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Dynamic modelling of parallel robot 2dof

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Dedication

We dedicate this work to whom do we prefer them over ourselves and who were and still a reason to facilitate the paths of life

To our parents

We dedicate it to our brothers and sisters, and we thank them for their encouragement and assistance, as well as to our family members. To all our friends from near and far.

Moreover, all those who stood beside us and helped us with everything they had.

We offer you this research

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Lists of terms

q	position vector
x	End-effector position
J	Jacobian matrix
L	length of leg
R	Half distance between two slider
r	Half-length of end-effector
τ	Motor force
Γ	Slider torque
p	Screw lead
n	Efficiency
M	Mass matrix
C	Coriolis effect
g	Gravity
G	Gravity force
W	Virtual work
M_{nac}	End-effector mass matrix
M_{mot}	Motor mass matrix
f_m	Inertia force of motor
f_N	Inertia force of end-effector
Fe_N	End-effector external force

List of abbreviations

PKM	Parallel kinematic machine
DOF	Degree of freedom
IDM	Invers dynamic model
FDM	Forward dynamic model
EOM	Equation of motion
GCI	Global condition index

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Introduction

The word “system” has become very popular in recent years. It is used not only in engineering but also in different fields science for research and fix problems and for development, and to mention the evolution. Man tried to use science and its various mathematical methods to develop these systems to facilitate work and increase productivity with high accuracy and speed.

Among the most important of these systems are robots of different types, sizes, and goals, and because they are extremely important in this time, especially in the scientific and technological development of studying it and delving into its details and trying to develop it, which is parallel robots. In addition, because we said parallel robots, there must be another type, and it is Serial robots, which has invaded the world with its development, but it remains limited in functions because its components are sequential. That is why parallel robots or parallel kinematic model was addressed as being the key to the current complex industrial processes because of its greater freedom and the possibility of more modification for better and faster solutions. Its dynamics, modeling and trying to develop it because of the degrees of freedom that we can control.

The study of dynamics of parallel robots is very important, when have rigid structure and because it contains some difficulties analyses. Researchers have tried to simplify it to this day, as one of the best ways to simplify its mechanisms is to integrate its movements and dynamics, especially if the matter is limited-to-limited degrees of freedom. For this purpose, we wanted to Processing the modeling of the parallel robots dynamics 2 DOF in order to try to improve its performance, accuracy and speed, and to find solutions to the problems of the internal shells that it contains. This work may be an important step for the development of this robot.

This work dividing to four parts that focus to the modelling dynamic of parallel robots body, the first one highlight on the state of art of this dynamic generally and the reason of this study.

the second part (chapter) specify geometric description, kinematic and the workspace that we used of the parallel robot 2 DOF and apply that one the CNC machine like a good model to discuss.

The third chapter explain how can we apply this modelling using one of methods can give us forward step to success, in addition give the main equations to help us in dynamic part.

Finally the robot dynamic simulation using the MATLAB, SOLIDWORKS & ANSYS simulation by entering the information and relations in the previous chapter and discussion the results.

I Chapter I: State of the art of dynamic parallel robot modelling

We as humans are used to manipulate objects all the time. For us, this is a natural thing and, most of the time; we do it without even thinking about it. However, when we want to imitate this behavior using robots, this process gets much more complicated.

Of course, the modelling of the robots or its behaviors is some difficult exactly when we want to make it on the parallel manipulator or hybrid especially in the part of linking and moving chains or components but it’s possible to achieve that and go to design. After modelling in addition other some studies if there is, this is the reason that made us highlight at dynamic parallel robot modelling.

In this chapter, we will start by introduction near of the reality about parallel robots and we will Acknowledge what’s it exactly, then see a small overview about that in order to take an idea about its role, after that, we enter to our general study about dynamic parallel modelling and the basic methods used in this model.

I.1 Introduction

A parallel robot can be conceived theoretically, as Sir Newton's hand and its fingertips grip a red apple (see Figure I.1). The hand palm constitutes the foundation platform of the parallel robot and the arms operate as serial robots linked to the base platform, all of which manipulate the apple collaboratively. The apple indicates a changing platform, which may be loaded right inside the parallel robot [1][2].

