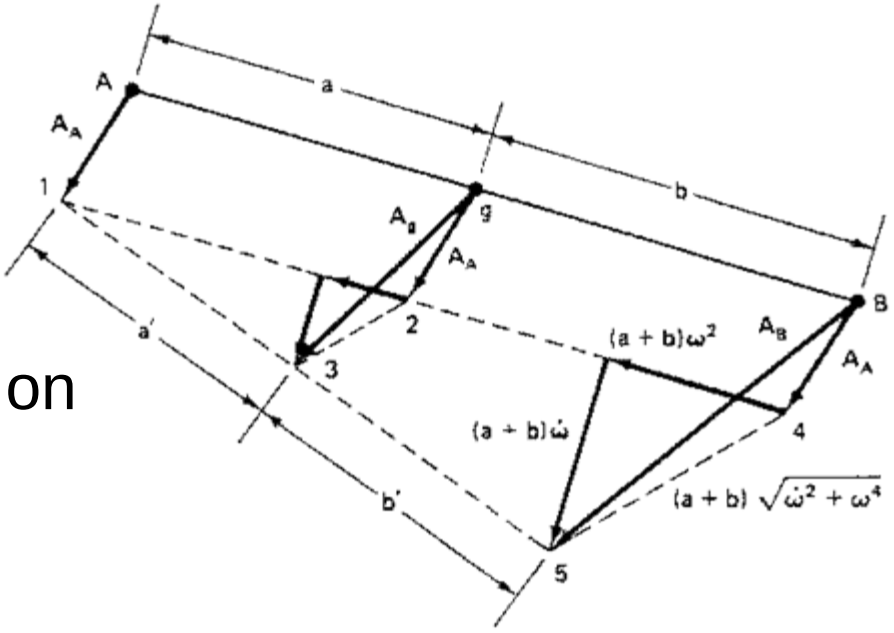
Graphical dynamics (cont.)

For the point B:

$$\vec{A}_B = \vec{A}_A +$$

the acceleration of g & B can be constructed as:

$$\frac{2'3}{4'5} = \frac{\overline{Ag}}{\overline{AB}} =$$



Always true for points on line AB

→ the rule

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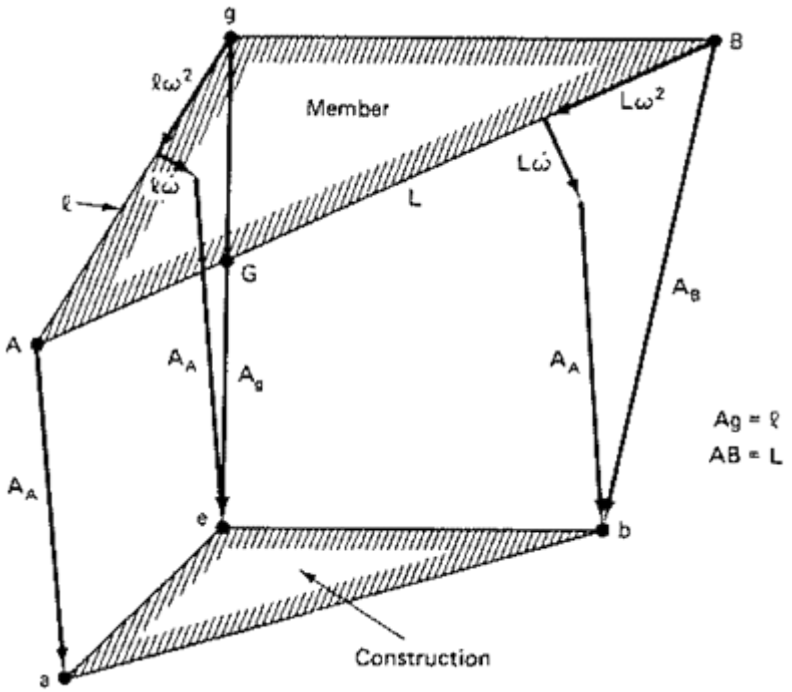
Graphical dynamics (cont.)

b) Case 2: if 3 points are

Construct a
with a base
from the line joining two
end points of and ,
the line joining the other
peak point of the
triangle with the point g
give its acceleration
( ).



(The proportional construction
rule still applies, see the proof in p.107)

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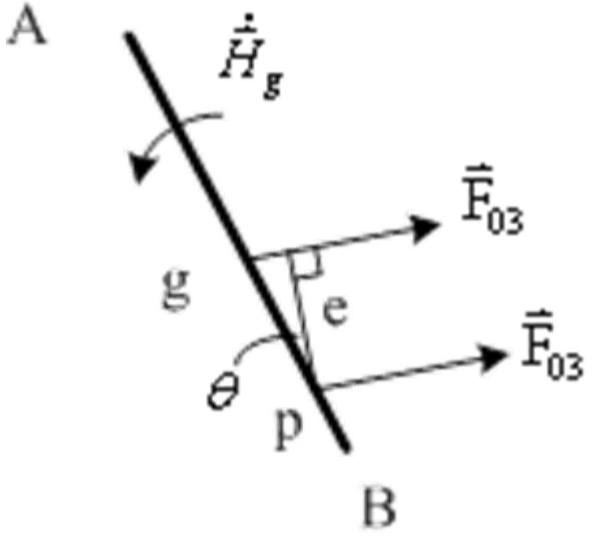
Graphical dynamics (cont.)

c) inertial force analysis

Two d'Alembert's inertial terms:

By the concept of center of percussion:



"e" is measured to the force.

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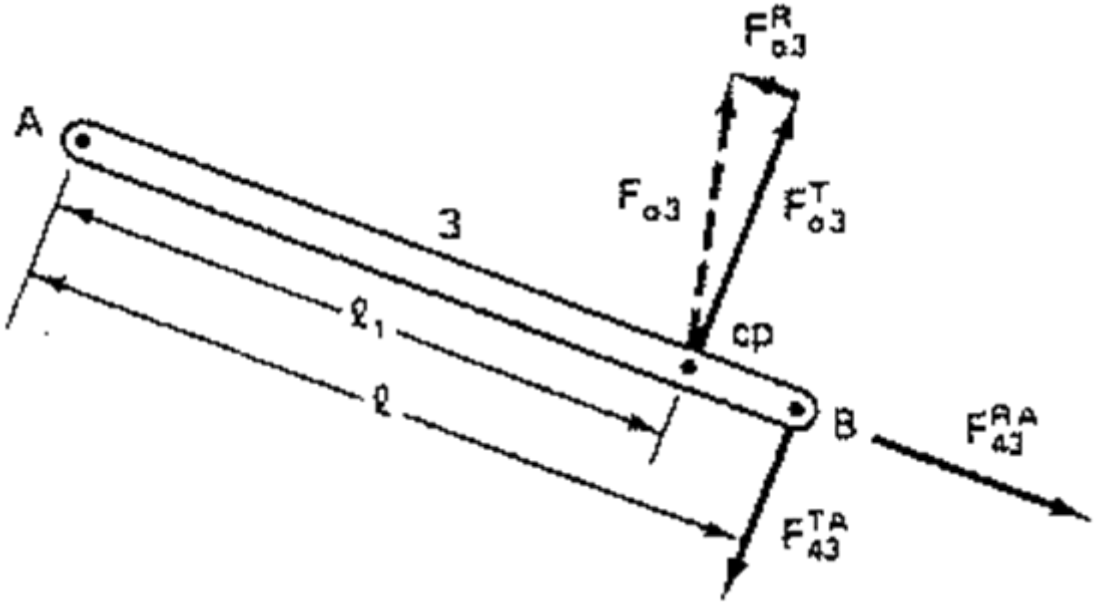
Graphical dynamics (cont.)

d) Dynamic force analysis

1) Divide the inertia force at "p" & the link force at "B" into their components, respectively.



