```matlab
% LIMPIEZA DE PANTALLA
clear all
close all
clc

% ================================
% DEFINICIÓN DE VARIABLES SIMBÓLICAS
% ================================
syms q1 q2 q3 q4 q5 q6 real
syms L real  % Longitud común

% ================================
% MATRICES HOMOGÉNEAS H1–H6
% ================================
Rt = @(R, t) [R, t; 0 0 0 1];

% H1: Z(q1) + traslación en X (marcos 6 → 5)
Rz1 = [cos(q1), -sin(q1), 0;
       sin(q1),  cos(q1), 0;
       0      ,   0     , 1];
H1 = Rt(Rz1, [L; 0; 0]);  % traslación en X

% H2: Y(q2) sin traslación (marcos 5 → 4 sobrepuestos)
Ry2 = [cos(q2), 0, sin(q2);
       0     , 1, 0;
      -sin(q2), 0, cos(q2)];
H2 = Rt(Ry2, [0; 0; 0]);

% H3: X(q3) + traslación en Z (marcos 4 → 3)
Rx3 = [1, 0, 0;
       0, cos(q3), -sin(q3);
       0, sin(q3),  cos(q3)];
H3 = Rt(Rx3, [0; 0; L]);

% H4: Y(q4) + traslación en Z (marcos 3 → 2)
Ry4 = [cos(q4), 0, sin(q4);
       0     , 1, 0;
      -sin(q4), 0, cos(q4)];
H4 = Rt(Ry4, [0; 0; L]);

% H5: X(q5) sin traslación (marcos 2 → 1 sobrepuestos)
Rx5 = [1, 0, 0;
       0, cos(q5), -sin(q5);
       0, sin(q5),  cos(q5)];
H5 = Rt(Rx5, [0; 0; 0]);

% H6: Z(q6) sin traslación (marcos 1 → 0 sobrepuestos)
Rz6 = [cos(q6), -sin(q6), 0;
       sin(q6),  cos(q6), 0;
       0      ,   0     , 1];
```

```
H6 = Rt(Rz6, [0; 0; 0]);

% H7: marco sobrepuesto al 6,5,4 → ahora será el nuevo marco 7
H7 = eye(4);

% ===============================
% MATRIZ DE TRANSFORMACIÓN GLOBAL
% ===============================
T = simplify(H1 * H2 * H3 * H4 * H5 * H6 * H7);

disp('==============================')
```

```
==============================
```

```
disp('Matriz simbólica de transformación homogénea global T =')
```

```
Matriz simbólica de transformación homogénea global T =
```

```
disp(T)
```

$$\left(\begin{array}{cccc} \sin(q_6)\,\sigma_3 - \cos(q_6)\,\sigma_6 & \sin(q_6)\,\sigma_6 + \cos(q_6)\,\sigma_3 & \cos(q_5)\,\sigma_9 + \sin(q_5)\,\sigma_{10} & L + L\,\sigma_{13} + L\,\mathrm{c} \\ \cos(q_6)\,\sigma_4 - \sin(q_6)\,\sigma_2 & -\sin(q_6)\,\sigma_4 - \cos(q_6)\,\sigma_2 & -\cos(q_5)\,\sigma_7 - \sin(q_5)\,\sigma_8 & L\,\sin(q_1)\,\sin(\\ -\sin(q_6)\,\sigma_5 - \cos(q_6)\,\sigma_1 & \sin(q_6)\,\sigma_1 - \cos(q_6)\,\sigma_5 & -\cos(q_5)\,\sigma_{11} - \cos(q_2)\,\sin(q_3)\,\sin(q_5) & L\,\cos(q_2)\,(\mathrm{c} \\ 0 & 0 & 0 & 1 \end{array}\right.$$

