

THE STATIC PROBLEM OF THE BUCKET

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Abstract: The paper presents a theoretical study about the free-body diagrams of the bucket and the vertical boom of the back hoe. The bucket and its contents have a weight W . The weight of the members is neglect.

Keywords: bucket, free-body diagrams, forces, couple moments

1. INTRODUCTION

Machines are two types of structures which are often composed of pin – connected multiple force members, members that are subjected to more than two forces. Machines contain moving parts and are designed to transmit and alter the effect of forces. Provided a frame or machine is properly constrained and contains no more supports or members than are necessary to prevent collapse, the forces acting at the joints and supports can be determined by applying the equations of equilibrium to each member. Once the forces at the joints are obtained, it is possible to design the size of the members, connections and supports using the theory of mechanics of materials and an appropriated engineering design code.

In order to determine the forces acting at the joints and supports of the machine, the structure must be disassembled and the free-body diagrams of its parts must be drawn.

The following important points must be observed:

- Isolate each part by drawing its outlined shape. Then show all the forces and couple moments that act on the part. Label and identify each known and unknown force and couple moments with reference to an established x, y coordinate system. Also, must to indicate any dimensions used for taking moments.
- Identify all the force members in the structure and represent their free-body diagrams as having two equal but opposite collinear forces acting at their points of application
- Forces common to any two contacting members act with equal magnitudes but opposite sense on the respective members. If the two members are treated as a system of connected members, then these forces are internal and are not shown on the free body diagram of the system; if the free body diagram of each member is drawn, the forces are external and must be shown on each of the free body diagrams.

2. FREE BODY DIAGRAMS OF THE BUCKET

The bucket and the vertical boom of the back hoe are shown in figure 1.a. The idealized model of the assembly is shown in figure 1, b. Not shown are the required dimensions and angles that must be obtained, along with the location of the center of gravity G of the load.

By inspection, members AB , BC , BE and HI are all two force members since they are pin connected at their end points and no other forces act on them.

The free body diagrams of the bucket and the boom are shown in figure 1, c, after the separations of the members. Note that the pin C is subjected to only two forces, the force of links BC and the force of the boom.



Fig. 1. (a)

For equilibrium, these forces must be equal in magnitude but opposite in direction, figure 1, d. The pin at B is subjected to three forces, figure 1, e. The force F_{BE} is caused by the hydraulic cylinder and forces F_{BA} , F_{BC} are caused by the links. These three forces are related by the two equations of force equilibrium applied to the pin.

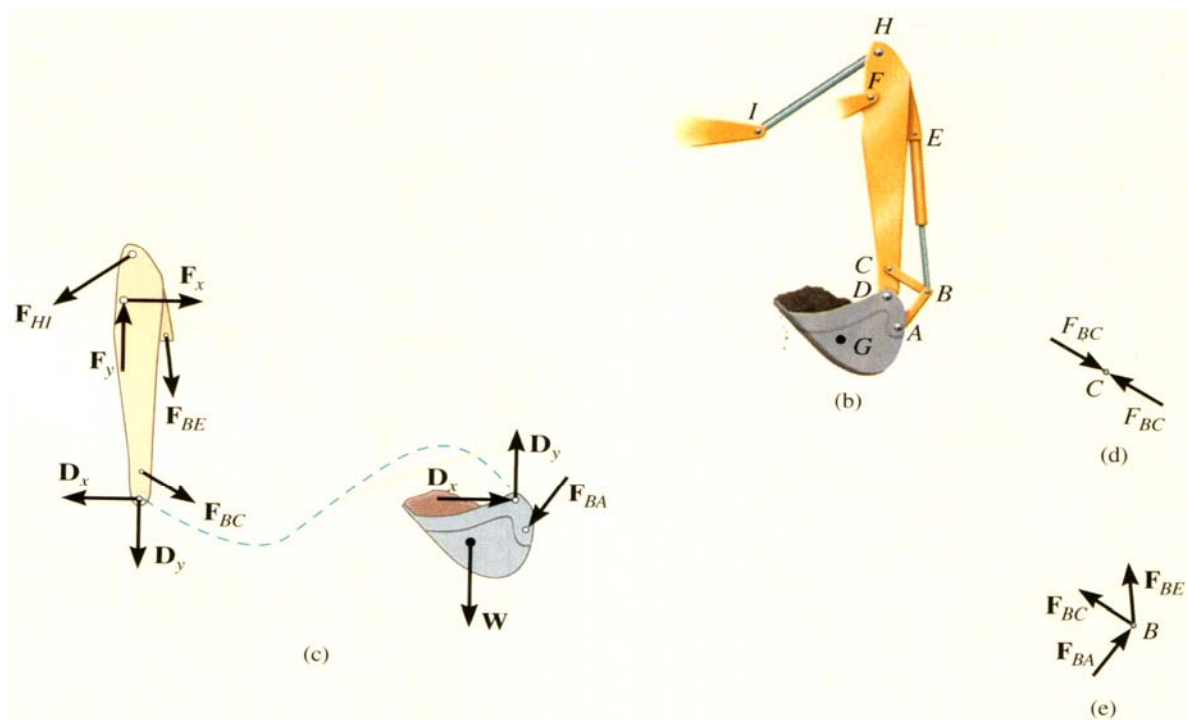


Fig. 1. b, c, d, e.