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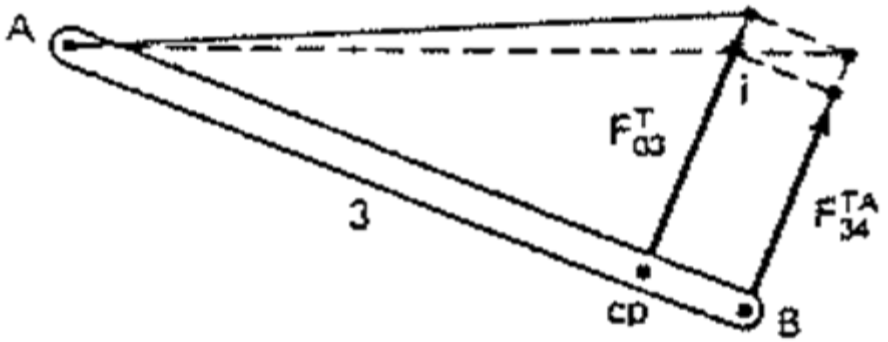
Graphical dynamics (cont.)

2) Take moments about A

$$\begin{cases} l_1 = \overline{AP} \\ l = \overline{AB} \end{cases}$$



Solve the equations by the graphical method

→ Using

→ The analytical method is also feasible.

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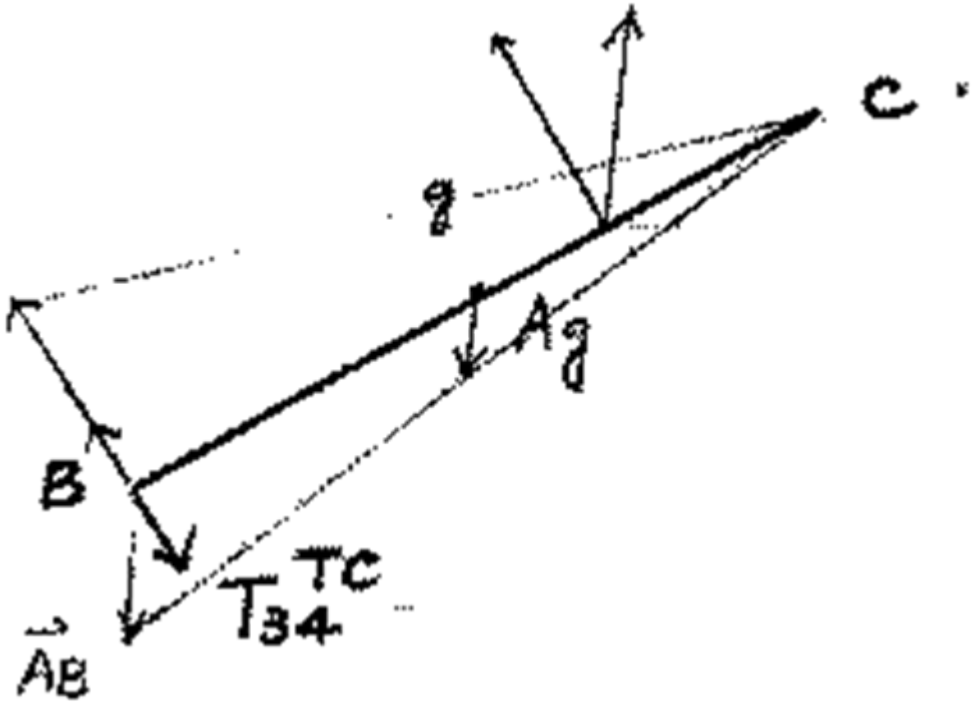
Graphical dynamics (cont.)

3) Apply the same procedure on the adjacent link4 & derive by taking moments about point



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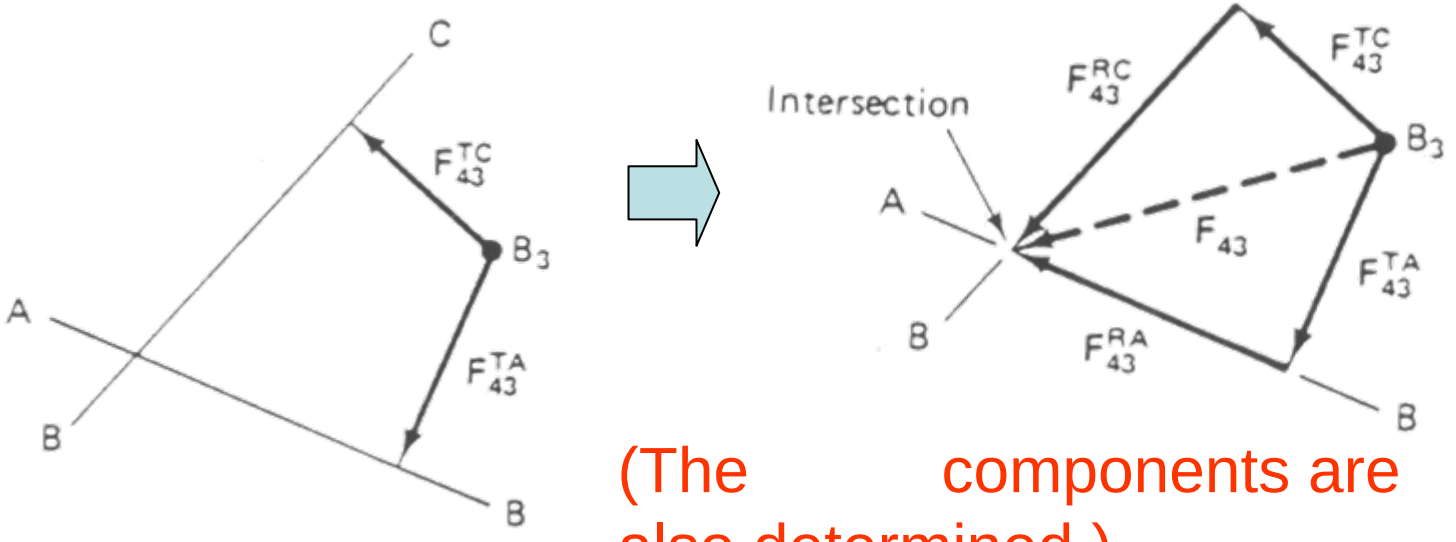
Graphical dynamics (cont.)