where

$$\sigma_1 = \cos(q_4)\sin(q_2) + \cos(q_2)\cos(q_3)\sin(q_4)$$

$$\sigma_2 = \sin(q_5)\,\sigma_7 - \cos(q_5)\,\sigma_8$$

$$\sigma_3 = \sin(q_5)\,\sigma_9 - \cos(q_5)\,\sigma_{10}$$

$$\sigma_4 = \sin(q_4)\,\sigma_{12} + \cos(q_2)\cos(q_4)\sin(q_1)$$

$$\sigma_5 = \sin(q_5)\,\sigma_{11} - \cos(q_2)\cos(q_5)\sin(q_3)$$

$$\sigma_6 = \sin(q_4)\,\sigma_{13} - \cos(q_1)\cos(q_2)\cos(q_4)$$

$$\sigma_7 = \cos(q_4)\,\sigma_{12} - \cos(q_2)\sin(q_1)\sin(q_4)$$

$$\sigma_8 = \cos(q_1)\cos(q_3) + \sin(q_1)\sin(q_2)\sin(q_3)$$

$$\sigma_9 = \cos(q_4)\,\sigma_{13} + \cos(q_1)\cos(q_2)\sin(q_4)$$

$$\sigma_{10} = \cos(q_3)\sin(q_1) - \cos(q_1)\sin(q_2)\sin(q_3)$$

$$\sigma_{11} = \sin(q_2)\sin(q_4) - \cos(q_2)\cos(q_3)\cos(q_4)$$

$$\sigma_{12} = \cos(q_1)\sin(q_3) - \cos(q_3)\sin(q_1)\sin(q_2)$$

$$\sigma_{13} = \sin(q_1)\sin(q_3) + \cos(q_1)\cos(q_3)\sin(q_2)$$

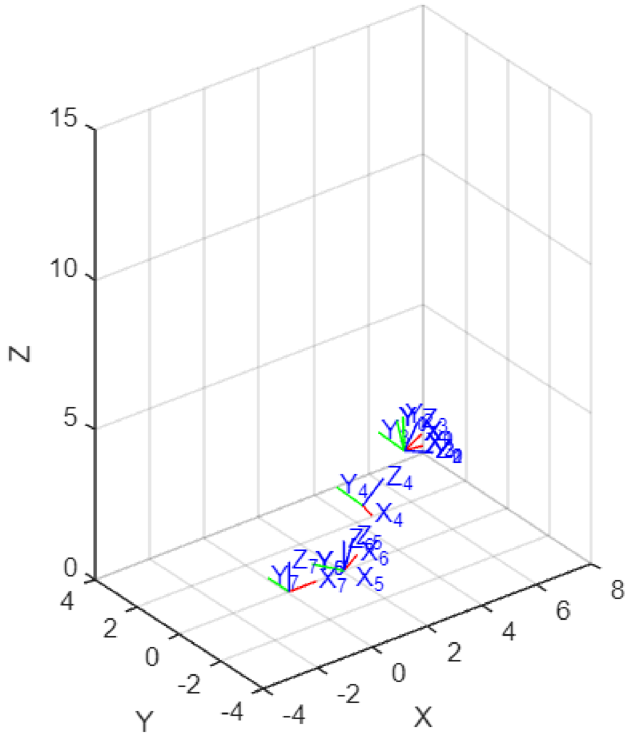
```
% ================================
% SIMULACIÓN NUMÉRICA
% ================================
q1_val = pi/6;  q2_val = pi/4;
q3_val = pi/8;  q4_val = -pi/6;
q5_val = pi/3;  q6_val = pi/9;
L_val = 2;
```

```
H1n = double(subs(H1, [q1, L], [q1_val, L_val]));
H2n = double(subs(H2, q2, q2_val));
H3n = double(subs(H3, [q3, L], [q3_val, L_val]));
H4n = double(subs(H4, [q4, L], [q4_val, L_val]));
H5n = double(subs(H5, q5, q5_val));
H6n = double(subs(H6, q6, q6_val));
H7n = eye(4);

H7_6 = H1n;
H6_5 = H7_6 * H2n;
H5_4 = H6_5 * H3n;
H4_3 = H5_4 * H4n;
H3_2 = H4_3 * H5n;
H2_1 = H3_2 * H6n;
H1_0 = H2_1 * H7n;

% ===============================
% VISUALIZACIÓN DE LAS TRAMAS
% ===============================
figure
axis equal
view(3)
grid on
xlabel('X')
ylabel('Y')
zlabel('Z')
axis([-4 8 -4 4 0 15])
hold on

trplot(eye(4), 'frame', '7', 'rgb', 'length', 1)
trplot(H7_6, 'frame', '6', 'rgb', 'length', 1)
trplot(H6_5, 'frame', '5', 'rgb', 'length', 1)
trplot(H5_4, 'frame', '4', 'rgb', 'length', 1)
trplot(H4_3, 'frame', '3', 'rgb', 'length', 1)
trplot(H3_2, 'frame', '2', 'rgb', 'length', 1)
