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TECHNICAL REPORT

THEME:

DIDACTIC MODULE FOR PROCESS OF AUTOMATION IN THE PAINTED OF GEOMETRICAL SOLIDS.

AUTHOR:

VINICIO GABRIEL TERÁN BURBANO

DIRECTOR:

ING. WASHINGTON MOSQUERA

IBARRA-ECUADOR

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DIDACTIC MODULE FOR PROCESS OF AUTOMATION IN THE PAINTED OF GEOMETRICAL SOLIDS.

Terán Burbano Vinicio Gabriel.
gaboteran89@hotmail.com
University Technical of North

Abstract: Robots appeared in the middle of the twentieth century and as they are a new and recent technology, they are a study object at research centers and universities all over the world. The correct understanding of their functioning and the way how to use them have made robots very useful in the industry.

At present, robotics and the automation of production line processes have become a necessity in the industries due to their competitiveness and the continuous improvement of the manufacturing practices of the end product. In many industries, robotic arms are used in welding processes, painting, assembly lines, pharmaceutics, etc. An example for the application of robotics is found in the car industry where it gained a large acceptation. Robotic arms are used in car companies for welding, assembling pieces or painting bodyworks due to the great accuracy they have performing their jobs.

In our country, the field of robotics is surging as many industries are in a continuous growth. However, most machineries with new technology are from abroad and the domestic production is very limited. Therefore, it is very important to produce technology in our country in order to stop the importations of machinery.

This robotics module is aimed to education and the performance of laboratory practices and its objective is to simulate an industrial process as the above mentioned to permit improve the handling and understanding of the functioning of the mechanic and electronic components that make up the module.

1. Content Development

1.1 Kinematics

Kinematics is the part of physics that studies the movement of mechanical systems, regardless of the forces causing this movement therefore does not involve differential equations as in the case of dynamics. (Reyes Cortés, 2012)

Two basic solve the robot kinematics problems, the first is known as the direct kinematic problem and second problem called inverse kinematics.

1.2 Resolution of the kinematic direct problem by geometric method.

The purpose of this problem is to find relationships that allow us to know the spatial location of the end of the robot apart from their precise articulate coordination skill. To obtain relations describing geometrical considerations this project will be used for easy deduction

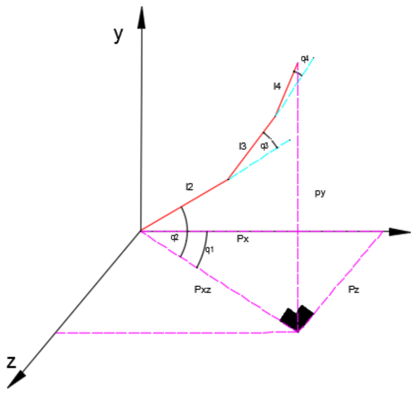

Figure 1 Diagram of joint variables

$$Pxz = l2\ cosq2 + l3[\cos(q2 + q3)] + l4[\cos(q2 + q3 + q4)]$$

$$Py = l2\ senq2 + l3[\mathrm{sen}(q2 + q3)] + l4[\mathrm{sen}(q2 + q3 + q4)]$$

$$Px = Pxz * cosq1$$

$$Pz = Pxz * senq1$$

1.3 Resolution of the inverse kinematic problem by geometric method

To solve the inverse problem you must first find q1.

$$tg\ q1 = \frac{Px}{Pz}$$

Then clearing q1 we have:

$$q1 = arctg\ \frac{Px}{Pz}$$

Now to find q3 use the theorem of cosines and the following is obtained:

$$Pxz^2 = Px^2 + Py^2$$

$$Pxz^2 + Pz^2 = l2^2 + l3^2 + 2l2l3cosq3$$

$$\cos q3 = \frac{Px^2 + Py^2 + Pz^2 - l2^2 - l3^2}{2l2l3}$$

$$q3 = arcos\ \frac{Px^2 + Py^2 + Pz^2 - l2^2 - l3^2}{2l2l3}$$

To calculate q2 is obtained as follows

$$q2 = arctg\left(\frac{l3\ sen\ q3}{l2 + l3\ cosq3}\right) - arctg\left(\frac{Py\ sen\ q3}{-\sqrt{(Px^2 + Py^2)}}\right)$$

1.4 Mathematical Model (Potential energy in 3 the links)

For the analysis of mathematical modeling of the robotic arm, it took into account only 3 links that comprises it.