4) For the point B on link 3, knowing with known for , two lines can be constructed and their intersection point determines the force both in direction and magnitude.



(The components are also determined.)

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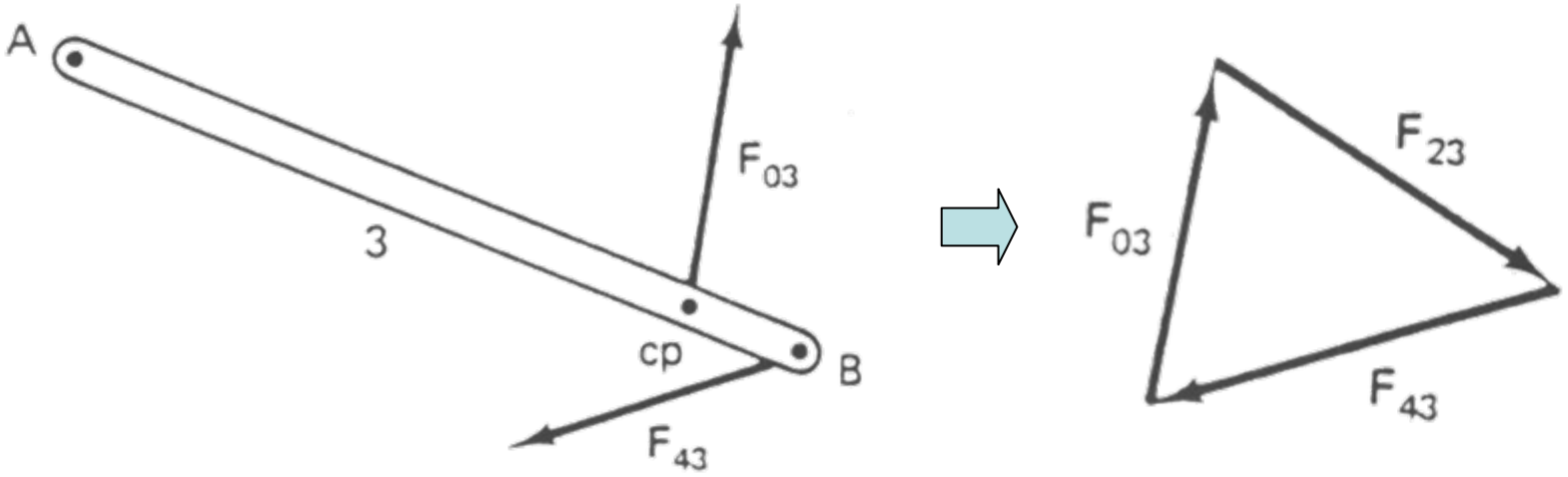
Graphical dynamics (cont.)

5) The force equation

To derive the force on the other end by known forces.

$\vec{F}_{23}$ can then be obtained by a close triangle.



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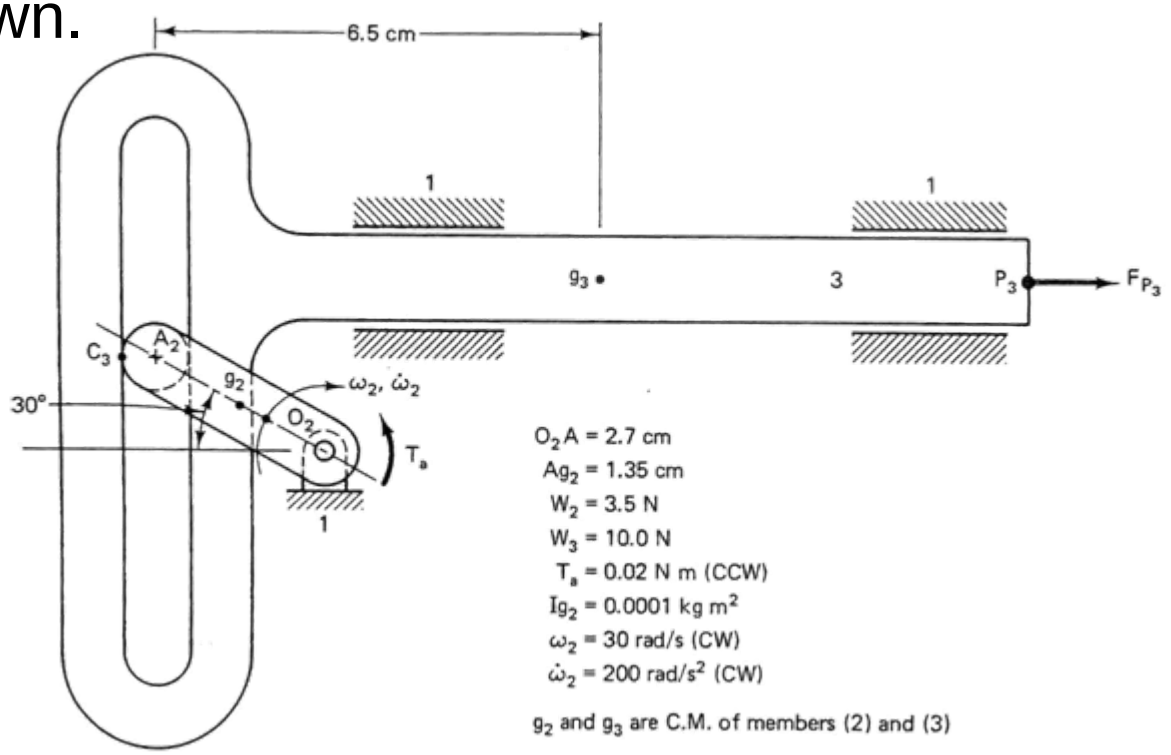
Example

- The Scotch Yoke (p.85)
  a) Known conditions

All link lengths, weights, T_a, I_{g2}, ω_2 and α_2 are assumed known.

Output:



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Example (cont.)

b) Dynamic power

Assume the graphical kinematic analysis has been completed.

→ Implies all , and are known.

→ & are known.

1) The power associated with T_a at O_2 is:

Power =

=

※ The negative sign means this power is from the mechanism at O_2.