trplot(H2_1, 'frame', '1', 'rgb', 'length', 1)
trplot(H1_0, 'frame', '0', 'rgb', 'length', 1)
```




```
% ================================
% CINEMÁTICA DIFERENCIAL SIMBÓLICA
% ================================
syms t
syms q1(t) q2(t) q3(t) q4(t) q5(t) q6(t)

H1t = Rt([cos(q1(t)), -sin(q1(t)), 0; sin(q1(t)), cos(q1(t)), 0; 0 0 1], [L;0;0]);
H2t = Rt([cos(q2(t)), 0, sin(q2(t)); 0 1 0; -sin(q2(t)), 0, cos(q2(t))], [0;0;0]);
H3t = Rt([1 0 0; 0 cos(q3(t)) -sin(q3(t)); 0 sin(q3(t)) cos(q3(t))], [0;0;L]);
H4t = Rt([cos(q4(t)), 0, sin(q4(t)); 0 1 0; -sin(q4(t)), 0, cos(q4(t))], [0;0;L]);
H5t = Rt([1 0 0; 0 cos(q5(t)) -sin(q5(t)); 0 sin(q5(t)) cos(q5(t))], [0;0;0]);
H6t = Rt([cos(q6(t)), -sin(q6(t)), 0; sin(q6(t)), cos(q6(t)), 0; 0 0 1], [0; 0; 0]);
H7t = eye(4);

Tt = simplify(H1t * H2t * H3t * H4t * H5t * H6t * H7t);

% Velocidad lineal
pt = Tt(1:3,4);
v = simplify(diff(pt,t));

% Velocidad angular
R = Tt(1:3,1:3);
R_dot = simplify(diff(R,t));
w_skew = simplify(R_dot * R.');
```

```
wx = (w_skew(3,2) - w_skew(2,3))/2;
wy = (w_skew(1,3) - w_skew(3,1))/2;
wz = (w_skew(2,1) - w_skew(1,2))/2;
w = simplify([wx; wy; wz]);

% ===============================
% RESULTADOS
% ===============================
disp('==============================')
```

```
==============================
```

```
disp('Matriz simbólica dependiente del tiempo Tt =')
```

```
Matriz simbólica dependiente del tiempo Tt =
```

```
disp(Tt)
```

$$\left(\begin{array}{cccc} -\sin(q_6(t))\,\sigma_3 - \cos(q_6(t))\,\sigma_6 & \sin(q_6(t))\,\sigma_6 - \cos(q_6(t))\,\sigma_3 & \sin(q_5(t))\,\sigma_{10} + \cos(q_5(t))\,\sigma_9 \\ \sin(q_6(t))\,\sigma_2 + \cos(q_6(t))\,\sigma_4 & \cos(q_6(t))\,\sigma_2 - \sin(q_6(t))\,\sigma_4 & -\sin(q_5(t))\,\sigma_8 - \cos(q_5(t))\,\sigma_7 \\ -\cos(q_6(t))\,\sigma_1 - \sin(q_6(t))\,\sigma_5 & \sin(q_6(t))\,\sigma_1 - \cos(q_6(t))\,\sigma_5 & -\cos(q_5(t))\,\sigma_{11} - \cos(q_2(t))\,\sin(q_3(t))\,\sin(q_5(t) \\ 0 & 0 & 0 \end{array}\right.$$