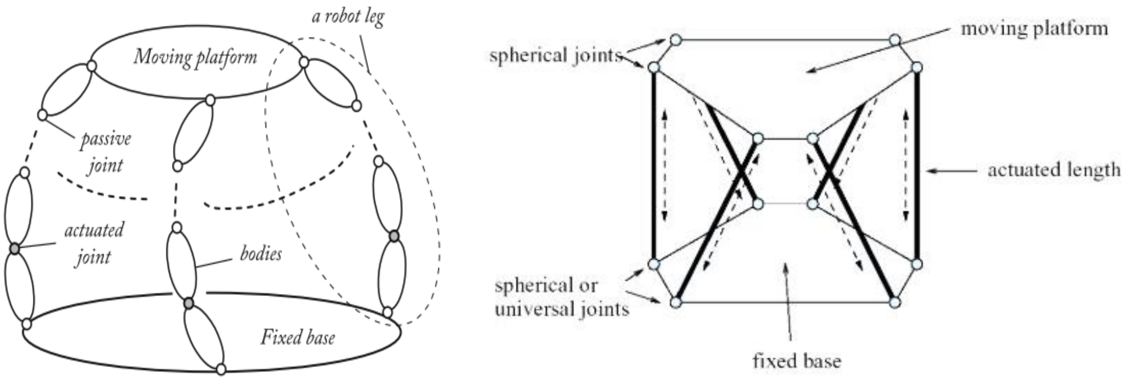
Figure I.1 – A hand clutching a red apple with its fingertips as a metaphor for a similar robot notion.

I.2 Definition

Parallel robots, also known as parallel manipulators or parallel kinematic machines (PKM), are a closed-loop mechanism that controls the motion of their end-effectors by connecting them to the base via at least two separate multiple linkages (kinematic chains). This loop is closed by an n-degree-of-freedom end-effector linked to the base by n separate chains with no more than two links, each operated by a single prismatic or rotary actuator [3] [4].

We deduce form this that the parallel robots consisting of three basics components are:

- The robot's base, which is a fixed component.
- The part on which the end-effector is generally placed
- Kinematic chains, which connect the base to the platform and are also referred to as robot legs



a) The gray joints denote the actuated joints ***b) Classic PKM platform (6DOF)***

Figure I.2: Simple drawing of general parallel robots

The dynamic study of Stewart platforms, which have a high force-torque capacity, high structural stiffness, and low moving mass, was the starting point for the parallel manipulator study. Under basic criteria, the research primarily dealt with the oscillation or inverse dynamics problems. Other publications, over a period, provided a more detailed study to solve the dynamic modeling of parallel manipulators utilizing various mechanical formalisms.

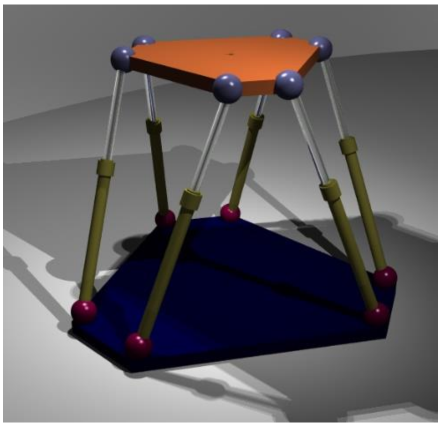


Figure I.3: Stewart platform

I.3 Overview

Maximum of the robots utilized these days are sequential palms wherein various connections are connected through impelled joints, accordingly shaping an unmarried open kinematic chain from the base linked to the give end-effector. Such a course of action gives a huge workspace and rather natural kinematics. In any case, in a couple of uses, severe requests on payload, exactness, or dynamic execution forestall the utilization of sequential robots.

Because many legs of the system share the controlled weight, parallel robots are extremely appealing for a variety of applications. As a result, each kinematic chain carries just a portion of the overall weight, allowing for the construction of robots that are fundamentally more rigid. As a result, such topologies allow for a reduction in the bulk of the moveable links (all actuators are primarily fixed on the base, and many legs are strained by tension/compression efforts), allowing for the employment of less powerful actuators. Structures with such features claimed to have a high payload, great dynamic capabilities, and excellent precision. Parallel robots are being employed in a variety of applications..[5]

I.4 General Comments

System: A system is described as a set of components which work jointly in order to to achieve a specific aim.

