DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

KATHMANDU UNIVERSITY

ENGG 111: MINI-PROJECT

Department of Computer Science School of Science,

Kathmandu University

STATICS - Engineering Mechanics

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ABSTRACT:

Hydraulic crane is a of heavy-duty equipment, used for raising or transferring heavy loads. Cranes do play the most vital role in the manufacturing industries. This project explores different force components and mechanism acting on the crane. Here, we consider the crane to be in static equilibrium state so that we can apply the fundamental equilibrium equations to solve the force components. Different conditions are taken to solve desired unknown forces or inclination of the crane. The problems are solved, manually and also by making a c program. In both instances the solution to the condition found to be similar. In implication, when we take less inclination the radius of the crane increases due to which the load capacity of the crane decreases. And we take more inclination the radius of the crane decreases due to which the load capacity of the crane increases. This explains the physics behind the change in load capacity due to change in reaction force of the Hydraulic Cylinder and the radius of the boom.

INTRODUCTION

Source: https://pngwing.com

A hydraulic crane is a type of heavy-duty equipment used for lifting and hoisting. Unlike smaller cranes, which rely on electric or diesel-powered motors, hydraulic cranes include an internal hydraulic system that allows the crane to lift heavier loads. The purpose of hydraulic cranes is to stay stable whilst lifting heavy weights. Although cranes have been used throughout the history of construction engineering, hydraulic cranes use a more technical design.

It depends on three separate parts when lifting incredibly heavy loads: the hydraulic cylinder, the pulley and the lever. The latter is a horizontal beam that takes on the task of the fulcrum. When a heavy object is loaded, an amount of force is applied at the other end, and in the other direction.

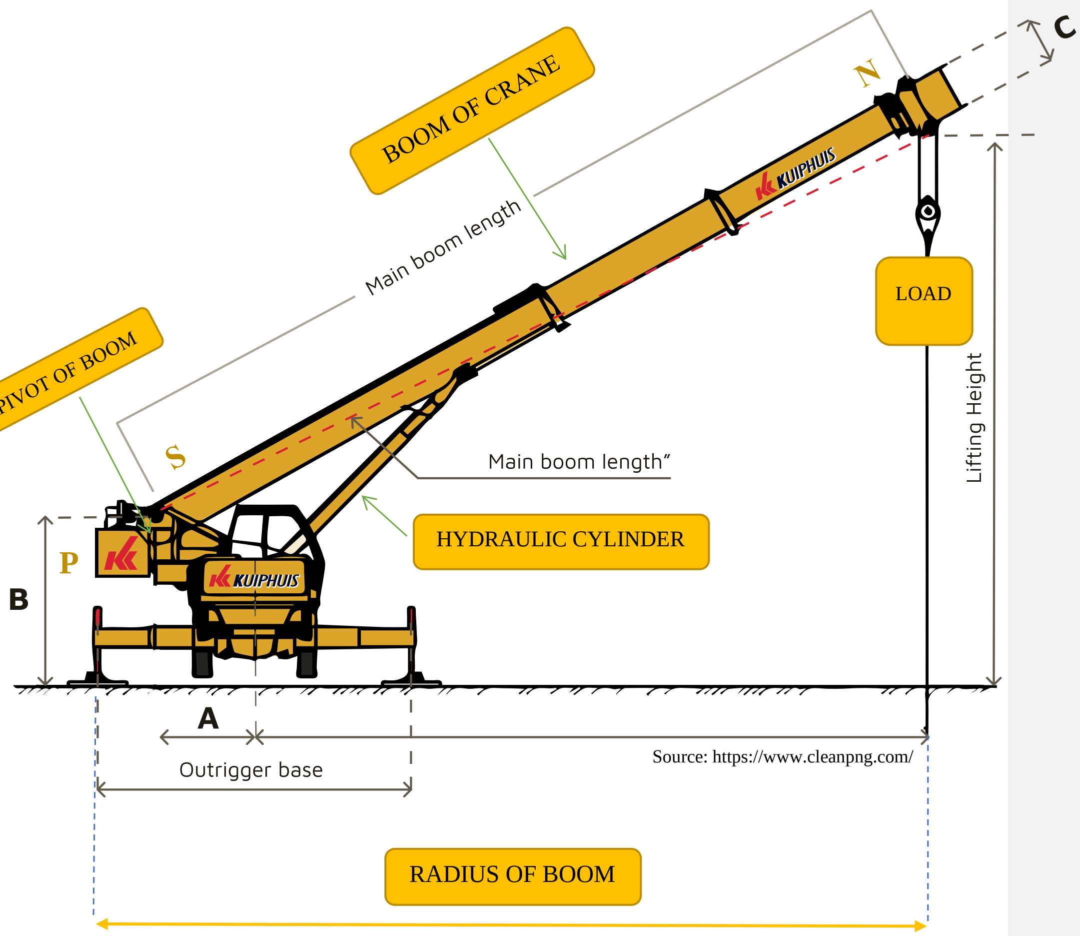
Known also as the jib, the pulley is a strut tilted to support a pulley block. The fixed block is wrapped with several layers of cable that is then pulled by machine or by hand. This can then create a force that is equal to the weight of the load. The hydraulic cylinder is then used to lift the load.

This paper studies a numerical problem of Statics from Engineering Mechanics which deals the application of hydraulic crane on lifting load and use of hydraulic cylinder in the process.

OBJECTIVES

- To determine the reaction force of hydraulic cylinder which withstands and maintains inclination of boom of the crane.
- To determine the reaction force of the crane body.
- To compare the different reaction force of hydraulic cylinder while changing the inclination of the Boom of the crane
- To make a c-program that lets the user to generate different conditions possible for the numerical.
- To compare the calculated solutions with the solutions that c program provides.

MAJOR TERMS TO KNOW:

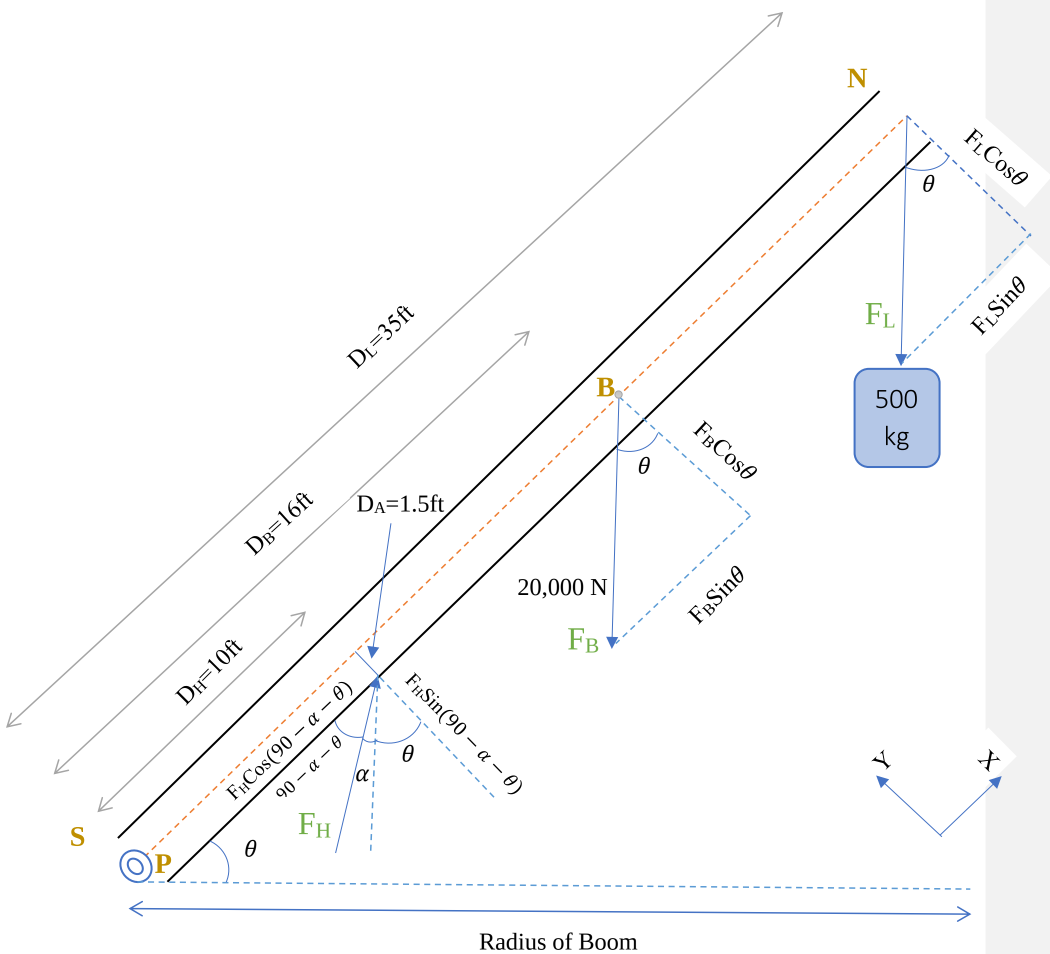


The point which I have marked with yellow boxes are important to know before solving the numerical.