where

$$\sigma_1 = \cos(q_4(t))\,\sin(q_2(t)) + \cos(q_2(t))\,\cos(q_3(t))\,\sin(q_4(t))$$

$$\sigma_2 = \cos(q_5(t))\,\sigma_8 - \sin(q_5(t))\,\sigma_7$$

$$\sigma_3 = \cos(q_5(t))\,\sigma_{10} - \sin(q_5(t))\,\sigma_9$$

$$\sigma_4 = \sin(q_4(t))\,\sigma_{12} + \cos(q_2(t))\,\cos(q_4(t))\,\sin(q_1(t))$$

$$\sigma_5 = \sin(q_5(t))\,\sigma_{11} - \cos(q_2(t))\,\cos(q_5(t))\,\sin(q_3(t))$$

$$\sigma_6 = \sin(q_4(t))\,\sigma_{13} - \cos(q_1(t))\,\cos(q_2(t))\,\cos(q_4(t))$$

$$\sigma_7 = \cos(q_4(t))\,\sigma_{12} - \cos(q_2(t))\,\sin(q_1(t))\,\sin(q_4(t))$$

$$\sigma_8 = \cos(q_1(t))\,\cos(q_3(t)) + \sin(q_1(t))\,\sin(q_2(t))\,\sin(q_3(t))$$

$$\sigma_9 = \cos(q_4(t))\,\sigma_{13} + \cos(q_1(t))\,\cos(q_2(t))\,\sin(q_4(t))$$

$$\sigma_{10} = \cos(q_3(t))\,\sin(q_1(t)) - \cos(q_1(t))\,\sin(q_2(t))\,\sin(q_3(t))$$

$$\sigma_{11} = \sin(q_2(t))\,\sin(q_4(t)) - \cos(q_2(t))\,\cos(q_3(t))\,\cos(q_4(t))$$

$$\sigma_{12} = \cos(q_1(t))\,\sin(q_3(t)) - \cos(q_3(t))\,\sin(q_1(t))\,\sin(q_2(t))$$

$$\sigma_{13} = \sin(q_1(t))\,\sin(q_3(t)) + \cos(q_1(t))\,\cos(q_3(t))\,\sin(q_2(t))$$

```
disp('==============================')
```

```
==============================
```

```
disp('Vector de velocidad lineal v =')
```

```
Vector de velocidad lineal v =
```

```
disp(v)
```

$$\left(\begin{array}{l} L\,\left(\cos(q_1(t))\cos(q_2(t))\,\frac{\partial}{\partial t}\,q_2(t)+\cos(q_1(t))\sin(q_3(t))\,\frac{\partial}{\partial t}\,q_1(t)+\cos(q_3(t))\sin(q_1(t))\,\frac{\partial}{\partial t}\,q_3(t)-\sin(q_1(t))\,\mathrm{s}\right.\\ L\,\left(\cos(q_1(t))\sin(q_2(t))\,\frac{\partial}{\partial t}\,q_1(t)-\cos(q_1(t))\cos(q_3(t))\,\frac{\partial}{\partial t}\,q_3(t)+\cos(q_2(t))\sin(q_1(t))\,\frac{\partial}{\partial t}\,q_2(t)+\sin(q_1(t))\,\mathrm{s}\right.\\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad -L\,\cos(q_2(t))\sin(q \end{array}\right.$$

```
disp('==============================')
```

```
==============================
```

```
disp('Matriz antisimétrica de velocidad angular w_skew =')
```

```
Matriz antisimétrica de velocidad angular w_skew =
```

```
disp(w_skew)
```