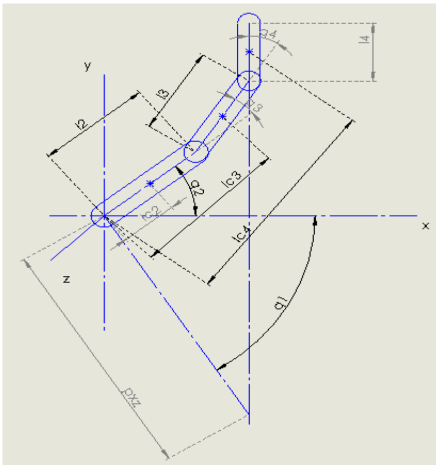

Figure 3 Diagram variant analysis

To calculate the potential energy you have to start with the mass times the acceleration of gravity and the height of its center of mass, therefore we have:

$$E_{p1} = m_1 g l_{c2} Sen(q_2)$$

$$E_{p2} = m_2 g[\ l_2\ Sen(q_2) + l_{c3} Sen(q_2 + q_3)]$$

$$E_{p3} = m_3 g[\ l_2\ Sen(q_2) + l_3 Sen(q_2 + q_3) + l_{c4} Sen(q_2 + q_3 + q_4)]$$

Where the sum of the potential energies of each link are given by:

$$E_p = E_{p1} + E_{p2} + E_{p3}$$

$$E_p = gSen(q_2)(m_1\ l_{c2} + m_2\ l_2 + m_3\ l_2) + gSen(q_2 + q_3)(m_2\ l_{c3} + m_3\ l_3) + m_2\ l_{c4}\ g\ sen(q_2 + q_3 + q_4)\ .$$

For the gravity vector in its derivatives:

$$g_1(q) = \frac{\partial\, Ep}{\partial\, q2} = gCos(q_2)(m_1\, l_{c2} + m_2\, l_2 + m_3\, l_2) + gCos(q_2 + q_3)(m_2\, l_{c3} + m_3\, l_3) + m_2\, l_{c4}\, g\, Cos(q_2 + q_3 + q_4)\,.$$

$$g_2(q) = \frac{\partial\, Ep}{\partial\, q3} = gCos(q_2 + q_3)(m_2\, l_{c3} + m_3\, l_3) + g\, Cos(q_2 + q_3 + q_4)(m_2\, l_{c4})$$

$$g_3(q) = \frac{\partial\, Ep}{\partial\, q4} = g\, Cos(q_2 + q_3 + q_4)(m_2\, l_{c4})$$

Be:
m1=0.8 kg, m2=0.8Kg, m3=0.22 kg
L2=0.31 m L3=0.26m L4=0.13m
Lc2= 0.15m Lc3=0.13m Lc4=0.07m

$$g_1(q) = \frac{\partial\, Ep}{\partial\, q2} = 9.8Cos(q_2)(0.8 * 0.15 + 0.8 * 0.31 + 0.22 * 0.31) + 9.8Cos(q_2 + q_3)(0.8 * 0.13 + 0.22 * 0.26) + 0.8 * 0.07 * 9.8\, Cos(q_2 + q_3 + q_4)\,.$$

$$g_2(q) = \frac{\partial\, Ep}{\partial\, q3} = 9.8Cos(q_2 + q_3)(0.8 * 0.13 + 0.22 * 0.26) + 0.8 * 0.07 * 9.8\, Cos(q_2 + q_3 + q_4)$$

$$g_3(q) = \frac{\partial\, Ep}{\partial\, q4} = 0.8 * 0.07 * 9.8\, Cos(q_2 + q_3 + q_4)$$