NOTE: All the numerical that I will be doing, I will only take 4 digits after the decimal. So that there will be some difference in calculation doing it manually and doing it in c-program, I will Take all the decimal digits while performing from c program and will observe the difference in answer.

Reference case:

In the given figure of Boom (SN) of the crane. The reaction force of the hydraulic cylinder is unknown. Using the information given in the figure. Find the reaction of the hydraulic cylinder F_R. Assume α to be between (20-25) θ to be 45°.



Solution of three Cases

Case I:

For Case I, I will be taking the same case given in the Original Question.

Solution:

Given Data in the Figure,

Let us consider,

Point 'B 'to be Center of gravity of the Boom (SN) and,

Point 'P' to be the pivot Where the body of the crane give the reaction force.

θ be the Angle between horizontal and the Boom.

α be the angle between Fh and the axis perpendicular to the hozontal surface.

F_H be the reaction force of the hydraulic cylinder to the boom.

F_L be the force of the given load.

F_B be the Center of gravity of Boom.

Here,

$F_L Cos\theta$ *and* $F_L Sin\theta$ are the vertical and horizontal components of the load F_L.

$F_B Cos\theta$ *and* $F_B Sin\theta$ are the vertical and horizontal components of Center of gravity of Boom F_B.

$F_H Sin(90 - \alpha - \theta)$ and $F_H Cos(90 - \alpha - \theta)$ are the vertical and horizontal components of the force of Hydraulic Cylinder.

Also,

D_L=35ft=10.6688m, D_B=16ft=4.8768m, D_H=10ft= 3.0488m, D_A=1.5ft =0.4572m

F_L=mass*g=500kg*10=5,000N

$\theta = 45'$

$\alpha = 22'$

Here, the main thing to notice is that the component $F_L Cos\theta$ and $F_B Cos\theta$ accts downward resulting a clockwise torque which means it gives negative torque but the component $F_H Sin(90 - \alpha - \theta)$ and $F_H Cos(90 - \alpha - \theta)$ give anticlockwise torque which means it gives positive torque.

Also, one thing to know is that the $F_H Cos(90 - \alpha - \theta)$ component is producing torque only because it is 1.5ft apart from the axis of boom had it been at the axis of the beam it would not have produced any kind of torque

Now, since the system is in Equilibrium, we can use balance Equation.

So, the net Torque i.e., $\sum\tau=0$,

Then,

$$\sum\tau=0$$

Or, $-F_L Cos\theta * D_L - F_B Cos\theta * D_B + F_H Sin(90 - \alpha - \theta) * D_H + F_H Cos(90 - \alpha - \theta) * D_A = 0$

Or, -5000*cos (45') *10.6688-20,000*cos (45') *4.8768+F_HSin (90-22-45) *3.0488+ F_HCos (90-22-45) *0.4572=0

Or, -37719.9041-68968.3670+F_H 1.1912+ F_H 0.4208=0

Or,106688.2711= F_H1.6120

Or, F_H=106688.2711/1.6120

Or, F_H=66183.7910N

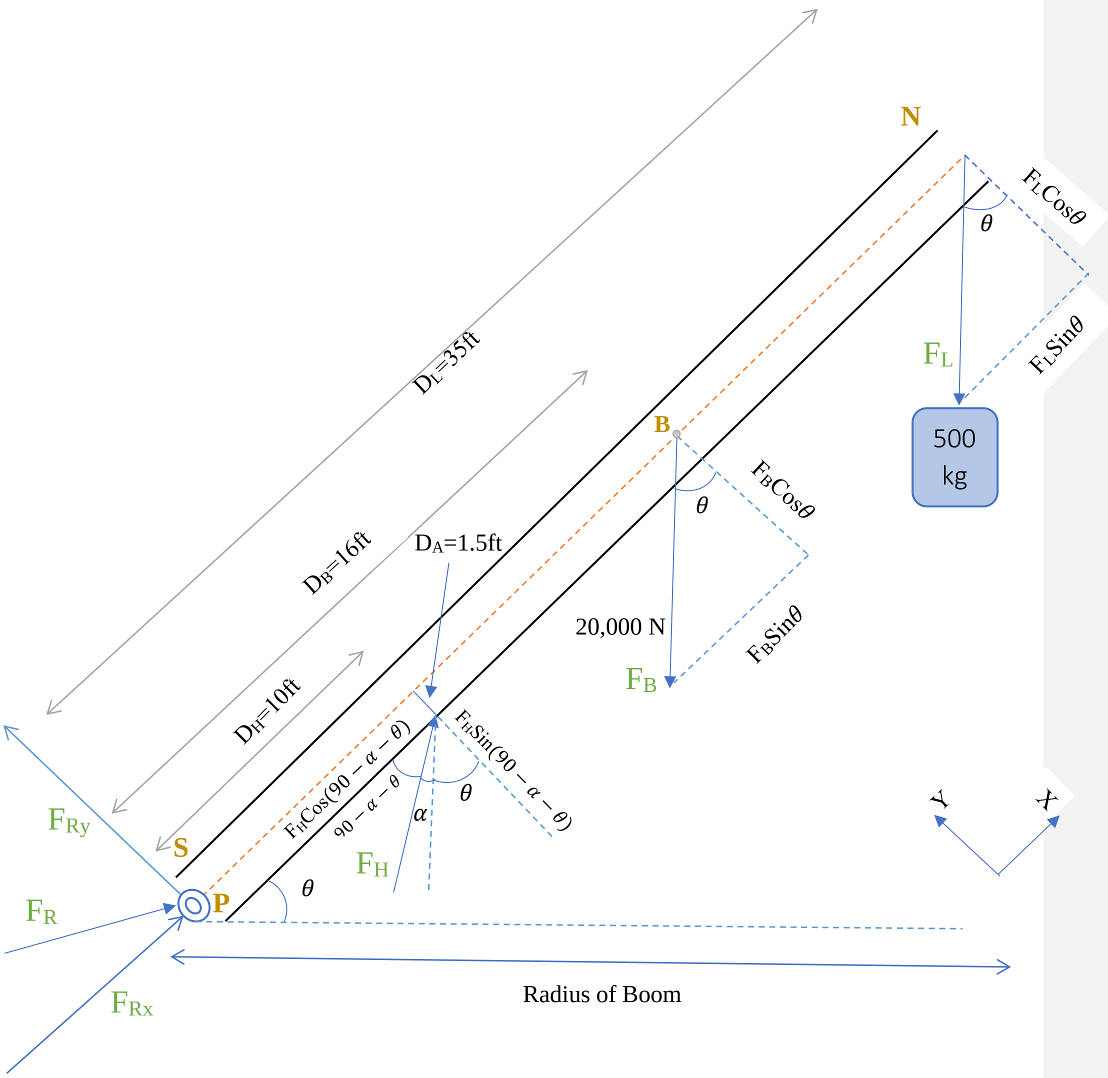
Therefore, The Reaction force on the Hydraulic is found to be 66183.7910N or 66.1837KN.

Now, we have come up with a formula though which we can directly find F_H .

$$F_H = \frac{DB * \mathrm{Fb}\cos(\theta) + DL * \mathrm{FL}\cos(\theta)}{DA * \mathrm{Cos}(90-\alpha-\theta) + \mathrm{DH} * \mathrm{Sin}(90-\alpha-\theta)}$$

Case II:

Here, we try to find reaction that the base of the crane gives to the pivot(P) of the Boom (SN) while it is at angle of, assume $\theta = 60', \alpha = 15'$.



Now, to find reaction force of hydraulic cylinder in this case we can directly apply our formula that we found in case I.

F_R be the reaction force of the crane's body to pivot joint.

We Know,

$F_{H=}\frac{DB*Fb\cos(\theta)+DL*FL\cos(\theta)}{DA*Cos(90-\alpha-\theta)+DH*Sin(90-\alpha-\theta)}$

$F_{H=}\frac{4.8768*20,000\cos(60)+10.6688*5000\cos(60)}{0.4572*Cos(90-15-60)+3.0488*Sin(90-15-60)}$

$F_{H=}\frac{48768+26672}{0.4416+0.7890}$

$F_{H=}\frac{75440}{1.2306}$

$F_{H=}$61303.4292N

Therefore, the reaction force given by the Hydraulic cylinder in this case is $61303.4292N$ or $61.3034KN$.

Now let's see the forces that are acting in x-components. Also let's take F_{Rx} to be positive and later on we can see whether the direction that we have assumed is right or wrong.

So,

$\sum x=0$

Or, F_{Rx}+ F_HCos$(90-\alpha-\theta)$- FbSin(θ)- FL Sin(θ)=0

Or, F_{Rx}+61303.4292*Cos (15)-20,000Sin (60)-5000*Sin (60) =0

Or, F_{Rx}+59214.5655-17320.5080-4340.1270=0

Or, F_{Rx}=-37553.9305N

Therefore, the x-component of the reaction force of the crane body to the Boom is -37553.9305N.

This shows that the direction that we have taken is wrong and we need to point the F_{Rx} towards negative x-axis while assuming to get the positive value. But it doesn't cause any change in the magnitude of F_{Rx}.

Now let's see the forces that are acting in y-components. Also let's take F_{Ry} to be positive and later on we can see whether the direction that we have assumed is right or wrong.