$$\begin{pmatrix} -\sigma_{15}\,\sigma_8 - \sigma_{12}\,\sigma_4 - \sigma_{13}\,\sigma_3 & \sigma_{14}\,\sigma_8 + \sigma_{10}\,\sigma_4 + \sigma_{11}\,\sigma_3 & \sigma_{18}\,\sigma_8 + \sigma_{16}\,\sigma_4 - \sigma_{17}\,\sigma_3 \\ \sigma_{13}\,\sigma_1 - \sigma_{12}\,\sigma_2 + \sigma_{15}\,\sigma_7 & \sigma_{10}\,\sigma_2 - \sigma_{11}\,\sigma_1 - \sigma_{14}\,\sigma_7 & \sigma_{17}\,\sigma_1 - \sigma_{18}\,\sigma_7 + \sigma_{16}\,\sigma_2 \\ \sigma_{12}\,\sigma_6 - \sigma_{13}\,\sigma_5 - \sigma_{15}\,\sigma_9 & \sigma_{14}\,\sigma_9 + \sigma_{11}\,\sigma_5 - \sigma_{10}\,\sigma_6 & \sigma_{18}\,\sigma_9 - \sigma_{16}\,\sigma_6 - \sigma_{17}\,\sigma_5 \end{pmatrix}$$

where

$$\sigma_1 = \cos(q_6(t))\,\sigma_{20} - \sin(q_6(t))\,\sigma_{19} + \sin(q_6(t))\,\sigma_{26}\frac{\partial}{\partial t}\;q_6(t) - \cos(q_6(t))\,\sigma_{25}\frac{\partial}{\partial t}\;q_6(t)$$

$$\sigma_2 = \sin(q_6(t))\,\sigma_{20} + \cos(q_6(t))\,\sigma_{19} - \sin(q_6(t))\,\sigma_{25}\frac{\partial}{\partial t}\;q_6(t) - \cos(q_6(t))\,\sigma_{26}\frac{\partial}{\partial t}\;q_6(t)$$

$$\sigma_3 = \sin(q_6(t))\,\sigma_{21} - \cos(q_6(t))\,\sigma_{22} + \sin(q_6(t))\,\sigma_{28}\frac{\partial}{\partial t}\;q_6(t) - \cos(q_6(t))\,\sigma_{27}\frac{\partial}{\partial t}\;q_6(t)$$

$$\sigma_4 = \cos(q_6(t))\,\sigma_{21} + \sin(q_6(t))\,\sigma_{22} + \cos(q_6(t))\,\sigma_{28}\frac{\partial}{\partial t}\;q_6(t) + \sin(q_6(t))\,\sigma_{27}\frac{\partial}{\partial t}\;q_6(t)$$

$$\sigma_5 = \cos(q_6(t))\,\sigma_{24} - \sin(q_6(t))\,\sigma_{23} + \sin(q_6(t))\,\sigma_{30}\frac{\partial}{\partial t}\;q_6(t) - \cos(q_6(t))\,\sigma_{29}\frac{\partial}{\partial t}\;q_6(t)$$

$$\sigma_6 = \sin(q_6(t))\,\sigma_{24} + \cos(q_6(t))\,\sigma_{23} - \cos(q_6(t))\,\sigma_{30}\frac{\partial}{\partial t}\;q_6(t) - \sin(q_6(t))\,\sigma_{29}\frac{\partial}{\partial t}\;q_6(t)$$

$$\sigma_7 = \cos(q_5(t))\,\sigma_{31} - \sin(q_5(t))\,\sigma_{32} - \cos(q_5(t))\,\sigma_{37}\frac{\partial}{\partial t}\;q_5(t) + \sin(q_5(t))\,\sigma_{36}\frac{\partial}{\partial t}\;q_5(t)$$

$$\sigma_8 = \sin(q_5(t))\,\sigma_{34} + \cos(q_5(t))\,\sigma_{33} - \cos(q_5(t))\,\sigma_{39}\frac{\partial}{\partial t}\;q_5(t) + \sin(q_5(t))\,\sigma_{38}\frac{\partial}{\partial t}\;q_5(t)$$