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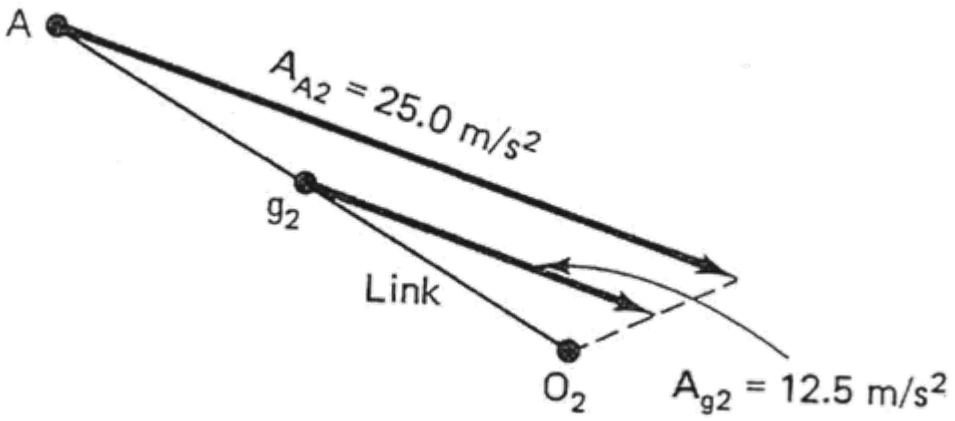
Example (cont.)

2) The acceleration of g_2 is obtained by the graphical method based on



3) D'Alembert's inertia terms and simplification

Inertia force F_{O2} = = 4.5 N

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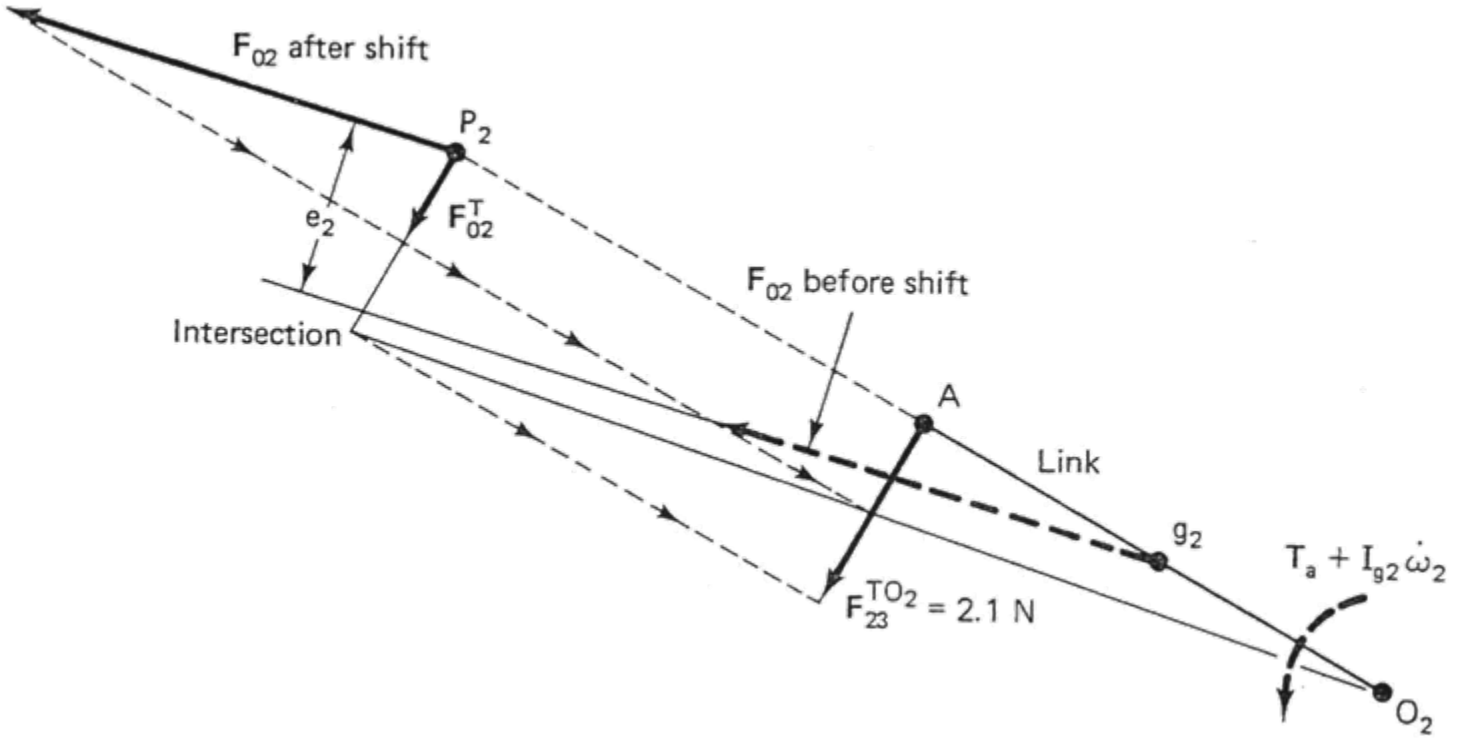
Example (cont.)



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Example (cont.)

※This locates p_2 but the point is not the center of percussion.

→ Think why?

※ Check the of the combined inertia couple.

→ Determine the location of

4) Apply triangle to get .

5) Force balance

Assume the contact between the crank and yoke is

→ at the contact point and to the slot.

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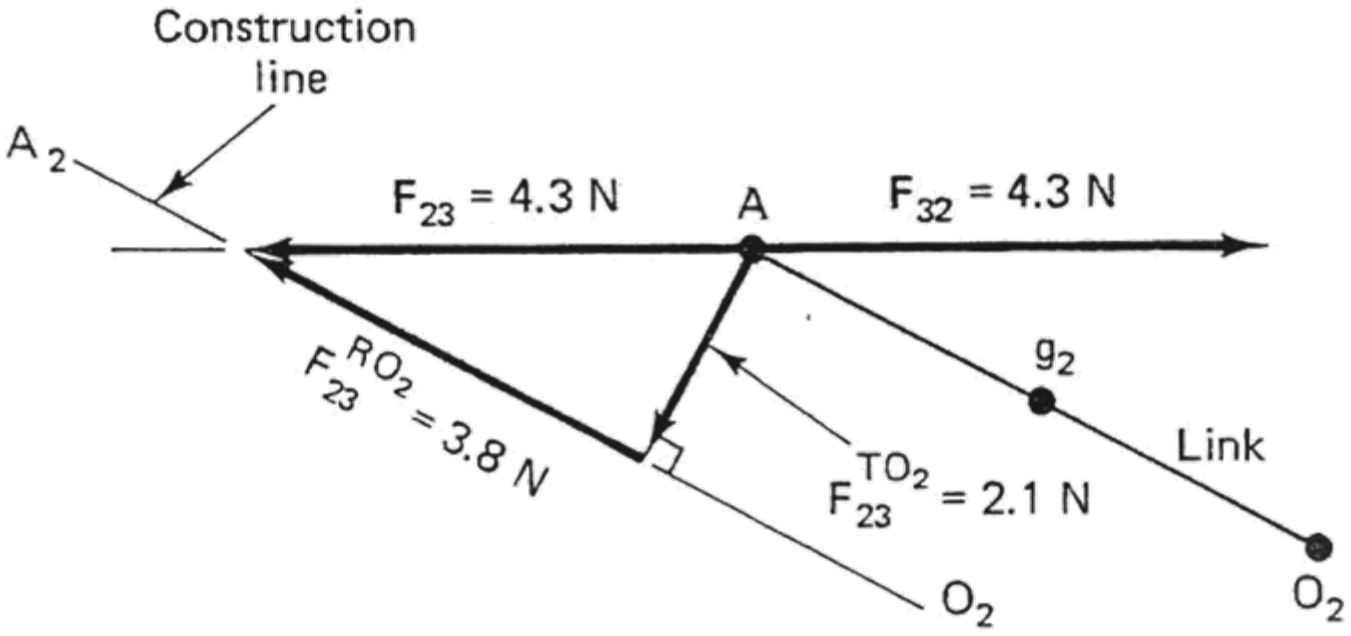
Example (cont.)