The main component variables in these components are referred to as output variables..

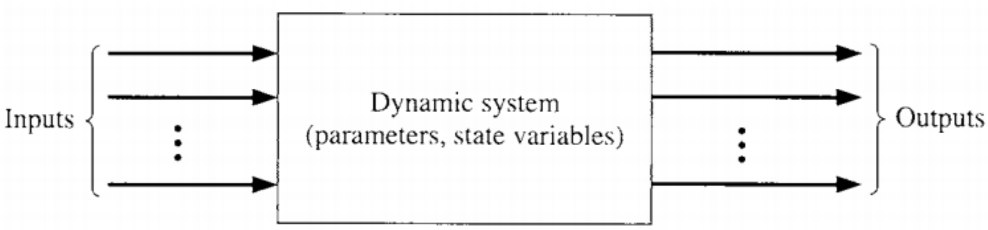


Figure I.4- A dynamic system visual presentation.

A full collection of variables, termed State variables, is required for that system. The status variables are the smallest set of system variables needed to fully represent the state of the system at any given moment and are very important in the modelling and analysis of dynamic systems.

All moving systems on earth and in space are composed of various material bodies related by certain force laws of almost every type that indicate that forces are unified in single or multi-value rules. The material part of all these structures, however, are bodies, solid and elastic systems that are related to the needed performance in the optimum manner. In taking account of these systems, we thus have to make a preliminary decision on how to shape these forces, model them and eventually model the masses.[6].

Dynamic system: is one whose state change with the time. Two main types in dynamical systems are encountered in applications: those for which the time variable in discrete and those for which it is continuous.

Rigid-body dynamics: Robots built from the body stiff offer linkages connected by joints to this body. Given that the connections of rigid are constant, robots usually have just few numbers.

The stiff dynamics of the body examines the movement of the linked systems through the influence of external forces.

Kinetic energy and angular momentum are the two most essential physical quantity in rigid body dynamics. Both lead to the concept of tensor inertia.

Modelling is the process of creating a model that represents the structure and operation of an interest system. A model is comparable, but simpler than the system. A key goal of a model is to allow the analyst to forecast the effect of system modifications. On the one hand, a model should be close to the actual system and incorporate the majority of its outstanding characteristics. Moreover, it should not be so complicated that it cannot be understood and experimented. The potential and greater equalization of realism and simplicity is a good model. Practices in simulation propose that iteratively increase the complexity of a model. Modeling validity is a significant problem. The validation of the model includes the simulations and comparisons between the model output and system output in known input circumstances.

A model for a simulation study is usually a mathematical model created with the aid of software for simulation. The classifications of the mathematical model include deterministic (fixed values for the input and output variables) or stochastic (probabilistic at least for one input or output); static (time is not taken into consideration) or dynamic (time-varying interactions among variables are taken into account). Simulation models often are dynamic and stochastic [6].

Robot control and simulation necessitate the use of a variety of mathematical models. Various modelling levels – geometric, cinematic, and dynamic – are needed based on the targets, job limitations and therefore the performance that is required.

It is not an easy process to obtain these models. The difficulty changes according on the complicated cinematics and degree of freedom of the mechanical structure.

Using these models on top of objects and simulation necessitates efficient and simple-to-use algorithms to estimate the geometric parameter values and, as a result, the robot's dynamic parameters. Furthermore, on-line application of an effect rule on a robot controller necessitates efficient models with fewer actions. These conditions are met by the approaches provided in this book. As a result, the dynamic element of the parallel manipulator will be the focus of this chapter's research.

I.5 Dynamics modelling

A dynamic model depicts an object's activity across time. It's utilized when an object's activity may be best characterized as a series of states that happen in a specific order.

A dynamic model connects the active forces that operate on a robot to the accelerations that they generate, or vice versa. These active forces might be both rotational moments and translational forces. Robot dynamics is the application of rigid-body dynamics to robotics where the robot mechanism is typically represented as a rigid-body system.