2. CALCULATING EFFORTS

To begin the design must first determine the forces and reactions, for which we will assume that the system we study is not moving or the system is in equilibrium

For solving the problem we will split the free body diagram where the forces and reactions are determined at point A

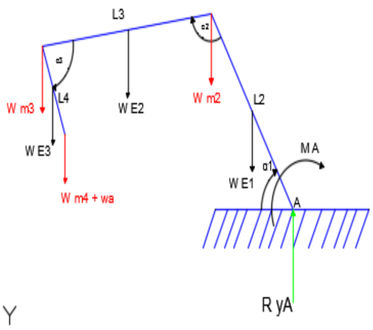

Fig 3 Free-body diagram

So:

W E1= link weight 1
W E2= link weight 2
W E3= link weight 3
W m2= motor weight 2
W m3= motor weight 3
W m4= motor weight 4
Wa= airbrush weight

Then the respective values to variables are added:

W E1= 0.8 Kg
W E2= 0.8 Kg
W E3= 0.2 Kg
W m2= 0.1 Kg
W m3= 0.039 Kg
W m4= 0.015 Kg
Wa=0.020 Kg
α1= 45.31°
α2= 123.11°
α3= 64.56°
L2= 262.2 mm
L3= 311.2 mm
L4= 130 mm

Taking all values necessary proceeds to solve the problem, starting with the calculation of the sum of the reactions.

$$\sum Fy = 0 \quad (\uparrow +)$$

RyA = W a + W m4 + W E3 + W m3 + W E2 + W m2 + W E1

$\boldsymbol{RyA = 19.36\ N}$

Later the moment is calculated at point A.

$\sum M = 0 \ \ (\uparrow +)$

Wa(410.991) + W m4 (410.9919 + W E3 (450.127) + W m3 (489.263) + W E2(336,83) + W m2 (184.398) + W E1 (92,199) − MA

$\boldsymbol{MA = 4744.9645\ N.mm}$

An analysis will be performed in the most critical link (critical point), in Figure 4 the relationship and the moment acting on the part of the link 1 is shown.

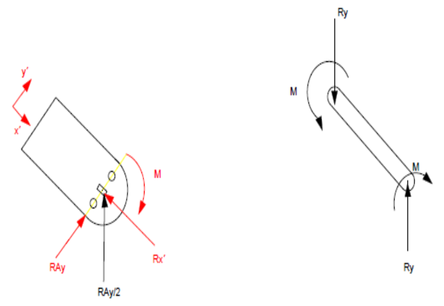

Fig 4 reactions and moments in the critical link.

$$\text{Cos}\ \alpha 1 = \frac{Rx'}{RAy/2}$$

$$Rx' = \text{RAy/2} * \text{Cos}\ (\alpha 1)$$

$$Rx' = 9.667 * \text{Cos}\ (45.31)$$

$$\boldsymbol{Rx' = 6.7985\ \text{N}}$$

$$M = \frac{MA}{2}$$

$$M = \frac{4744.9645}{2}$$

$$\boldsymbol{M = 2372.45\ \text{N.mm}}$$

We proceed to calculate the normal stress of the piece, where you should know the area and the force acting on this

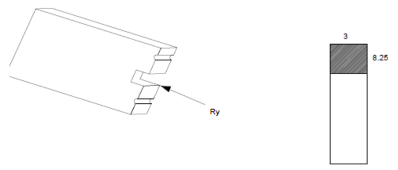

Fig 5 Cut piece of critical link

To find the area start from the following formula

$$A = 3 * 10^{-3}(8.25 * 10^{-3})$$

$$A = 2.47 * 10^{-3} * (4)$$

$$\boldsymbol{AT = 9.9 * 10^{-5}}\ \text{m2}$$

It is the normal stress and has

$$\sigma = \frac{F}{AT}$$

$$\sigma = \frac{6.7985\ N}{9.9 * 10 - 5\ m2}$$

$$\boldsymbol{\sigma = 0.0686\ \text{MPa}}$$

For the next step we calculate the existing inertia to calculate the bending effort.