So,

$$\sum y=0$$

Or, F_{Ry}+ F_HSin$(90-\alpha-\theta)$- FbCos(θ)-FL Cos(θ)=0

Or, F_{Ry}=20,000* $Cos(60)$+5000*Cos (60) - 61303.4292 ∗Sin (15)

Or, F_{Ry}=10000+2500+15866.49501

Or, F_{Ry}=-3366.4950N

Therefore, the y-component of the reaction force of the crane body to the Boom is -3366.4950N or -3.3664KN.

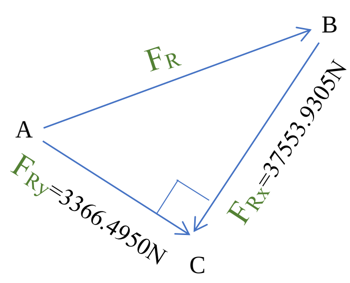
This shows that the direction that we have taken is wrong and we need to point the F_{Ry} towards negative y-axis while assuming to get the positive value. But it doesn't cause any change in the magnitude of F_{Ry}.

Now by using Pythagoras's theorem,

$$F_R=\sqrt{(F_{Rx})2+(F_{Ry})2}$$

$$F_R=\sqrt{(37553.9305)2+(3366.4950N)2}$$

$$F_R=37704.5250N$$



Therefore, the reaction force that the body of the crane give to the pivot of Boom is 37704.5250N or 37.7045KN

CASE III:

Here, we find how reaction force of hydraulic cylinder changes while the crane lifting the same Load changes the inclination from angle 70’ to angle15’.

Solution:

Given,

Load to lift is F_L= 5,500N.

Here, F_B=22,500N

First Condition: $\theta = 15' ,\alpha = 60'$

Now, we can use the equilibrium condition formula to find F_H,

$$F_{H}=\frac{\mathrm{DB}*\mathrm{Fb}\cos(\theta)+\mathrm{DL}*\mathrm{FL}\cos(\theta)}{\mathrm{DA}*\mathrm{Cos}(90-\alpha-\theta)+\mathrm{DH}*\mathrm{Sin}(90-\alpha-\theta)}$$

$$F_{H}=\frac{4.8768*22{,}500\cos(15)+10.6688*5500\cos(15)}{0.4572*\mathrm{Cos}(90-60-15)+3.0488*\mathrm{Sin}(90-60-15)}$$

$$F_{H}=\frac{105989.1091+56678.9820}{0.4416+0.7890}$$

$$F_{H}=\frac{162668.0911}{1.2306}$$

F_H=132185.9996N

Second Condition: $\theta = 70' ,\alpha = 5'$

Now, while the crane is at angle 75’ the F_H becomes,

$$F_{H}=\frac{DB*\mathrm{Fb}\cos(\theta)+DL*\mathrm{FL}\cos(\theta)}{DA*\mathrm{Cos}(90-\alpha-\theta)+\mathrm{DH}*\mathrm{Sin}(90-\alpha-\theta)}$$

$$F_{H}=\frac{4.8768*22{,}500\cos(75)+10.6688*5500\cos(75)}{0.4572*\mathrm{Cos}(90-5-75)+3.0488*\mathrm{Sin}(90-5-75)}$$

$$F_{H}=\frac{28399.6961+15187.0874}{0.4502+0.5294}$$

F_H=44494.4707N

So,

Difference of Force in two conditions is,

F= F_H at angle 15'- F_H at angle 75'

F= 132185.9996-44494.4707

F=87691.5289N.

What did I find taking these two conditions?

Condition I:

While the boom of the crane is at angle 15' the radius of the crane is more, also at 15' the reaction force to the hydraulic cylinder is very larger that is to say if we increase more load the force on hydraulics increases and at some point, it can't handle it and the hydraulic cylinder failure can be seen for that crane can't lift heavy loads at this inclination.

So, when we take less inclination the radius of the crane increases due to which the load capacity of the crane decreases.

Condition II:

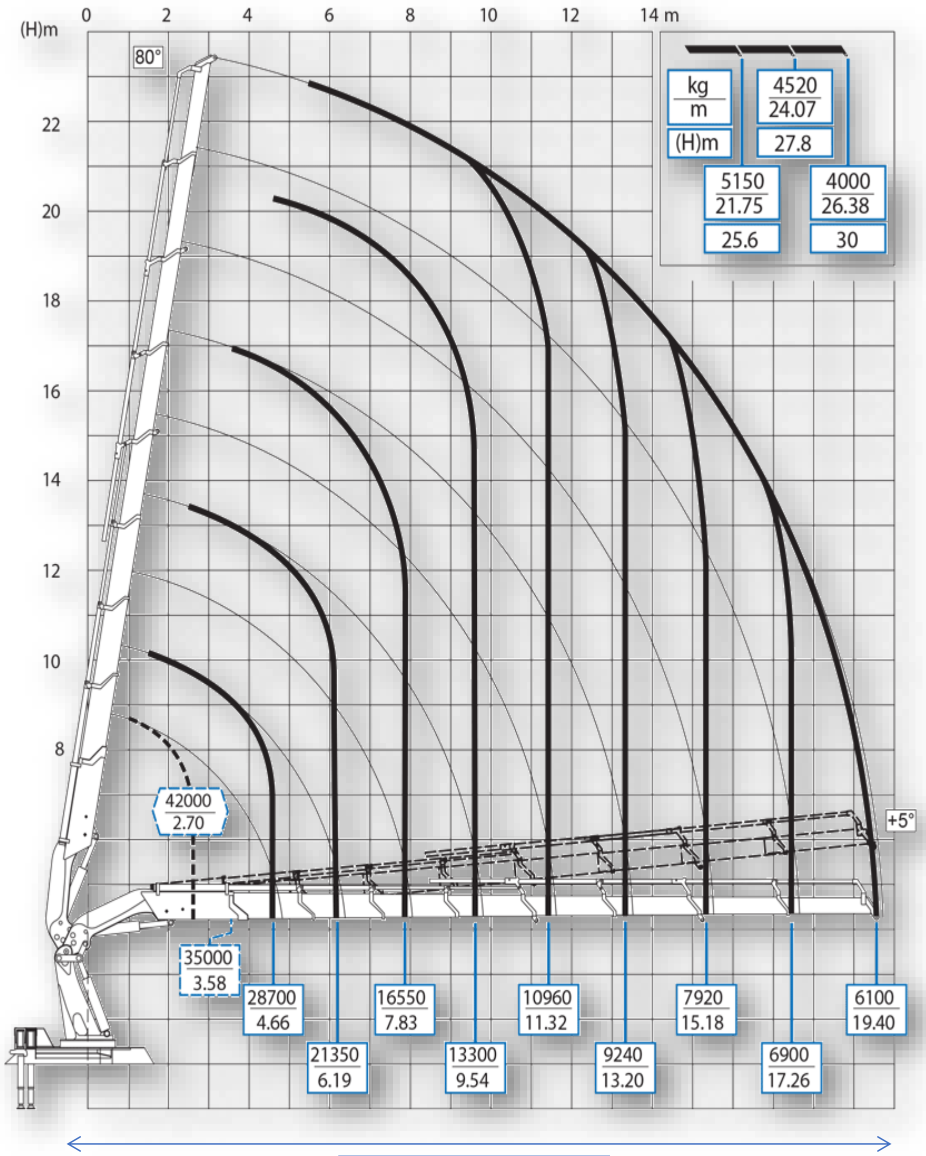
While the boom of the crane is at angle 70' the radius of the crane is less in comparison to while it was in 15' inclination, and also at 70' the reaction force to the hydraulic cylinder is comparatively less which says that we can lift heavy load at this angle without having failure in the hydraulic system of the crane.

Here what we can conclude is that when we take more inclination the radius of the crane decreases due to which the load capacity of the crane increases.

This is exactly seen in the load chart of the crane which proves that we are going through a right approach.

Also, Load Chart is shown in next page though which we can see the change in load capacity of the crane while the inclination of the crane changes.