※With known line of action for
→ F_{23} can be obtained.

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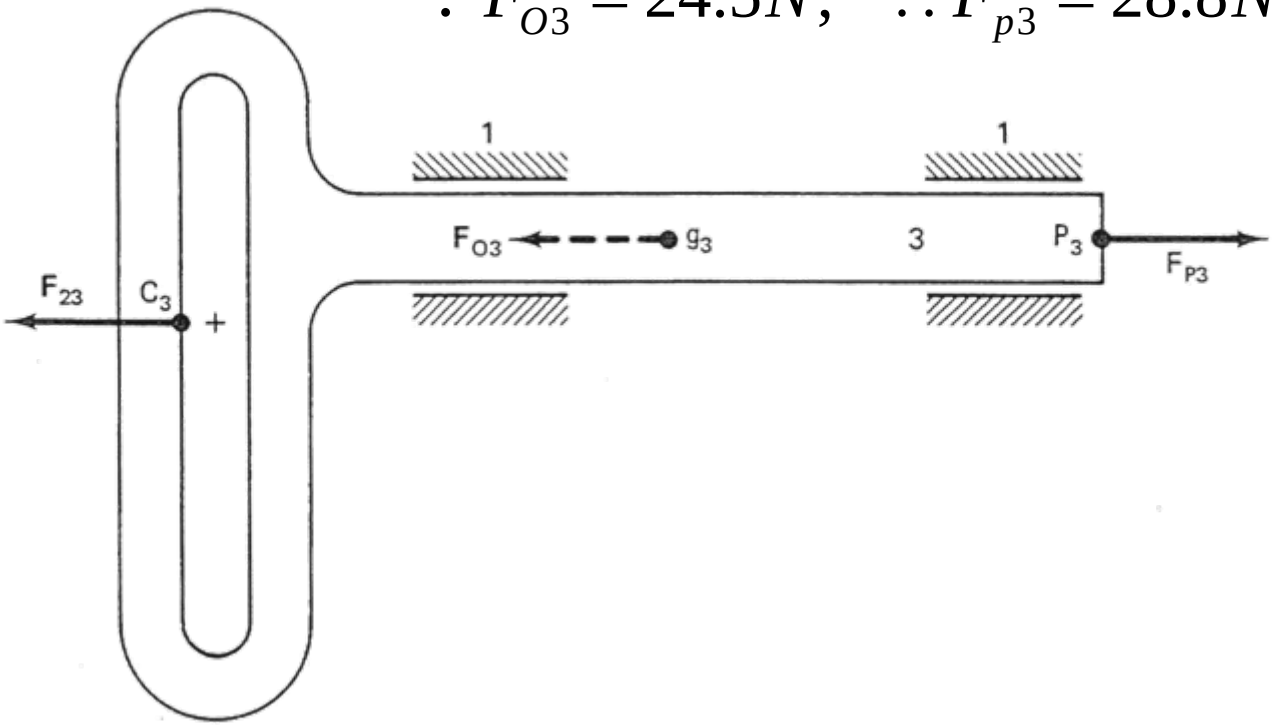
Example (cont.)

※ The force balance on link 3

$$\because \vec{F}_{O3} = 24.5N, \quad \therefore \vec{F}_{p3} = 28.8N$$



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Example (cont.)

Power input required at P_3

= = 11.5 Watt

※ The difference between this input power and the required output power

= 11.5 - 0.6 = 10.9 watt

which is required to cause a

This power is not lost from the system but of the parts and to the surroundings at

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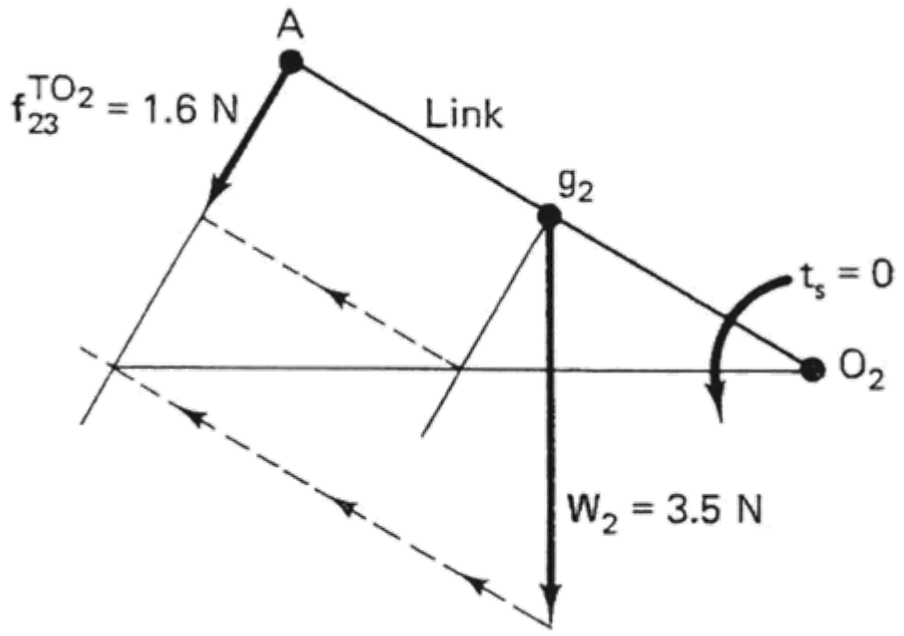
Example (cont.)

c) Static analysis

Substitute F_{O2} with the (3.5 N).

→ are the force and torque required to maintain the system to at the position.



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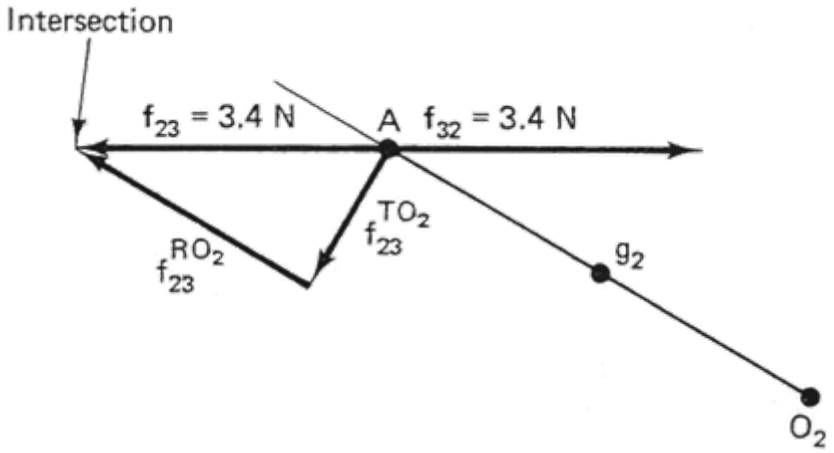
Example (cont.)