In Figure 6 is the graph for the resolution of inertias.

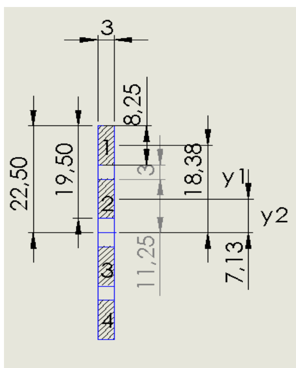

Fig 6 Diagram of area moment of inertia

$$Y1 = 22.5 - (8.25/2)$$

$$Y1 = 18.375 \text{ mm}$$

$$Y2 = 11.25 - (8.25/2)$$

$$Y2 = 7.125 \text{ mm}$$

Below the moment of inertia is calculated Link Part applying Steiner's theorem.

$$I = (b * h)3/12 \; + \; A * d2$$

where:
b=width
h= height
A=rectangle area analyzed
d= distance between centers

Then we have:

$$I1 = \frac{(3 * 8.25^3)}{12} + 3(8.25)(18.375)^2$$

$$\boldsymbol{I}1 = 8496{,}9443 \text{ mm4}$$

$$\boldsymbol{I}1 = I4$$

$$I2 = \frac{(3 * 8.25^3)}{12} + 3(8.25)(7.125)^2$$

$$\boldsymbol{I}2 = 1396.828 \text{ mm4}$$

$$\boldsymbol{I}2 = I3$$

Previous inertia is added to obtain the total inertia

$$It = I1+I2+I3+I4$$

$$\boldsymbol{I}t = 19787.624 \text{ mm4}$$

For the calculation of bending stress:

$$\sigma = \frac{M\,c}{I}$$

where:
M= bending moment
c = distance from neutral axis to the farthest fiber
I=moment of inertia about the neutral axis

$$\sigma = \frac{2372.45\ N.mm(22.5)mm}{19787.624\ mm4}$$

$$\boldsymbol{\sigma = 2.6976\ \mathrm{MPa}}$$

Efforts are added:

$$\sigma x = 2.6976 + 0.0686$$

$$\boldsymbol{\sigma x = 2.7662\ \mathrm{MPa}}$$

To calculate the safety factor use the following formula:

$$n = \frac{Sy}{\sigma x}$$

where:

Sy=yield point

Sy=61 MPa (PMMA)

$$n = \frac{61\ MPa}{2.7662\ \mathrm{MPa}}$$

$$\mathbf{n = 22}$$

In calculating the Von Mises stress, the forces cancel and therefore we have:

$$\sigma' = (\sigma x2 \; - \; \sigma x\, \sigma y \; + 3\zeta xy2\,)1/2$$

$$\sigma' = \sigma x$$

$$n = \frac{Sy}{\sigma'}$$

$$n = \frac{61MPa}{2.7662\mathrm{MPa}}$$

$$\mathbf{n = 22}$$

For testing of the calculations previously made solid use the Solidwork software. The results shown by the software resemble those obtained. Calculations are performed at the most critical link.

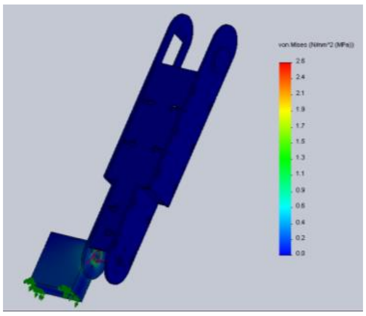

Fig 7 Von Mises result in solidwork

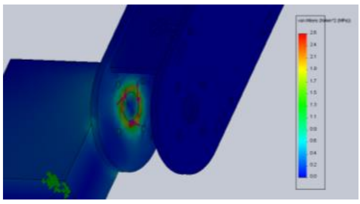

Fig 8 Moment applied to link

Besides will do the safety factor calculation to know if the arm structure will support the efforts and charges subject.