I.5.1 Inverse Dynamic Model (IDM)

An inverse dynamic model calculates the torques and/or forces that the robot's actuators must provide in order for the end-effector to move in a specific direction. It has been used to control the movements and forces of robots.

I.5.2 Forward Dynamic Model (FDM)

For given forces, locations, and velocities, a forward dynamic model computes the accelerations of the state variables. A direct dynamic model is another name for it. It's primarily utilized in simulations.

I.5.3 Implicit Dynamic Model (ImplDM)

We provide an implicit dynamic model that is equivalent to a robot's equations of motion (EOM).

I.6 Why we interested in the Parallel Robots Dynamics?

Its dynamic model heavily influences robot design and control. The inverse dynamic model can be used to pick actuators for robot design, while the direct dynamic model is used to run simulations in order to test the robot's performance and compare the relative benefits of different control methods. The inverse dynamic model is used in robot control to calculate the actuator torques required to achieve a desired motion. It's also utilized to figure out what dynamic parameters are required for to achieve control and simulation applications.

The majority of works that can be utilized to compute the dynamic models of (flexible and/or rigid) parallel robots are broad works that define general equations for limited or closed-loop systems.[5]

However, the information deficiency is generally the following:

- They frequently fail to recognize, and do not give easy methods for computing, that Jacobian matrices needed for setting dynamic constraints in the dynamic model are not that simple.
- Most of these projects offer no efficient method for calculating dynamic models in terms of the reduction of the '+,' '–', 'after' and '/' operators needed to get the individual model expression. However, this optimization is important to model production to anticipate and manage robot behavior and speed up the ideal robot design process till that have best possible control.
- The facts that (i) dynamic modeling may degenerate in the presence of specific types of singularities and (ii) this degeneration may be avoided by optimum planning of trajectories is entirely missing (optimal with respect to a criterion based on the dynamic model).
- They do not offer experimental evidence showing that parallel manipulators models can be extremely accurate even if they are complex.

I.7 Dynamic modelling of parallel robots

Due of their several closed loops, parallel robots are complicated multi-body systems that are challenging to describe. For design requirements and sophisticated control of parallel robots, dynamic modeling is required.

The dynamic and kinematic models of the legs are created utilizing serial robot-specific approaches and, finally, basic loops. As a result, the computational complexity of the suggested models can be lowered by employing approaches established for serial robots many years ago. The platform's dynamics are calculated using Newton-Euler equations, which calculate total forces and moments on a solid body. We present a new technique for calculating the inverse Jacobian matrix of parallel robots utilizing the Jacobian matrices of the legs since the robot's Jacobian matrix is required. [7]

Figure I.5 -Parallel Robot ABB IRB 360 Flex-picker

I.7.1 Inverse dynamic modelling of parallel robots

A parallel robot is a multi-body complicated system with several closed loops. It is made up of parallel legs that link a moving platform to a stationary foundation. Non-redundant robots are those in which the number of active joints is equal to the platform's degrees of freedom. The number of legs is represented by m, while the number of degrees of freedom (DOF) of the platform is represented by n. The frame $\sum_p$ is fastened to the platform, while the frame $\sum_p$ is fastened to the base. The forces and torques of motorized joints are calculated using the inverse dynamic model as a function of the mobile platform's intended trajectory.