The system can be maintained by or a combination of

→ Assume

$f_{23}^{TO_2}$ is obtained by similar triangle technique on W_2.

→ Assume contact



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Example (cont.)

f_{23} is and obtained as 3.4N.

on the member 3 → $f_{p3} = f_{23} = 3.4$ N

The total force on p_3 is

The total power input is then:

Power =

= 12.9 Watt

※ The extra power introduced is (12.9 -11.5) = 1.4 watt which produces the

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Example (cont.)

d) Friction effect

The presence of friction at C_3
of force

Assume or friction, the coefficient of friction establishes the of total force relative to the surface.

Except the force to the slot, an upward component is present.

$\therefore$ perpendicular if
inclined if

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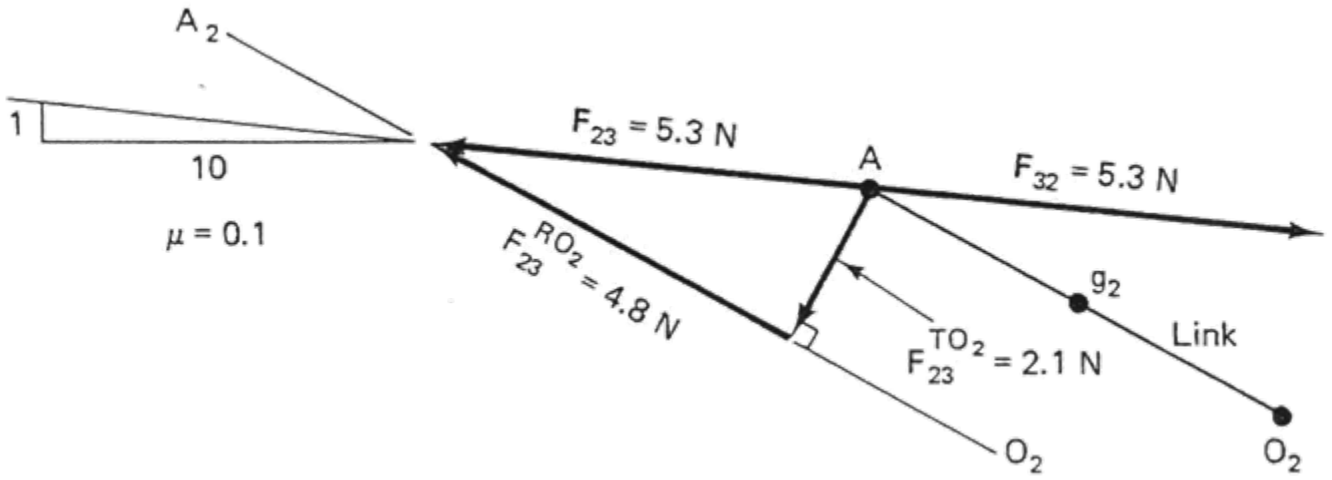
Example (cont.)



The line of action of changes to an direction.

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Example (cont.)

→ By the same procedure, the intersection point with another line of action from determines F_{23} which is than before.

The force F_{p3} increases to 29.8 N (=24.5+5.3)

The dynamic power will increase to:

Power =

= 11.9 Watt

※ This dynamic power takes account of the effect with an amount of:
(11.9 -11.5) = 0.4 watt
which is by the of the system.

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Example (cont.)

e) Summary

Effect	F_{p3}	P_{input}	P_{output}
Dyn. effect	28.8N		Watt
Static effect	+ 3.4N		N/A
Friction effect	+ 1.0N		N/A

The total power = Watt

= Watt

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Example (cont.)

→ Design analysis:

Total power	Amount	Nature	Design approach
Power output			
Dynamic power			
Static power			
Friction consumption			

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Example (cont.)

→Questions:

(1) $\omega \uparrow \rightarrow Power \uparrow ?$

(2) $\alpha \uparrow \rightarrow Power \uparrow ?$

(3) How do they affect the total power?

→

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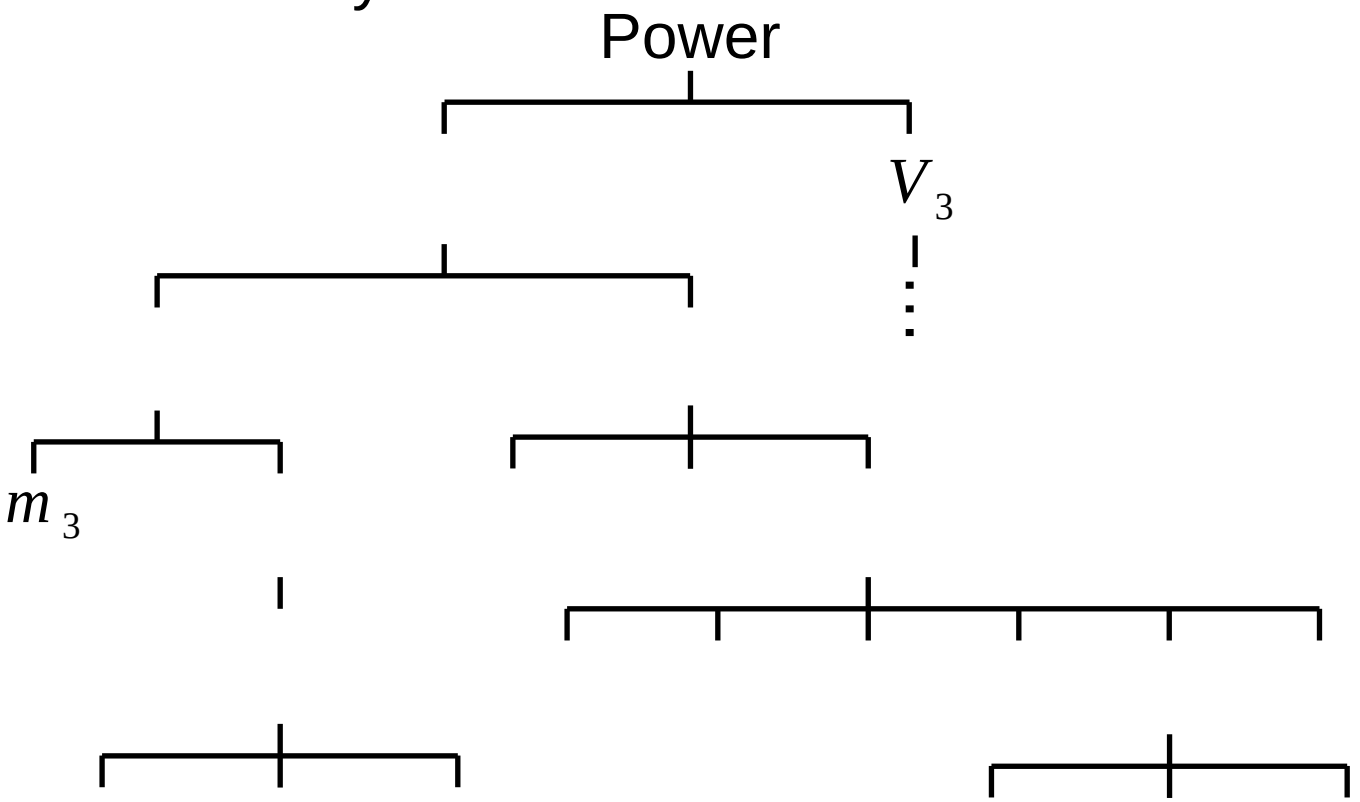
Example (cont.)