$$\sigma_9 = \cos(q_5(t))\,\sigma_{35} - \sin(q_5(t))\,\sigma_{40}\frac{\partial}{\partial t}\;q_5(t) + \cos(q_2(t))\cos(q_3(t))\sin(q_5(t))\frac{\partial}{\partial t}\;q_3(t) + \cos(q_2(t))\cos(q_5(t))$$

$$\sigma_{10} = \cos(q_6(t))\,\sigma_{25} - \sin(q_6(t))\,\sigma_{26}$$

$$\sigma_{11} = \sin(q_6(t))\,\sigma_{25} + \cos(q_6(t))\,\sigma_{26}$$

$$\sigma_{12} = \cos(q_6(t))\,\sigma_{27} - \sin(q_6(t))\,\sigma_{28}$$

$$\sigma_{13} = \sin(q_6(t))\,\sigma_{27} + \cos(q_6(t))\,\sigma_{28}$$

$$\sigma_{14} = \sin(q_5(t))\,\sigma_{37} + \cos(q_5(t))\,\sigma_{36}$$

$$\sigma_{15} = \sin(q_5(t))\,\sigma_{39} + \cos(q_5(t))\,\sigma_{38}$$

$$\sigma_{16} = \sin(q_6(t))\,\sigma_{30} - \cos(q_6(t))\,\sigma_{29}$$

```
disp('==============================')
```

```
==============================
```

```
disp('Vector de velocidad angular w =')
```

```
Vector de velocidad angular w =
```

```
disp(w)
```

$$\left(\begin{array}{l} \frac{(\sin(q_5(t))\,\sigma_{22}+\cos(q_5(t))\,\sigma_{21})\,\sigma_6}{2}+\frac{(\sin(q_6(t))\,\sigma_8+\cos(q_6(t))\,\sigma_{10})\,\sigma_1}{2}-\frac{(\cos(q_6(t))\,\sigma_8-\sin(q_6(t))\,\sigma_{10})\,\sigma_2}{2}+ \\ \frac{(\sin(q_6(t))\,\sigma_9+\cos(q_6(t))\,\sigma_{11})\,\sigma_1}{2}-\frac{(\cos(q_6(t))\,\sigma_9-\sin(q_6(t))\,\sigma_{11})\,\sigma_2}{2}+\frac{(\sin(q_5(t))\,\sigma_{24}+\cos(q_5(t))\,\sigma_{23})\,\sigma_6}{2}+ \\ \frac{\partial}{\partial t}\,q_1(t)-\sin(q_2(t))\frac{\partial}{\partial t}\,q_3(t)+\cos(q_2(t))\sin(q_3(t))\frac{\partial}{\partial t}\,q_4(t \end{array}\right.$$

where

$$\sigma_1=\cos(q_6(t))\,\sigma_{16}-\sin(q_6(t))\,\sigma_{15}+\sin(q_6(t))\,\sigma_{26}\frac{\partial}{\partial t}\,q_6(t)-\cos(q_6(t))\,\sigma_{25}\frac{\partial}{\partial t}\,q_6(t)$$

$$\sigma_2=\sin(q_6(t))\,\sigma_{16}+\cos(q_6(t))\,\sigma_{15}-\cos(q_6(t))\,\sigma_{26}\frac{\partial}{\partial t}\,q_6(t)-\sin(q_6(t))\,\sigma_{25}\frac{\partial}{\partial t}\,q_6(t)$$

$$\sigma_3=\sin(q_5(t))\,\sigma_{17}+\cos(q_5(t))\,\sigma_{18}-\sin(q_5(t))\,\sigma_{22}\frac{\partial}{\partial t}\,q_5(t)-\cos(q_5(t))\,\sigma_{21}\frac{\partial}{\partial t}\,q_5(t)$$