LOAD CHART



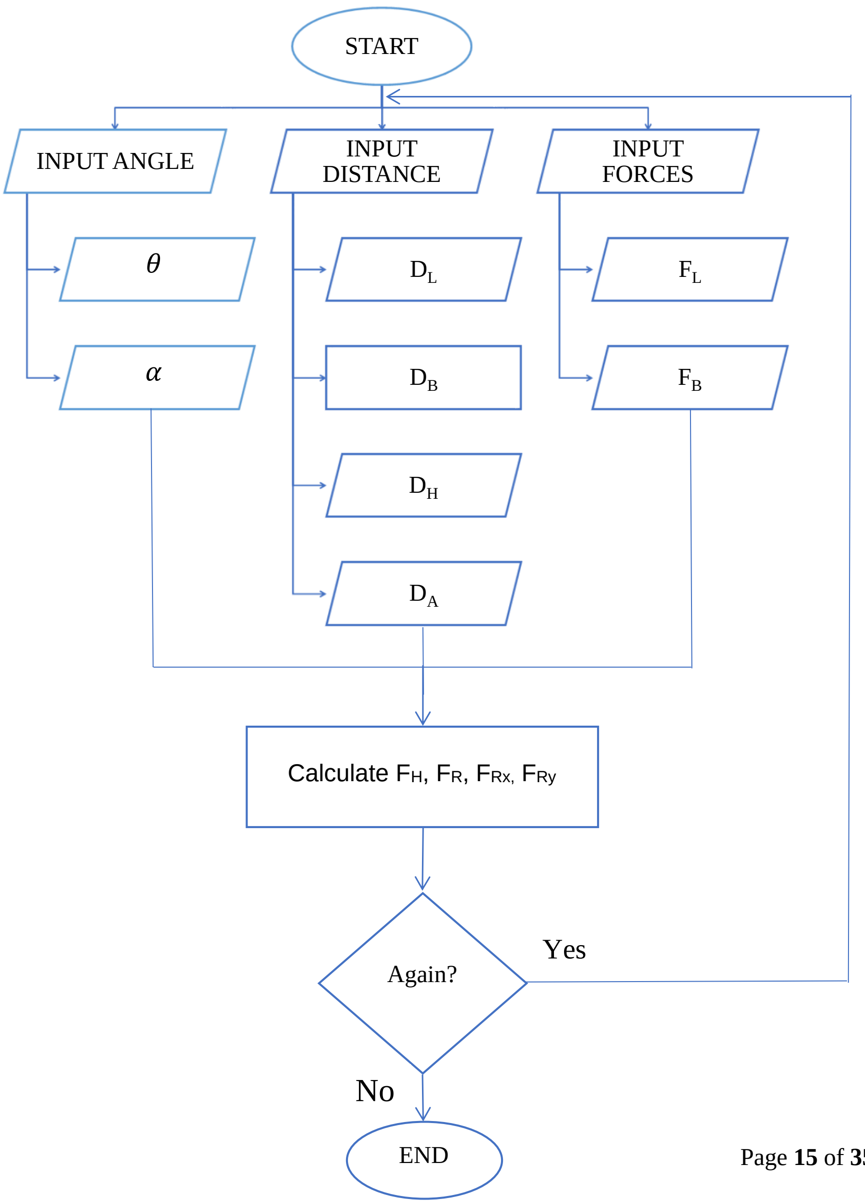
RADIUS OF BOOM

Source: https://giuffre.com/

Thus, when inclination increases the radius of Boom decreases, resulting the increase in Load Capacity.

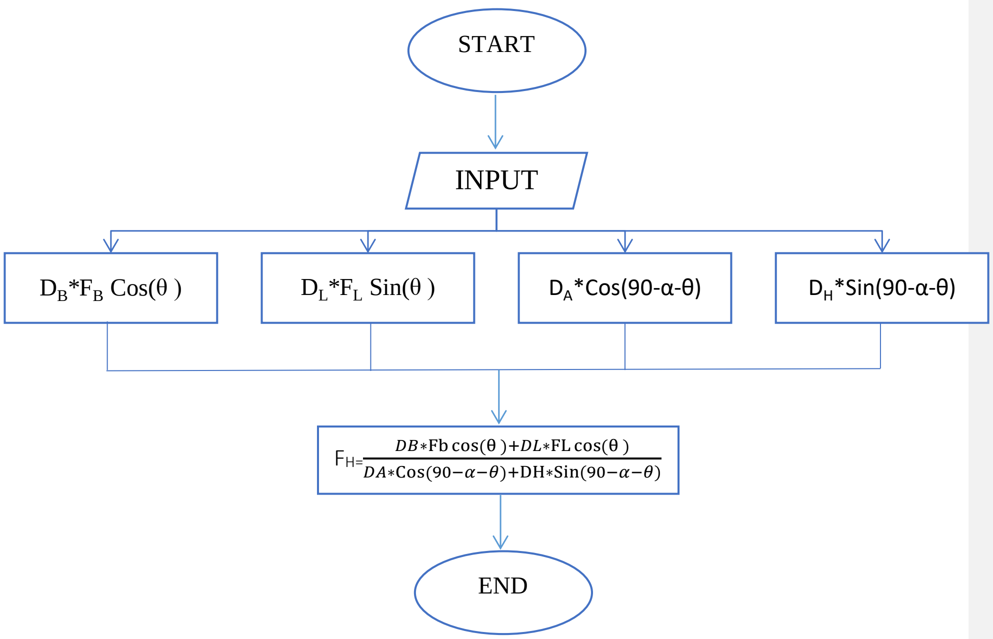
FLOWCHART AND ALGORITHM:

Note*: I have included 1main flowchart with 3 separate flowchart and algorithm for 3 different cases which will be programmed and complied in a single file in my final C-program file.*



CASE I:

This is the reference case where the reaction force of the hydraulic cylinder is found.



ALGORITHM:

Step 1: Start.

Step 2: Enter Angles, Forces and Distance.

*Step 3: Calculate D_B*F_B Cos (θ), DL*F_L Sin (θ), DA*Cos(90-α-θ), DH*Sin(90-α-θ).*

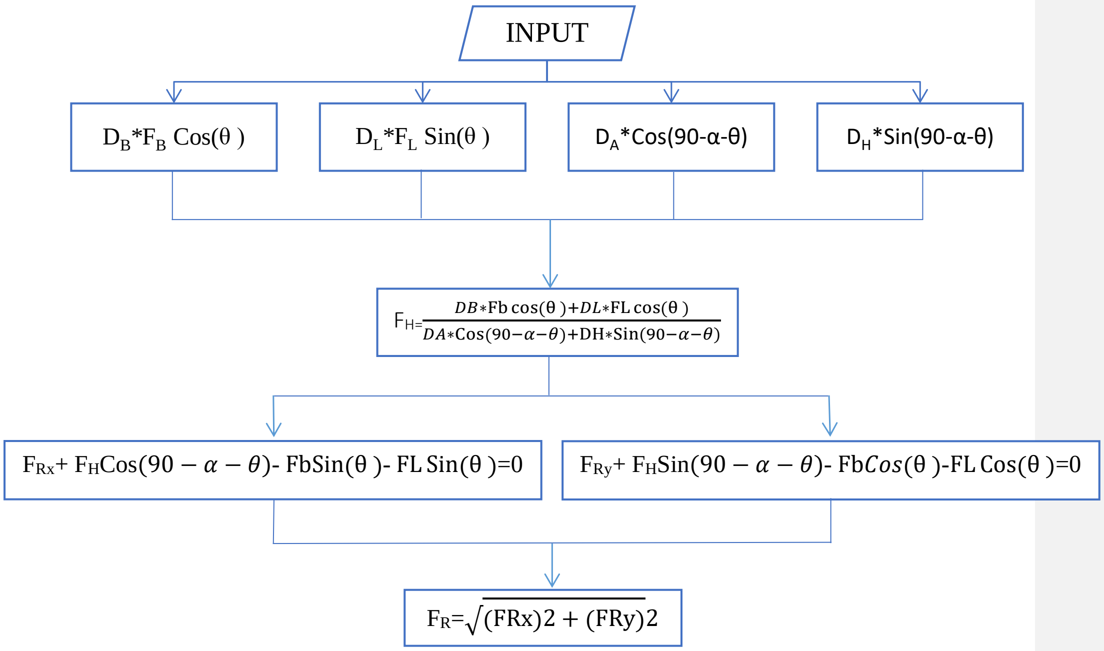
Step 4: Calculate $F_{H}=\frac{DB*Fb\cos(\theta\ )+DL*FL\cos(\theta\ )}{DA*Cos(90-\alpha-\theta)+DH*Sin(90-\alpha-\theta)}$.

Step 5: Print F_H.

Step 6: Stop.

CASE II:

Here, in this case, we find the reaction force of the crane body to the pivot of the boom.



ALGORITHM:

Step 1: Start.

Step 2: Enter Angles, Forces and Distance.

*Step 3: Calculate D_B*F_B Cos (θ), DL*F_L Sin (θ), DA*Cos(90-α-θ), DH*Sin(90-α-θ).*

Step 4: Calculate $F_{H}=\frac{DB*Fb\cos(\theta)+DL*FL\cos(\theta)}{DA*Cos(90-\alpha-\theta)+DH*Sin(90-\alpha-\theta)}$.

Step 5: Calculate $F_{Rx}+F_H Cos(90-\alpha-\theta)$- $FbSin(\theta)$- $FL\,Sin(\theta)$=0.