→ Factor analysis:



Output loading Geometry of part

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Elastodynamics

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Elastodynamic analysis

- Using results of dynamic analysis to derive the & at a cross section for the calculations of stress, stress and stress.
- A combination of dynamics and of .

  → for example:

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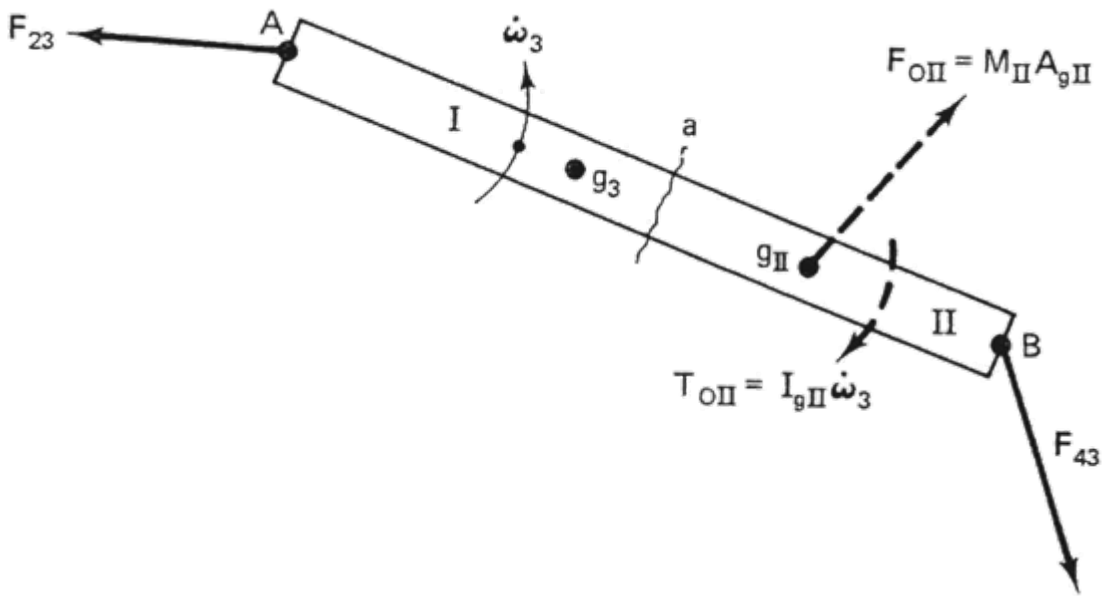
Elastodynamic analysis (cont.)

- The analysis

  1) cut the link AB at point ”a“.

  2) obtain A_{gII} by the rule.

→



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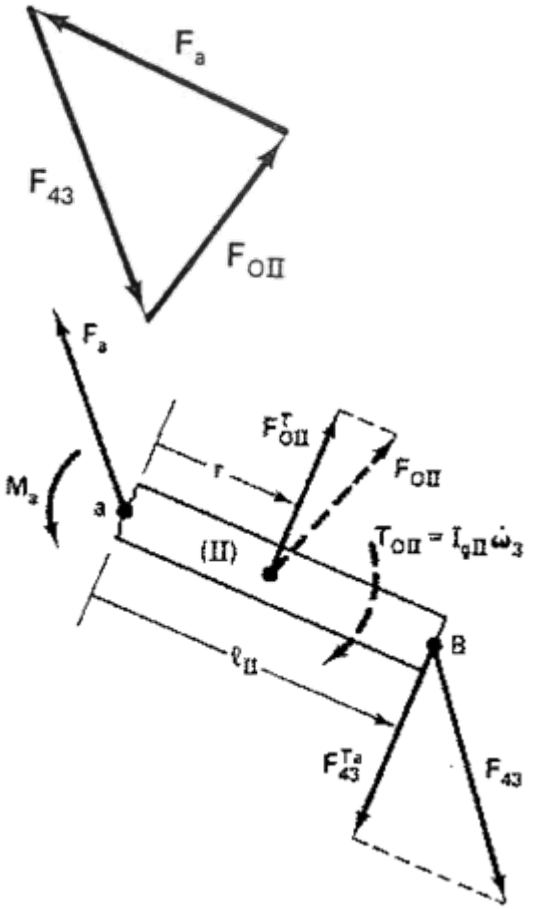
Elastodynamic analysis (cont.)

3) assume the force & moment at the cross section ”a“ are

$\vec{F}_a$ can be obtained by



$\vec{M}_a$ can be found by

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Elastodynamic analysis (cont.)

4) Shear stress from
   Axial stress from
   Bending stress from

   Z : modulus.

5) Stress →
   →

※ The and can therefore be evaluated.

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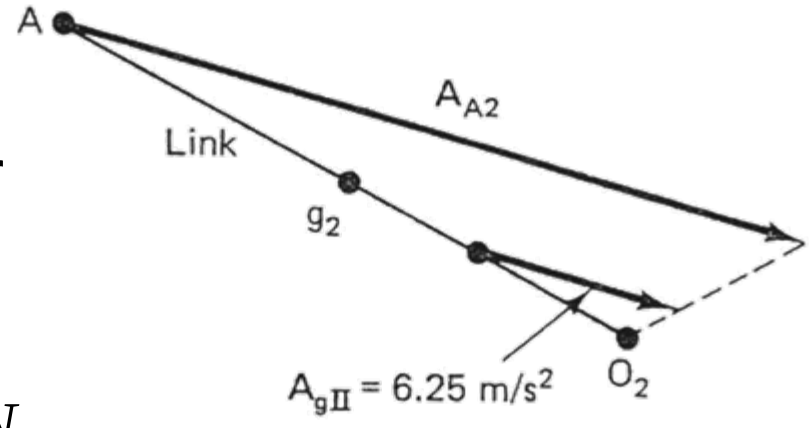
Example

- The Scotch Yoke

  a) Assume link 2 is a rectangular bar with uniform cross section. The stresses on the cross section in the middle of link 2 are desired.