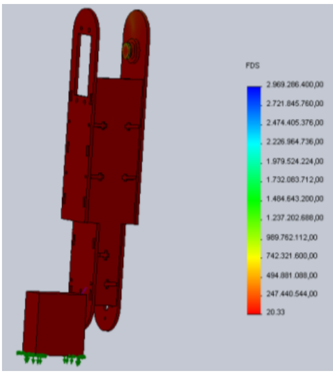

Fig 9 Safety factor

3. GRAPHIC INTERFACE (GUIDE)

For the development of this graphical interface, will be used 3 boxes to input vectors positions and orientation respectively, two buttons on which the first compiles the program that makes the movements of the robotic arm, the second button makes the operation simulation in Simulink and besides it observed five graphs of angles vs. time

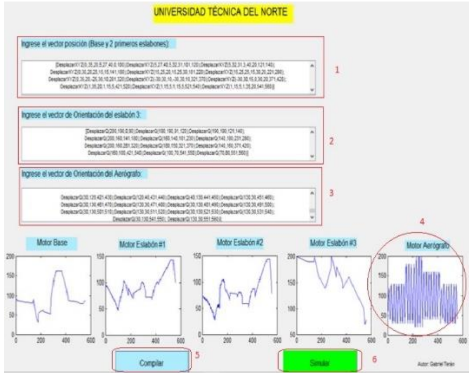

Fig 10 graphic interface

4.1 Flow chart of programming in GUIDE

In Figure 11 the programming describe process that was used in the graphical interface for performing action painting of different geometric solid (pyramid).

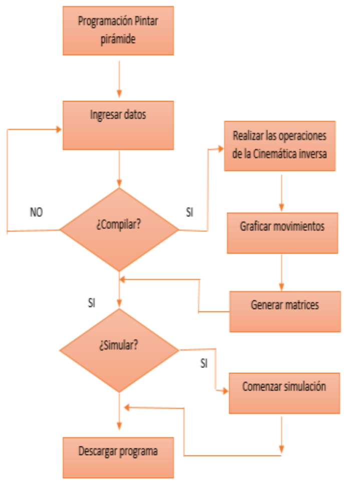

Fig 11 Flow chart of the graphical interface

4. CONCLUSIONS

- By applying the theoretical knowledge the main criteria are established to optimize the sizing of the components involved in this module, then by applying these theoretical foundations it is concluded that the use of lightweight materials is vital for the proper performance of the arm, in addition the electrical and electronic components are small in size because the didactic approach of this project, however these meet the goal of simulating an industrial process.

- After learning about the electronic and electrical components that make up the modules and how they perform their respective comparisons with other components of similar characteristics, in order to evaluate and select the right components for optimal performance of this project.
- The development of a graphical interface is a useful and versatile tool that helps students simulate control and input data for the generation of arm movements without jeopardizing the main program for this module.
- By making multiple paint testing taking into account certain variables have the conclusion that the quality of the painting depends on the speed of the airbrush motion and the distance at which the paint is spread, because spraying over small distances generates paint buildup and vice versa and maintain a constant speed to spray.

5. RECOMMENDATIONS

- To improve the operation of the robotic arm it is recommended to take into account for scheduling weight and torques that make up the arm, however, this project is not taken into account because only the inverse kinematics were performed and does not take into account these parameters.
- Further research is recommended to consider the design of the compressed air system and feeding the paint system.
- It is suggested to use the manual proposed to prevent misuse in the module, and thus ensure proper operation, in addition to abide with preventive maintenance to keep in top condition this module.
- Action should be performed painted in an area free of wind because the spraying is affected by this.
- Use sources that provide pure signals so there are no interruptions in the operation of the arm.

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Bibliography of the author

Vinicio Gabriel Terán Burbano

Born in the city of Ibarra -Imbabura-Ecuador, on March 27, 1989.

University studies at the Technical University North, Mechatronics Engineering Career