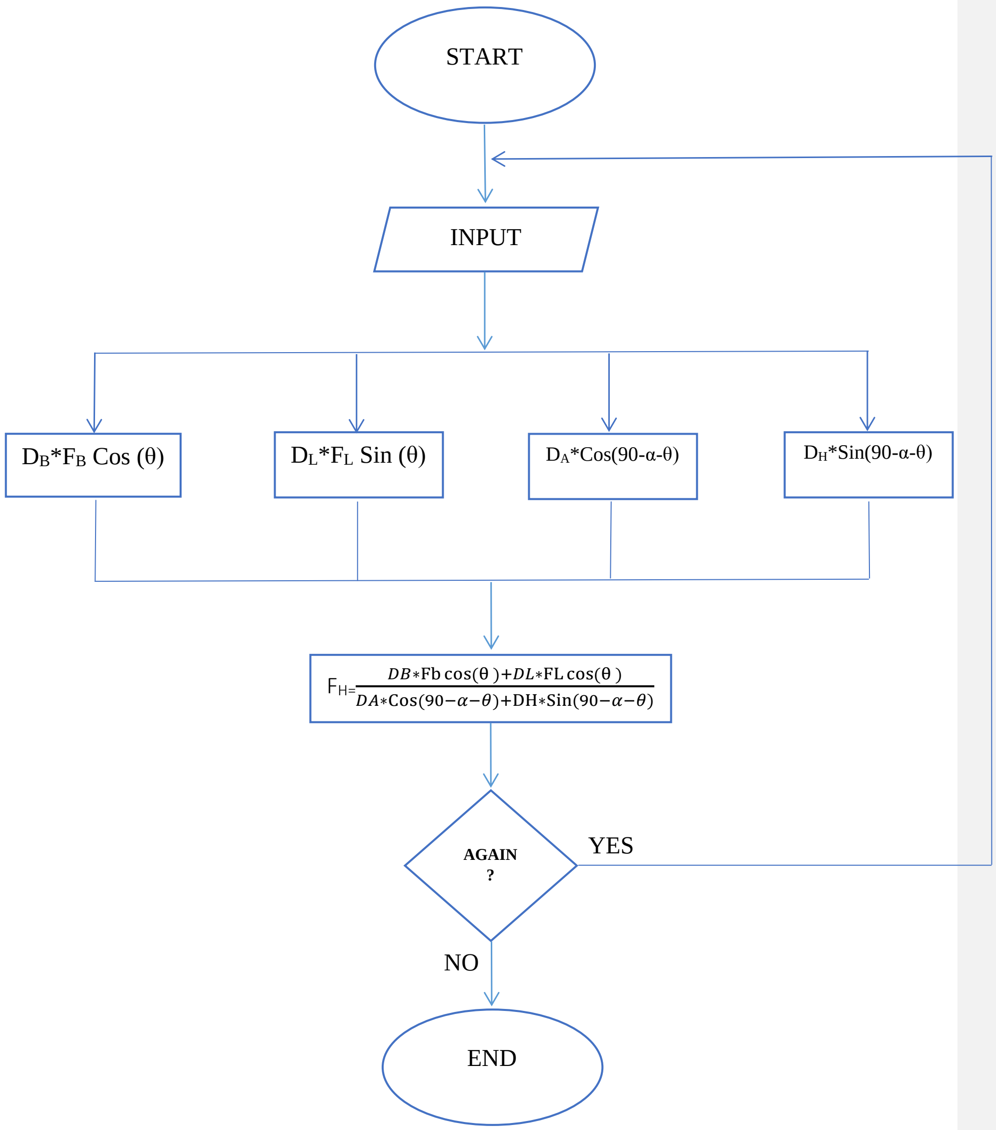
Step 6: Calculate $F_{Ry}+F_H Sin(90-\alpha-\theta)$- $FbCos(\theta)$-$FL\,Cos(\theta)$=0.

Step 7: Calculate $F_R=\sqrt{(FRx)2+(FRy)2}$.

Step 8: STOP.

CASE III:

NOTE: Similar to case I we find the F_H i.e., reaction force on hydraulic cylinder but here, we Find two or more different values of F_H by changing the inclination of the boom of the crane (α and θ) so that we can compare the difference of F_H while changing inclination.



ALGORITHM:

Step 1: Start.

Step 2: Enter Angles, Forces and Distance.

*Step 3: Calculate D_B*F_B Cos (θ), DL*F_L Sin (θ), DA*Cos(90-α-θ), DH*Sin(90-α-θ).*

Step 4: Calculate $F_H = \frac{DB*Fb\cos(\theta)+DL*FL\cos(\theta)}{DA*Cos(90-\alpha-\theta)+DH*Sin(90-\alpha-\theta)}$.

Step 5: Print F_H.

Step 6: Go to Step 2:

Step 7: Compare Different values of F_H.

Step 8: Stop.

Here, we obtain different values of F_H by giving multiple inputs of the inclination of the boom of the crane. Then, we compare the forces and observes the changing behavior of the force while the angle changes.

PROGRAM DESCRIPTION

SOURCE CODE:

Program Starts:

Here, is the list of Header files required to run the program.

The #define directive allows the definition of macros within my source code.

Commented [sk1]: These macro definitions allow constant values to be declared for use throughout my code.
Here, Degree_to_Radian is Declared.

```
Project > C Main.c > main(void)

//____________________________________________________Required Preprocessros____________________________________________________

#include <stdio.h>
#include <math.h>
#include <systemtopologyapi.h>
#define Degree_to_Radian 0.0174532925;
```

These are the int, float and char Variables declared in the program and it is declared Globally.

Commented [sk2]: These Globally declared variables has global scope so it can be used any where within the source code.

```
// ____________________________________________________Declaring Global variables____________________________________________________

float x, y, Angle_Theta_in_Degree, Angle_in_Radian, Sin_Angle, Cos_Angle, Sin_cal, Cos_cal;
float a, b, Alpha_Angle_in_Degree, Hydraulic_Angle, Hydraulic_Angle_Radian, Hydraulic_Sin_Angle, Hydraulic_Cos_Angle;
float Mass_of_Load, Weight_of_Load, Load_Force, Boom_Force;
float Boom_Length, COG_Length, Hydraulic_Length, Hydraulic_Axis_Length, BL, COG_L, HL, HAL, Feet_to_Meter;
float Hydraulic_Reaction_Force, Vertical_Load_Force, Vertical_Cog_Force, Hydraulic_Force, Hydraulic_Axis_Force;
float Resultant_Force, Force, Resultant_Ans;
float xcomp, x_Comp, Force_x, ycomp, y_Comp, Force_y;
float X_Component_Force, y_Component_Force, Resultant_Crane_Force, Crane_Resultant, Crane_Resultant_Force;
float array[10], arr[10], arra[10];
int case_num, counter, condition;
char name[50];
```

Here, I have declared the functions that will be given a definition later on below the main section of the program.

Commented [sk3]: This is the prototype of the function which tells complier that the function of this name will be defined later on in the program.

I have Declared all the function so that they have Parameter (where we pass an argument while calling the function from main section) and a return value to pass the result to the main section.

```
//____________________________________________________Declation of function____________________________________________________

float Angle_Input(float);
float Angle_Calculation(float *Angle_Cal);
float Distance_Calulation(float);
float Reaction_Force(float);
float xComponent_Force(float);
float yComponent_Force(float);
float Resultant(float);
```

The Main Section Starts.

```
//______________________________________________________Main Section_______________________________________________________

float main(void)
{
    system("color 3");
    printf("\n\n\n--------------------------------------------------Enter your name to proceed.----------------------------------------
    scanf("%s", &name);
top:
    printf("\n\n______________________________________________Hello,%s welcome to my C-Program_______________________________________
    printf("\n\nThis Program includes Three Diffrent Cases:\nPlease,Enter:\n\n=> 1 : For CaseI    ( This Case Includes the Calculation
    scanf("%d", &case_num);
```

Switch case Starts:

Inside the Switch Case Section, I have given 3 Different Cases I, II and III similar to my LabReport-1.

Case I: This Case performs the calculation of the Resultant force of the Hydraulic Cylinder of the crane.

```
    // -------------------------------------------------------Switch Case Starts--------------------------------------------------

    switch (case_num)
    {
    case 1:
        // _______________________________________For Angle of Boom of the crane i.e"θ"_______________________________________

    First:
        printf("\n\nEnter the Angle of Boom in Degree : ");
        scanf("%f", &Angle_Theta_in_Degree);
        Angle_Input(Angle_Theta_in_Degree);
        Sin_Angle = Angle_in_Radian;
        x = Angle_Calculation(&Sin_Angle);
        Cos_Angle = Angle_in_Radian;
        y = Angle_Calculation(&Cos_Angle);
```

Here, we give an alpha(α) angle as an Input. And calculate $(90 - \theta - \alpha)$.

```
        //_________________________For Angle of Hydraulic Cylinder and the Boom of the crane i.e(90-θ-α)_________________________

        printf("\n\nEnter the Alpha Angle in Degree : ");
        scanf("%f", &Alpha_Angle_in_Degree);
        Hydraulic_Angle = 90 - Angle_Theta_in_Degree - Alpha_Angle_in_Degree;
        Angle_Input(Hydraulic_Angle);
        Hydraulic_Sin_Angle = Angle_in_Radian;
        a = Angle_Calculation(&Hydraulic_Sin_Angle);
        Hydraulic_Cos_Angle = Angle_in_Radian;
        b = Angle_Calculation(&Hydraulic_Cos_Angle);
```

Commented [sk4]: Here the system("color 3 "); is used to change the font color to aqua , while printing the result in Terminal.

Commented [sk5]: Here, the user can choose any cases to perform as their wish by giving their desired Input.

Commented [sk6]: αis the angle between Resultant Hydraulic Force (Fh)and the axis perpendicular to the surface.

Commented [sk7]: $(90 - \theta - \alpha)$is the angle between Resultant Hydraulic Force (Fh) and the Boom of the crane.