  → derive the rule by triangular



$$F_{OII} = \left(\frac{3.5}{2}\right)\left(\frac{6.25}{9.8}\right) = 1.1N$$

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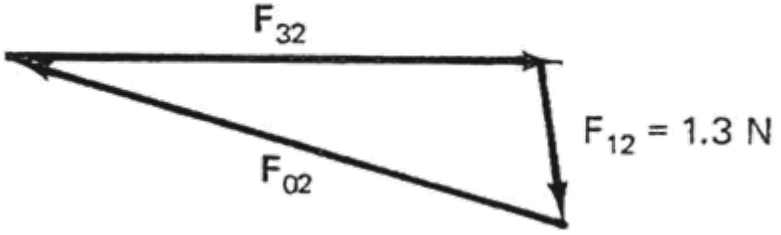
Example (cont.)

→ Obtain by proportion from and T_{OII} is obtained as:

$$T_{OII} = I_{gII}\dot{\omega}_2 = \qquad = 0.0025Nm \quad (\qquad)$$

→ From a force balance of the entire member:

get $F_{12} = 1.3N$



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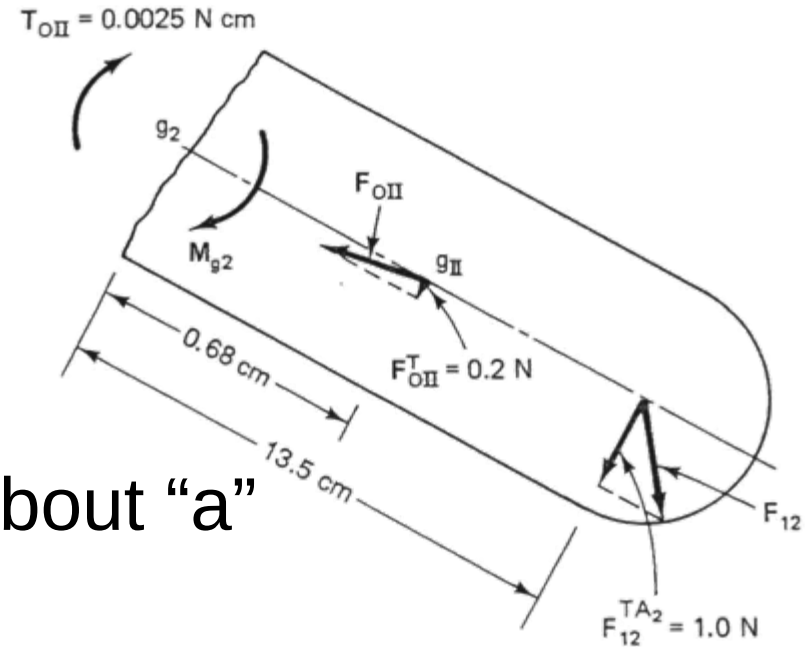
Example (cont.)

→ Knowing F_{12} and F_{OII}, can be obtained from a force balance on part II



→ shear stress

→ axial stress

→ Summing moments about "a"

→ bending stress

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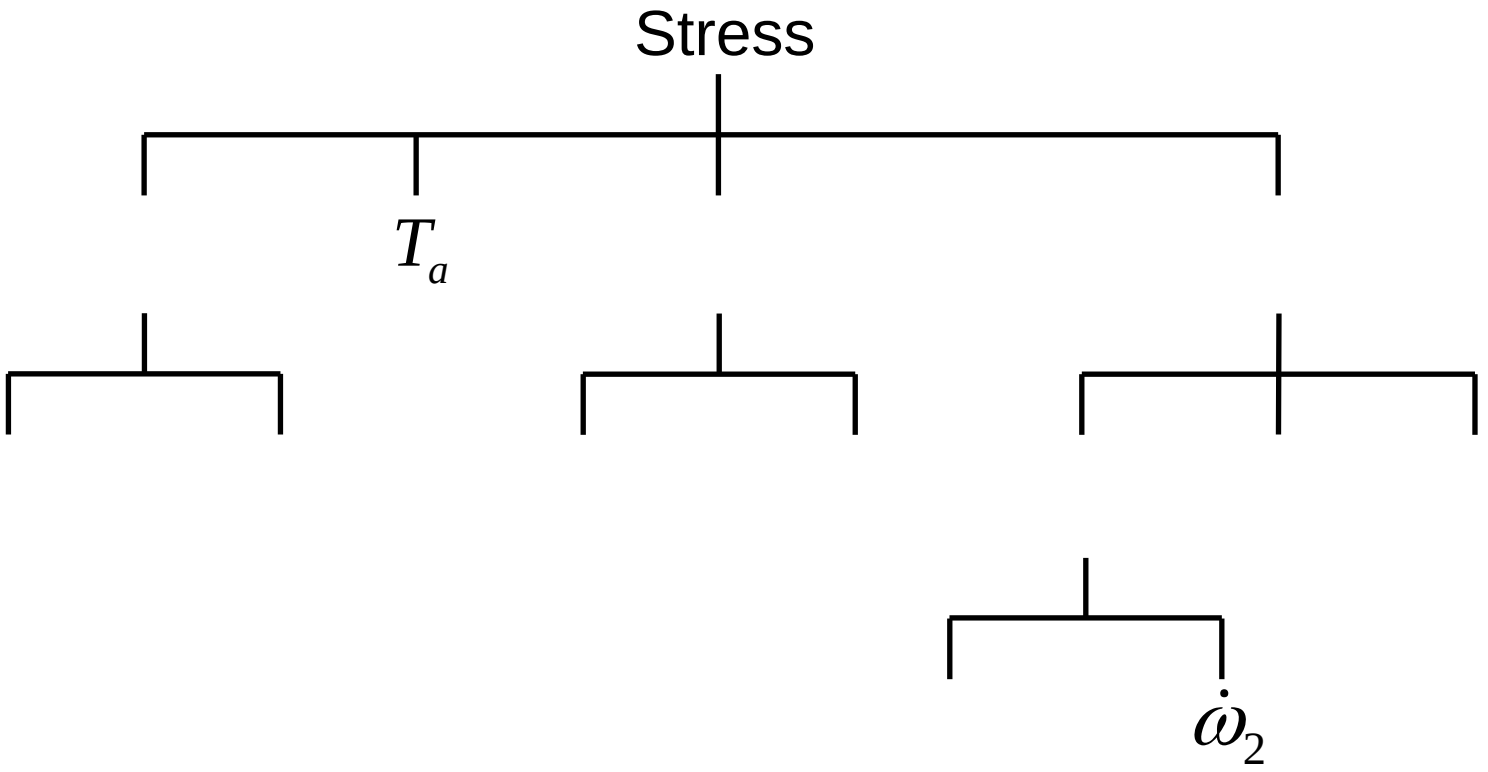
Example (cont.)

→ Factor analysis:



→ Question: will ω_2 affect this stress and how?

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END of Chap_3b

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