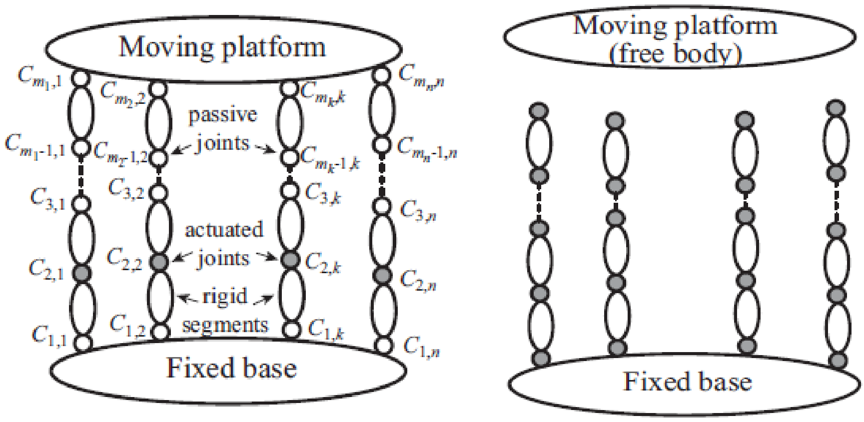
We propose using structural features of parallel robots to derive dynamic models by partitioning the system into two subsystems: the platform and the legs. The platform's dynamics are computed as a function of its Cartesian variables (spatial Cartesian location, velocity, and acceleration), whereas the legs' dynamics are calculated as a function of their joint variables $(q_i, \dot{q}_i, \ddot{q}_i)$. After projecting these dynamics on the active joint axis, the active joint torques are calculated by adding them together.

I.7.2 Direct dynamic model of parallel robots

The Cartesian location and velocity of the platform may be used to represent the state of the parallel robot. As a function of the state variables and the input of the motorized joint torques and forces, the robot's direct dynamic model delivers the platform Cartesian acceleration.

Summary to say, Parallel robots can be seen in dynamics as:

- A tree structure + platform.
- Loops are closed using constraints equations (Jacobian matrices).



a) Kinematic chain *b) virtual tree structure*

Figure I.6- Structures of parallel robot's dynamics

I.8 Methods of dynamic modelling

I.8.1 Dynamic Modelling Methods of serial Robots:

Before we talk about the methods, of modelling of parallel robots we must know first about the serial robots and its modelling methods because it is the starting point that brought us to deduce the Dynamic Modelling Methods PKM. So, the serial manipulator is an open loop-chain kinematic structure consists of many links joined in series by various types of joints, notably revolute and prismatic joints., those methods like Euler-Lagrange, Virtual Work method and others are very important for dynamic modelling whether in the serial or the parallel robots.

I.8.2 Dynamic Modelling Methods of Parallel Robots:

For parallel robots, in fact, there is only one method specifically designed for it, which is **Khalil's method**, which he deduced from serial robot's methods. These are the most famous methods The Euler-Lagrange method; the Newton-Euler recursive method, the D'Alembert method, and Kane's method are all examples of these methods. We'll go through these approaches in more detail later[2].

I.8.2.1 Euler-Lagrange Method

In order to obtain the dynamic equations, the Euler-Lagrange method uses the concept of energy conservation in a mechanism. Analytic and closed-form equations are used. By differentiating the Lagrangian function, the Euler-Lagrange equations are derived:

$$L(q,\dot{q}) = T(q,\dot{q}) - V(q) \qquad \text{(I-1)}$$

Which yields:

$$\frac{d}{dt}\left(\frac{\partial \mathrm{L}}{\partial \mathrm{L}}\right)-\frac{\partial \mathrm{L}}{\partial \mathrm{q}}=\frac{d}{dt}\left(\frac{\partial \mathrm{T}}{\partial \dot{q}}\right)-\left(\frac{\partial \mathrm{T}}{\partial \mathrm{q}}-\frac{\partial \mathrm{V}}{\partial \mathrm{q}}\right)=\Gamma \qquad \text{(I-2)}$$

T and V are the kinematic and potential energies, respectively. This method is useful for studying dynamic characteristics as well as analyzing control methods. However, because it is dependent on energy, it is less geometrically obvious, and it is said to be computationally inefficient.

I.8.2.2 Newton-Euler Method / Luh-Walker-Paul's Algorithm

The dynamic equations are derived using the Newton-Euler method, which takes use of the balance of forces and torques in a Mechanism. Numeric and recursive-form equations are used. Newton's equations of motion are used in this method:

$$f = ma \quad , \quad \tau = \mathcal{L}^T\dot{\omega} + \omega \times (\mathcal{L}^T\, \omega) \qquad \text{(I-3)}$$

where f, m, a, and L represent the body's linear momentum, angular momentum, mass, linear acceleration, angular velocity, and inertia, respectively. The dynamics are calculated using two loops in the method:

–Forward Loop: moves from base to end to evaluate the velocities and the accelerations.