$$\sigma_4=-\sin(q_5(t))\,\sigma_{19}+\cos(q_5(t))\,\sigma_{20}+\sin(q_5(t))\,\sigma_{24}\frac{\partial}{\partial t}\,q_5(t)+\cos(q_5(t))\,\sigma_{23}\frac{\partial}{\partial t}\,q_5(t)$$

$$\sigma_5=\sin(q_4(t))\,\sigma_{28}-\cos(q_4(t))\,\sigma_{30}\frac{\partial}{\partial t}\,q_4(t)+\cos(q_4(t))\sin(q_1(t))\sin(q_2(t))\frac{\partial}{\partial t}\,q_2(t)+\cos(q_2(t))\sin(q_1(t))\,\mathrm{s}$$

$$\sigma_6=\cos(q_5(t))\,\sigma_{27}-\sin(q_5(t))\,\sigma_{32}\frac{\partial}{\partial t}\,q_5(t)+\cos(q_2(t))\cos(q_3(t))\sin(q_5(t))\frac{\partial}{\partial t}\,q_3(t)+\cos(q_2(t))\cos(q_5(t))$$

$$\sigma_7=\sin(q_4(t))\,\sigma_{29}+\cos(q_4(t))\,\sigma_{31}\frac{\partial}{\partial t}\,q_4(t)+\cos(q_2(t))\cos(q_4(t))\sin(q_1(t))\frac{\partial}{\partial t}\,q_1(t)+\cos(q_1(t))\cos(q_4(t))$$

$$\sigma_8=\cos(q_5(t))\,\sigma_{22}-\sin(q_5(t))\,\sigma_{21}$$

$$\sigma_9=\cos(q_5(t))\,\sigma_{24}-\sin(q_5(t))\,\sigma_{23}$$

$$\sigma_{10}=\sin(q_4(t))\,\sigma_{30}+\cos(q_2(t))\cos(q_4(t))\sin(q_1(t))$$

$$\sigma_{11}=\sin(q_4(t))\,\sigma_{31}-\cos(q_1(t))\cos(q_2(t))\cos(q_4(t))$$

$$\sigma_{12}=\cos(q_5(t))\,\sigma_{32}+\cos(q_2(t))\sin(q_3(t))\sin(q_5(t))$$

$$\sigma_{13}=\sin(q_6(t))\,\sigma_{26}-\cos(q_6(t))\,\sigma_{25}$$

$$\sigma_{14}=\cos(q_6(t))\,\sigma_{26}+\sin(q_6(t))\,\sigma_{25}$$

$$\sigma_{15}=\sin(q_5(t))\,\sigma_{27}+\cos(q_5(t))\,\sigma_{32}\frac{\partial}{\partial t}\,q_5(t)+\cos(q_5(t))\sin(q_2(t))\sin(q_3(t))\frac{\partial}{\partial t}\,q_2(t)+\cos(q_2(t))\sin(q_3(t))$$

```
%{
==============================
DESCRIPCIÓN DEL PROCEDIMIENTO Y RESULTADOS
==============================

Cinemática Directa:
Se modela una cadena cinemática con 7 marcos (del 7 al 0), donde se aplican
rotaciones sobre Z, Y y X, así como traslaciones en los ejes X y Z. Se utilizan
matrices homogéneas H1 a H7 para describir la posición y orientación del efector
final respecto al marco base. La matriz global T resulta de multiplicar las
transformaciones sucesivas.

Cinemática Diferencial:
Las matrices se redefinen como funciones del tiempo y se deriva simbólicamente la
transformación T(t). Se calcula:
- La **velocidad lineal** `v`, obtenida al derivar la posición del efector respecto
al tiempo.
- La **velocidad angular** `w`, obtenida a partir de la derivada de la matriz de
rotación y su transpuesta, extrayendo los componentes de la matriz antisimétrica
`w_skew`.

Resultados:
Se obtiene la matriz T dependiente del tiempo, junto con los vectores `v` y `w`.
Estos permiten analizar el comportamiento dinámico del manipulador.
%}
```