Input Force: Here, we give the mass of the load to be lifted by the crane and the COG of Boom of the crane as an Input.

Commented [sk8]: This is a point (Center of Gravity of the Boom of the Crane) where the mass of the Boom is assumed to be conserved and where the force of gravity is acted.

```c
//_____________________________________________________Force Input______________________________________________________

printf("\n\nEnter the Mass of the Load to be Lifted by the crane : ");
scanf("%f", &Mass_of_Load);

Weight_of_Load = Mass_of_Load * 10;
Load_Force = Weight_of_Load;

printf("\n\nEnter the Force By the COF of the Boom : ");
scanf("%f", &Boom_Force);
```

Input Distance: Here, we give 4 Different Distance as an Input. In fact, the Input Distance is Given in Feet which is later on converted in meter while calculating.

Commented [sk9]: 1. The length of Boom of Crane.
2.The Distance of COG from Pivot of Boom.
3.The Distance of Hydraulic cylinder from the Pivot of Boom.
4.The Distance of Hydraulic Cylinder from the axis of Boom.

```c
//___________________________________________________Input Distance____________________________________________________

printf("\n\nEnter The Length of Boom in Feet : ");
scanf("%f", &Boom_Length);
BL = Distance_Calulation(Boom_Length);

printf("\n\nEnter The distance of COG in Feet : ");
scanf("%f", &COG_Length);
COG_L = Distance_Calulation(COG_Length);

printf("\n\nEnter The distance of Hydraulic Cylinder from the Pivot in Feet : ");
scanf("%f", &Hydraulic_Length);
HL = Distance_Calulation(Hydraulic_Length);

printf("\n\nEnter The distance of Hydraulic Cylinder from the axis of Boom in Feet : ");
scanf("%f", &Hydraulic_Axis_Length);
HAL = Distance_Calulation(Hydraulic_Axis_Length);
```

Calculation and Result of Case I:

Commented [sk10]: Here, Before showing the Result it shows all
the Inputs that we have gave in this Case.

```c
// <============================================Calculation of Case-I ===================================================>

float Result = Reaction_Force(Force);

printf("\n\nThe Datas that You have Entered are:\n\n");
printf("\t\t\t----------------------------------------------------------------------\n");
printf("\t\t\t\t------------------------------------------------------------");
printf("\n\t\t\t\t\t| Angle Between Boom of Crane and Horizontal  |  %.2f", Angle_Theta_in_Degree);
printf("\n\t\t\t\t\t| Angle Betwn Hydraulic Cylinder & Vertical   |  %.2f", Alpha_Angle_in_Degree);
printf("\n\t\t\t\t\t| Weight that is Given to Crane to lifts      |  %.0fN", Weight_of_Load);
printf("\n\t\t\t\t\t| Force of Centrer of Gravity of the Boom     |  %.0fN", Boom_Force);
printf("\n\t\t\t\t\t| The Distance of Boom From the pivot in Feet |  %.2f", Boom_Length);
printf("\n\t\t\t\t\t| The Distance of COG From the pivot in Feet  |  %.2f", COG_Length);
printf("\n\t\t\t\t\t| The Distance of Hydraulic Cylinder in Feet  |  %.2f", Hydraulic_Length);
printf("\n\t\t\t\t\t| The Distance From Axis to Surface of Boom   |  %.2f", Hydraulic_Axis_Length);
printf("\n\t\t\t\t\t------------------------------------------------------------\n");
printf("\t\t\t----------------------------------------------------------------------");

printf("\n\n\nThefore, Considering All the Given Datas, Resultant Force of the Hydraulic Cylinder is : %.10f\n\n", Result);

if (case_num == 2)
{
    goto Second;
}
break;
```

Case II: This Case is Similar to Case I where we find the X and Y components of Resultant Force of the Boom to the Cranes Body and Finally Find the Resultant Force of the Crane.

Commented [sk11]: Here I Have used (goto First;) in which "goto" is a jumping statement, and, "First" is the label which is also given above the Case I so that when the program reaches this step it jumps to that First label in Case I.

```c
case 2:

    goto First;
Second:
    //<==========================================Calcultion of Case-II==================================================>

    Force_x = abs(xComponent_Force(x_Comp));
    printf("The X component of Resultant Force is: %.10f", Force_x);

    Force_y = abs(yComponent_Force(y_Comp));
    printf("\n\nThe Y component of Resultant Force is: %.10f", Force_y);

    Crane_Resultant_Force = Resultant(Resultant_Crane_Force);
    printf("\n\nTherefore, the Final Resultant Force of the Crane is: %.10f\n\n", Crane_Resultant_Force);

    break;
```

Case III: In this case the we can compare the Resultant force of Boom of the Crane of Multiple Inputs. This case is simply the loop of Case I with some Addition.

Commented [sk12]: This Case is used to Compare the Resultant force of Boom of the crane by giving multiple Inputs.

```c
case 3:

    printf("\n\nEnter the Number of Different Entries you would like to give:");
    scanf("%d", &counter);
    for (int i = 1; i <= counter; i++)
    {
        printf("\n\n\n______________________________________________________________Data No.%d_____________________________________
        printf("\n\nEnter the Angle of Boom in Degree:");
        scanf("%f", &Angle_Theta_in_Degree);
        Angle_Input(Angle_Theta_in_Degree);
        Sin_Angle = Angle_in_Radian;
        x = Angle_Calculation(&Sin_Angle);
        Cos_Angle = Angle_in_Radian;
        y = Angle_Calculation(&Cos_Angle);

        //________________________________For Angle of Hydraulic Cylinder with Vertical i.e"α"_________________________________

        printf("\n\nEnter the Alpha Angle in Degree:");
        scanf("%f", &Alpha_Angle_in_Degree);
```

Here, Again For Case III we give an alpha(α) angle as an Input. And calculate $(90 - \theta - \alpha)$.

Commented [sk13]: (α) is the angle between Resultant Hydraulic Force (Fh)and the axis perpendicular to the surface.

Commented [sk14]: $(90 - \theta - \alpha)$is the angle between Resultant Hydraulic Force (Fh) and the Boom of the crane.

```c
        //_________________________For Angle of Hydraulic Cylinder and the Boom of the crane i.e(90-θ-α)______________________

        Hydraulic_Angle = 90 - Angle_Theta_in_Degree - Alpha_Angle_in_Degree;
        Angle_Input(Hydraulic_Angle);
        Hydraulic_Sin_Angle = Angle_in_Radian;
        a = Angle_Calculation(&Hydraulic_Sin_Angle);
        Hydraulic_Cos_Angle = Angle_in_Radian;
        b = Angle_Calculation(&Hydraulic_Cos_Angle);
```

Input Force: Here, we give the mass of the load to be lifted by the crane and the COG of Boom of the crane as an Input.

```c
//________________________________________________Input Force________________________________________________

printf("\n\nEnter the Mass of the Load to be Lifted by the crane:");
scanf("%f", &Mass_of_Load);

Weight_of_Load = Mass_of_Load * 10;
Load_Force = Weight_of_Load;

printf("\n\nEnter the Force By the COF of the Boom:");
scanf("%f", &Boom_Force);
```

Input Distance: Here, we give 4 Different Distance as an Input. In fact, the Input Distance is Given in Feet which is later on converted in meter while calculating

```c
// ________________________________________________Input Distance________________________________________________

printf("\n\nEnter The Length of Boom in Feet: ");
scanf("%f", &Boom_Length);
BL = Distance_Calulation(Boom_Length);

printf("\n\nEnter The distance of COG in Feet:");
scanf("%f", &COG_Length);
COG_L = Distance_Calulation(COG_Length);

printf("\n\nEnter The distance of Hydraulic Cylinder from the Pivot in Feet:");
scanf("%f", &Hydraulic_Length);
HL = Distance_Calulation(Hydraulic_Length);

printf("\n\nEnter The distance of Hydraulic Cylinder from the axis of Boom in Feet:");
scanf("%f", &Hydraulic_Axis_Length);
HAL = Distance_Calulation(Hydraulic_Axis_Length);
```

Calculation and Result of Case III

```c
    // <=========================================Calculation of CaseIII==================================================>

    array[i] = Reaction_Force(Force);
    arr[i] = Angle_Theta_in_Degree;
    arra[i] = Alpha_Angle_in_Degree;

    printf("\n\nThe Datas that You have Entered are:\n\n");
    printf("\n\t\t\t\t===> Angle Between Boom of Crane and Horizontal : %.2f", Angle_Theta_in_Degree);
    printf("\n\t\t\t\t===> Angle Betwn Hydraulic Cylinder & Vertical  : %.2f", Alpha_Angle_in_Degree);
    printf("\n\t\t\t\t===> Weight that is Given to Crane to lifts     : %.0fN", Weight_of_Load);
    printf("\n\t\t\t\t===> Force of Centrer of Gravity of the Boom    : %.0fN", Boom_Force);
    printf("\n\t\t\t\t===> The Distance of Boom From the pivot in Feet: %.2f", Boom_Length);
    printf("\n\t\t\t\t===> The Distance of COG From the pivot in Feet : %.2f", COG_Length);
    printf("\n\t\t\t\t===> The Distance of Hydraulic Cylinder in Feet : %.2f", Hydraulic_Length);
    printf("\n\t\t\t\t===> The Distance From Axis to Surface of Boom  : %.2f", Hydraulic_Axis_Length);
}
for (int i = 1; i <= counter; i++)
{
    printf("\n\nThe Resultant Force for Data.no%d is %.10f for the Given Data.\n\n", i, array[i], arr[i], arra[i]);
}
break;
```

Commented [sk15]: This is a point (Center of Gravity of the Boom of the Crane) where the mass of the Boom is assumed to be conserved and where the force of gravity is acted.