Provided the structure is properly supported and contains no more supports or members than are necessary to prevent the collapse, then the unknown forces at the supports and connections can be determined from the equations of the equilibrium. If the structure lies in the x - y plane, then for each free body diagram draw the loading must satisfy

$$\begin{cases} \sum_i F_x = 0 \\ \sum_i F_y = 0 \\ \sum_i M_0 = 0 \end{cases} \quad (1)$$

The selection of the free body diagrams used for the analysis is completely arbitrary. They may represent each of the members of the structure, a portion of the structure, or its entirety. For example, consider finding the six components of the pin reactions at A, B, C.

The frame is shown in figure 2, a. If the frame is dismembered, as it is in figure 2, b, these unknown can be determined by applying the three equations of equilibrium (1) to each of the two members.

The free body diagram of the entire frame can also be used for the part of the analysis, figure 2, c.

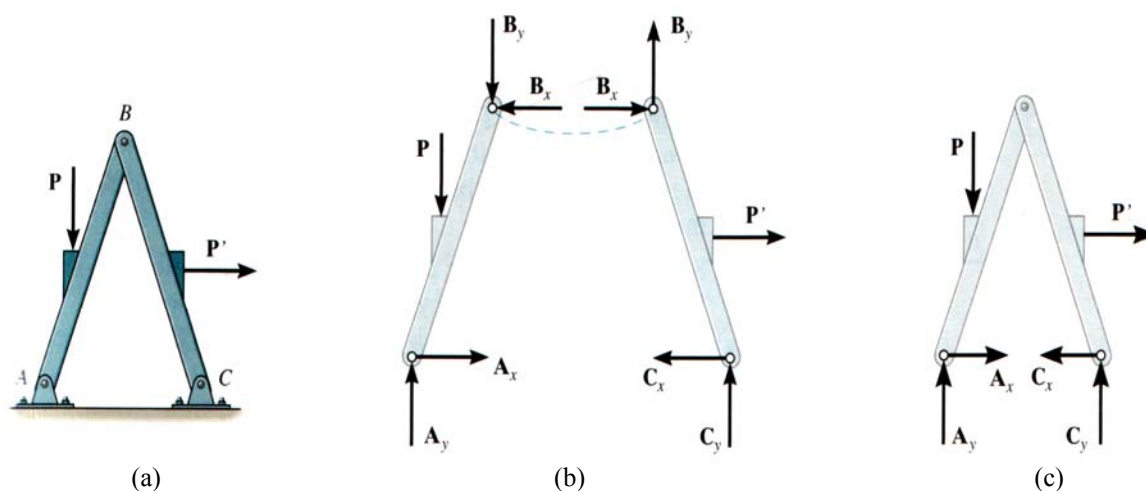


Fig. 2

$$\begin{cases} \sum_i F_x = 0 \\ \sum_i F_y = 0 \\ \sum_i M_0 = 0 \end{cases} \Rightarrow \begin{cases} A_x - B_x = 0 \\ A_y - P - B_y = 0 \\ -P \cdot \frac{l_{AB}}{2} \cos \alpha - B_y l_{AB} \cos \alpha + B_x l_{AB} \sin \alpha = 0 \end{cases} \quad (2)$$

where α is an angle between AB and the horizontal plane, A_x .

$$\begin{cases} \sum_i F_x = 0 \\ \sum_i F_y = 0 \\ \sum_i M_0 = 0 \end{cases} \Rightarrow \begin{cases} P' + B_x - C_x = 0 \\ B_y + C_y = 0 \\ -P' \frac{l_{BC}}{2} \sin \alpha - B_x l_{BC} \sin \alpha - B_y l_{BC} \cos \alpha = 0 \end{cases} \quad (3)$$

where l_{AB}, l_{BC} are the effective lengths.

$$\begin{cases} B_x l_{AB} \sin \alpha - B_y l_{AB} \cos \alpha = P \cdot \frac{l_{AB}}{2} \cos \alpha \\ -B_x l_{BC} \sin \alpha - B_y l_{BC} \cos \alpha = P' \cdot \frac{l_{BC}}{2} \sin \alpha \end{cases} \quad (3)$$

Generally, $l_{AB} = l_{BC}$ and result

$$-2B_y l_{AB} \cos \alpha = \frac{l_{AB}}{2} (P \cos \alpha + P' \sin \alpha) \Rightarrow B_y = -\frac{(P \cos \alpha + P' \sin \alpha)}{4 \cos \alpha} \quad (4)$$

After determined the force B_y is easy to determined the remained forces.

$$B_x = \frac{P \cos \alpha - P' \sin \alpha}{4 \sin \alpha} = A_x \quad (5)$$

$$A_y = P + B_y = \frac{3P \cos \alpha - P' \sin \alpha}{4 \cos \alpha} \quad (6)$$

Furthermore, the answer can be checked in part by applying the three equations of equilibrium to the remaining second member. In general, then this problem can be solved by writing at most six equilibrium equations using free body diagrams of the members and /or the combination of connected members. Any more than six equations written would not be unique from the original six and would only serve to check the results.

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