Commented [sk16]: I.. The length of Boom of Crane.
II.The Distance of COG from Pivot of Boom.
III.The Distance of Hydraulic cylinder from the Pivot of Boom.
IV.The Distance of Hydraulic Cylinder from the axis of Boom.

Commented [sk17]: This case helped me to compare the Resultant force of the crane from which I Came with a conclusion which exactly meets the physics (Crane can lift more load when the Boom is at higher Inclination (Inclination of Boom is inversely proportional to the radius of Boom)) of actual Load chart of the crane.

Default:

Commented [sk18]: This runs when the Input given by user doesn't Match any Defined Cases.

Switch case statements are used to execute only specific case (Here1,2and 3) statements based on the switch expression. If switch expression does not match with any case, default statements are executed by the program.

```
    default:
    here:
        printf("\n\n================================================Your Given Input is wrong===================================
        printf("\n\n_______________________________________________Do you want to try again????__________________________________
        printf("\n=> 1 : Try Again\n=> 0 : End the Program\n\n");
        scanf("%d", &condition);

        switch (condition)
        {
        case 1:
            goto top;
            break;
        case 0:
            break;

        default:
            goto here;
            break;
        }
        break;
    }
}
```

Since, we have three Cases 1,2 and 3.

The user will be instructed to Enter 1 for case 1 , 2 for case 2 and 3 for case 3.

If user gives any Input except these then the cases inside the Swirch case will not match and it directs towards Defautlt Case.

In Default, First it prints "Your Given Input is Wrong" and then it asks if the user wants to try running the program again .

Here again the user is provided with two cases 1 to try again and 0 to 2nd the program

It user inputs 0 then the program is ended or else if the user gives 1 as an Input then the goto jumoing statemnet jumps the program to inintail state where it again asks to Enter the Case user want to perform.

Function Starts

Angle Function: Here, the Argument which is given as an Input is passed in “ Angle ” parameter.

Commented [sk19]: This Function Converts the given Degree to radian because in C the trigonometric function is calculated in radian value.

```
//-------------------------------------------------Function for Input of Angles----------------------------------------------------

float Angle_Input(float Angle)
{
    Angle_in_Radian = Angle * Degree_to_Radian;
    return Angle_in_Radian;
}
```

Angle Calculation: Here, the *Angle_Cal is a float pointer parameter which takes the Address of the Argument which is passed by the main function.

Commented [sk20]: This Function calculates the Sin and Cosine value of the given Angles and Returns it.

```
//-------------------------------------------------Function for Calculation of Angles------------------------------------------------

float Angle_Calculation(float *Angle_Cal)
{
    if (Angle_Cal == &Sin_Angle || Angle_Cal == &Hydraulic_Sin_Angle)
    {
        float Sin_cal = sin(*Angle_Cal);
        return Sin_cal;
    }
    else
    {
        float Cos_cal = cos(*Angle_Cal);
        return Cos_cal;
    }
}
```

Distance Function: Here, the Argument which is given as an Input is passed in “Distance” parameter.

Commented [sk21]: Since, the distance that we given as an Input is in Feet so this Function Converts it into Meter and Returns it.

```
//----------------------------------------Function for Converting given distance in meter----------------------------------------

float Distance_Calulation(float Distance)
{
    Feet_to_Meter = 0.3048 * Distance;
    return Feet_to_Meter;
}
```

First Case Calculation : Here, the Argument which is given as an Input is passed in "Resultant_Force" parameter.

Commented [sk22]: This Function performs the calculation of First Case where it calculates the Resultant Force of the Hydraulic Cylinder.

```
// ---------------------------------------------------First case Calculation---------------------------------------------------

float Reaction_Force(float Resultant_Force)
{
    Vertical_Load_Force = Load_Force * BL * y;
    Vertical_Cog_Force = Boom_Force * COG_L * y;
    Hydraulic_Force = HL * a;
    Hydraulic_Axis_Force = HAL * b;

    Resultant_Force = (Vertical_Cog_Force + Vertical_Load_Force) / (Hydraulic_Force + Hydraulic_Axis_Force);
    Resultant_Ans = Resultant_Force;
    return Resultant_Ans;
}
```

X-Component: Here, the Argument which is given as an Input is passed in "xcomp" parameter.

Commented [sk23]: This Function is used for Case III where it calculates the X component of the Resultant force of the Boom of the crane.

```
//---------------------------------------------function for finding Xcomponent of the force---------------------------------------------

float xComponent_Force(float xcomp)
{
    xcomp = Boom_Force * x + Load_Force * x - Resultant_Ans * b;
    X_Component_Force = xcomp;
    return xcomp;
}
```

Y-Ccomponent: Here, the Argument which is given as an Input is passed in "ycomp" parameter.

Commented [sk24]: This Function is used for Case III where it calculates the Y component of the Resultant force of the Boom of the crane.

```
// -------------------------------------------function for finding Ycomponent of the force-------------------------------------------

float yComponent_Force(float ycomp)
{
    ycomp = Boom_Force * y + Load_Force * y - Resultant_Ans * a;
    y_Component_Force = ycomp;
    return ycomp;
}
```

Resultant Force: Here, the Argument which is given as an Input is passed in "Resultant_Crane_Force" parameter.

Commented [sk25]: This Function is the Result of Case III which is used to calculate the Resultant Force of Boom of the Crane.

```
//-----------------------------------------function for finding Resultant of the force-----------------------------------------

float Resultant(float Resultant_Crane_Force)
{
    Resultant_Crane_Force = sqrt(pow(X_Component_Force, 2) + pow(y_Component_Force, 2));
    Crane_Resultant = Resultant_Crane_Force;
    return Crane_Resultant;
}
```

OUTPUT

Just after running the program. Here, is what you see.

Now, to proceed one needs to Enter their name then after that the program welcomes you.

```
PROBLEMS   OUTPUT   TERMINAL   DEBUG CONSOLE                                   Code
Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.

Install the latest PowerShell for new features and improvements! https://aka.ms/PSWindows

PS C:\Users\KarKi\Desktop\Coding\C\Mech.project> cd "c:\Users\KarKi\Desktop\Coding\C\Mech.project\Project\" ; if ($?) { gc
c Main.c -o Main } ; if ($?) { .\Main }


----------------------------------------------Enter your name to proceed.-------------------------------------------------


==> Sanskar


__________________________________________Hello,Sanskar welcome to my C-Program_____________________________________________
```

Now you are given to choose among any three cases. Similar to the numerical from the theory report.

=> 1: For Case I

This Case Includes the Calculation of Resultant Force on Hydraulic Cylinder of Boom of the Crane.

=> 2: For Case II
This Case Includes the Calculation of Resultant Force on the Pivot of Boom of the Crane.

=> 3: For Case III

This Case Compares the Resultant Force on Hydraulic Cylinder by giving Different Inputs

```
This Program includes Three Diffrent Cases:
Please,Enter:

=> 1 : For CaseI   (This Case Includes the Calculation of Resultant Force on Hydraulic Cylinder of Boom of the Crane.)
=> 2 : For CaseII  (This Case Includes the Calculation of Resultant Force on the Pivot of Boom of the Crane.)
=> 3 : For CaseIII (This Case Compares the Resultant Force on Hydraulic Cylinder by giving Different Inputs.)
```

Case I:

Enter 1, then give the Inputs that are asked, step by step. The user is required to give all the inputs as asked in the preferred unit.

```
 The Case you Choose is: 1

Enter the Angle of Boom in Degree : 45

Enter the Alpha Angle in Degree : 22

Enter the Mass of the Load to be Lifted by the crane : 500

Enter the Force By the COF of the Boom : 20000

Enter The Length of Boom in Feet : 35

Enter The distance of COG in Feet : 16

Enter The distance of Hydraulic Cylinder from the Pivot in Feet : 10

Enter The distance of Hydraulic Cylinder from the axis of Boom in Feet : 1.5
```

Now after the user give all the Inputs, it displays all the Data given by the user.

```
The Datas that You have Entered are:

                          ----------------------------------------------------------------------
                                  -------------------------------------------------------
                                  | Angle Between Boom of Crane and Horizontal  |  45.00
                                  | Angle Betwn Hydraulic Cylinder & Vertical   |  22.00
                                  | Weight that is Given to Crane to lifts      |  5000N
                                  | Force of Centrer of Gravity of the Boom     |  20000N
                                  | The Distance of Boom From the pivot in Feet |  35.00
                                  | The Distance of COG From the pivot in Feet  |  16.00
                                  | The Distance of Hydraulic Cylinder in Feet  |  10.00
                                  | The Distance From Axis to Surface of Boom   |  1.50
                                  -------------------------------------------------------
                          ----------------------------------------------------------------------
```

And, finally it shows the Result.

Commented [sk26]: F_H=66190.1093750000N is the output from the program whereas the output when I did this case theoretically was, F_H=66183.7910N the small difference in answer is seen only because when the question was solved theoretically the calculation was done taking only 4 digits decimal place after every point but in C program it is programmed to take upto 10 places of decimal.

```
Thefore, Considering All the Given Datas, Resultant Force of the Hydraulic Cylinder is : 66190.1093750000
```

Case II:

Similarly if the user choose Case II, The process to give input is same the only difference is in answer where it also calcultaes the Resultant force of the Boom of the Crane.

```
 The Case you Choose is: 2

Enter the Angle of Boom in Degree : 60

Enter the Alpha Angle in Degree : 15

Enter the Mass of the Load to be Lifted by the crane : 500

Enter the Force By the COF of the Boom : 20000

Enter The Length of Boom in Feet : 35

Enter The distance of COG in Feet : 16

Enter The distance of Hydraulic Cylinder from the Pivot in Feet : 10

Enter The distance of Hydraulic Cylinder from the axis of Boom in Feet : 1.5
```

Again, it shows all the Data Given by the user in Case II.

```
The Datas that You have Entered are:

                        ----------------------------------------------------------------------
                                --------------------------------------------------------
                                | Angle Between Boom of Crane and Horizontal  |  60.00
                                | Angle Betwn Hydraulic Cylinder & Vertical   |  15.00
                                | Weight that is Given to Crane to lifts      |  5000N
                                | Force of Centrer of Gravity of the Boom     |  20000N
                                | The Distance of Boom From the pivot in Feet |  35.00
                                | The Distance of COG From the pivot in Feet  |  16.00
                                | The Distance of Hydraulic Cylinder in Feet  |  10.00
                                | The Distance From Axis to Surface of Boom   |  1.50
                                -------------------------------------------------------
                        ----------------------------------------------------------------------


Thefore, Considering All the Given Datas, Resultant Force of the Hydraulic Cylinder is : 61306.6914062500
```

Then, it gives the Result of Case II. Here, the negative sign in the components means that Assumed direction was Wrong, but the Magnitude Remains the same.

Commented [sk27]: The Answers when done manually:
I.F_X=-37553.9305N
II.F_Y=-3366.4950N
III.F_H=61303.4292N
IV.F_R=37704.5250N
The Answers from the Program are:
I.F_X= -37567.0781250000N
II.F_Y=- 3367.3398437500N
III.F_H= 61306.6914062500N
IV.F_R= 37717.6914062500N

```
The X component of Resultant Force is: -37567.0781250000

The negative sign indicates that the direction we assumed was wrong.

The Y component of Resultant Force is: -3367.3398437500

The negative sign indicates that the direction we assumed was wrong.

Therefore, the Final Resultant Force of the Crane is: 37717.6914062500
```

Case III:

Here since the case 3 is made to Compare different datas so the program also asks the number of entries user want to give.

```
 The Case you Choose is: 3

Enter the Number of Different Entries you would like to give: 2
```

This is Data no 1 in which the user gives some inputs a its 1st entry.

```
________________________________________________________Data No.1________________________________________________________


Enter the Angle of Boom in Degree:15

Enter the Alpha Angle in Degree:60

Enter the Mass of the Load to be Lifted by the crane:550

Enter the Force By the COF of the Boom:22500

Enter The Length of Boom in Feet: 35

Enter The distance of COG in Feet:16

Enter The distance of Hydraulic Cylinder from the Pivot in Feet:10

Enter The distance of Hydraulic Cylinder from the axis of Boom in Feet:1.5
```

This shows the Data that we had entered in Data no1.

```
The Datas that You have Entered are:

                        ----------------------------------------------------------------------
                                --------------------------------------------------------
                                | Angle Between Boom of Crane and Horizontal  |  15.00
                                | Angle Betwn Hydraulic Cylinder & Vertical   |  60.00
                                | Weight that is Given to Crane to lifts      |  5500N
                                | Force of Centrer of Gravity of the Boom     |  22500N
                                | The Distance of Boom From the pivot in Feet |  35.00
                                | The Distance of COG From the pivot in Feet  |  16.00
                                | The Distance of Hydraulic Cylinder in Feet  |  10.00
                                | The Distance From Axis to Surface of Boom   |  1.50
                                -------------------------------------------------------
                        ----------------------------------------------------------------------
```

Now since we gave 2 entries so, the user also should give next data as 2nd entry.

```
________________________________________________________Data No.2________________________________________________________

Enter the Angle of Boom in Degree:70

Enter the Alpha Angle in Degree:5

Enter the Mass of the Load to be Lifted by the crane:550

Enter the Force By the COF of the Boom:22500

Enter The Length of Boom in Feet: 35

Enter The distance of COG in Feet:16

Enter The distance of Hydraulic Cylinder from the Pivot in Feet:10

Enter The distance of Hydraulic Cylinder from the axis of Boom in Feet:1.5
```

This shows the data that user had entered in entry no 2.

```
The Datas that You have Entered are:

                         ----------------------------------------------------------------------
                                 --------------------------------------------------------
                                 | Angle Between Boom of Crane and Horizontal  |  70.00
                                 | Angle Betwn Hydraulic Cylinder & Vertical   |  5.00
                                 | Weight that is Given to Crane to lifts      |  5500N
                                 | Force of Centrer of Gravity of the Boom     |  22500N
                                 | The Distance of Boom From the pivot in Feet |  35.00
                                 | The Distance of COG From the pivot in Feet  |  16.00
                                 | The Distance of Hydraulic Cylinder in Feet  |  10.00
                                 | The Distance From Axis to Surface of Boom   |  1.50
                                 --------------------------------------------------------
                         ----------------------------------------------------------------------
```

Finally, the Result of both the Data are given.

Commented [sk28]: The Answers when done manually:
I.FH=132185.9996N
II.FH=44494.4707N
The Answers from the Program are:
I.FH=132193.0937500000N
II.FH=46807.6367187500N

```
The Resultant Force of Data.no1 is 132193.0937500000 for the Given Input.


The Resultant Force of Data.no2 is 46807.6367187500 for the Given Input.
```

Now what if the user gives an Invalid Input i.e., Except Case 1,2and 3.

Commented [sk29]: This Case is operated as a default case, if the user gives the wrong input. Then, the user will be given choice to try again to enter it correctly or to end the program.

```
This Program includes Three Diffrent Cases:
Please,Enter:

=> 1 : For CaseI   (This Case Includes the Calculation of Resultant Force on Hydraulic Cylinder of Boom of the Crane.)
=> 2 : For CaseII  (This Case Includes the Calculation of Resultant Force on the Pivot of Boom of the Crane.)
=> 3 : For CaseIII (This Case Compares the Resultant Force on Hydraulic Cylinder by giving Different Inputs.)

 The Case you Choose is: 0


=============================================Your Given Input is wrong==================================================

____________________________________________Do you want to try again????_________________________________________________
=> 1 : Try Again
=> 0 : End the Program
```

If user want to try again user needs to Enter 1.

```
 The Case you Choose is: 0


=============================================Your Given Input is wrong==================================================

____________________________________________Do you want to try again????_________________________________________________
=> 1 : Try Again
=> 0 : End the Program

1


__________________________________________Hello,Sanskar welcome to my C-Program____________________________________________



This Program includes Three Diffrent Cases:
Please,Enter:

=> 1 : For CaseI   (This Case Includes the Calculation of Resultant Force on Hydraulic Cylinder of Boom of the Crane.)
=> 2 : For CaseII  (This Case Includes the Calculation of Resultant Force on the Pivot of Boom of the Crane.)
=> 3 : For CaseIII (This Case Compares the Resultant Force on Hydraulic Cylinder by giving Different Inputs.)

 The Case you Choose is:
```

If user want to end the program, user need to Enter 0.

```
=============================================Your Given Input is wrong==================================================

____________________________________________Do you want to try again????_________________________________________________
=> 1 : Try Again
=> 0 : End the Program

0


                                                  End of the Program
```

End of the Program

Commented [sk30]: Finally, the Program Ends. 😄

Conclusion:

The project was carried out to determine the reaction force of the hydraulic cylinder, reaction force of the crane body and to compare the different reaction force of hydraulic cylinder while changing the inclination of the boom of the crane.

Initially, what I had expected was, for a particular load a crane could easily lift till some inclination but hardly increase the inclination further. In fact, it was observed that the crane lifts heavier load when the inclination of the crane increase, this was due to the increase in radius of the Boom of the crane and decrease in Reaction Force of the Hydraulic Cylinder.

Later, I came to know the physics behind the change of load capacity is caused due to change in reaction force of the Hydraulic Cylinder and the radius of the boom.

REFERENCE:

[1] Fundamentals of Crane Hydraulics | CD Industrial Group Inc. (cdiginc.com)

[2] https://science.howstuffworks.com/transport/engines-equipment/hydraulic-crane.htm

[3]https://youtu.be/CSpcAdPF-E4