– Backward Loop: moves from end to base to compute the forces and torques.

It is systematic and efficient for real time implementation of the control schemes.

I.8.2.3 D'Alembert Method / Principle of Virtual Work

To obtain the dynamic equations, this method uses the idea of virtual work conservation in a mechanism. The total of variations in work arising from virtual forces operating via a real displacement or real forces acting via a virtual displacement equals zero, according to this formula. The displacement is tiny and conforms to the system's limitations:

$$0 = \sum_i (f_i - m_i a_i)^T\, \delta x_i = 0 \qquad \text{(I-4)}$$

Where f_i represents an applied force, f_i represents a particle's mass, a_i represents a particle's acceleration, δx_i represents an infinitesimal displacement compatible with the restrictions, and I represents a specific particle in the system [2].

I.8.2.4 Kane's Method

While deriving the equations of motion of a system, Kane's method has the Lagrange form of D'Alembert principle and gives numerous advantages. It does not necessitate the employment of energy functions or, as a result, the difficulty of their differentiation. It employs generalized forces, with non-contributing forces being removed directly by projection. It allows you to use variables other than generalized coordinates, which can have a big impact on the equations of motion that arise. For multi-body systems, this method is also more useful.

Parallel robot's methods: All the methods for serial robots can be adapted to parallel robots. In addition to those methods, there exist one method designed for parallel robots in particula, it's **Khalil's Method**.

I.8.2.5 Khalil's Method:

Khalil proposed [8] to obtain the equations of motion of a parallel robot by extending the systematic approach of the modelling of a serial robot. This approach proceeds as follows:

- Each of a parallel robot's kinematic legs is treated as a separate serial robot, and the inverse dynamic model of this kinematic leg is constructed using one of the approaches described for serial robot modeling.
- • On the moving platform, the equilibrium of all efforts (torques and forces) is determined. These efforts originate from each of the kinematic legs, the moving platform's acceleration, and external forces (weight, contact, etc.).
- On the moving platform, the whole effort is transferred onto the active joints.

Because each leg contributes to the overall effort on the moving platform, this technique is extremely straightforward for dealing with kinematic limitations:

$$\Gamma = FDKM_{robot}^{T}\left(W_{platform} + \sum_{i=1}^{N_{legs}}\left(J_i^T\ IDKM_{leg(i)}^{T}\ IDM_{leg(i)}\right)\right) \qquad \text{(I-5)}$$

Where $FDKM_{robot}^{T}$ is the parallel robot's forward differential kinematic model, $W_{platform}$ is the wrench vector for the moving platform's dynamics, J_i^T is the Jacobian matrix relating the terminal point of the i^{th} leg's velocity to the end-effector velocity, $IDKM_{leg(i)}^{T}$ is the inverse differential kinematic model of the i^{th} leg, and $IDM_{leg(i)}$ is the inverse dynamic model of the i^{th} leg. Any of the current serial robot algorithms may be used to calculate the $IDKM_{leg(i)}^{T}$.

I.9 Conclusion

when we start talking about parallel robots it had better to have a background about closed loop mechanism which is in command of their end-effectors' movement, this last introduce the result that we want arrive on.

Modeling of dynamics parallel robots was among the current state of knowledge, issues are an important work to discuss, it and apply it for large framework because the most are constructed of the rigid body offer links have a constant shape, these links connected together by joints in order to help us for represent the configuration of robots and its dynamic modelling. This dynamic modelling is an important also for design and control because it represented the behaviors of robots as a rigid-body and its end effectors. From that, we can deduce the case of robots (position, inertia, velocity...) according on the dynamic model type.

Since there is a dynamic modelling of parallel manipulators, then there a method for apply it and it namely Khalil's method that he introduced from the different serial robots modelling methods, which goal to find equation of motion of these parallel manipulators.

II Chapter II: Geometric Description of 2Dof parallel robots

Parallel robotics has can be much less developed than serial robotics. However, researches in this field continues to grow, especially because it more attracts companies and researcher, proving the growing interest it arouses, that because it may offer several advantages over their serial counterparts, like high dynamic capacities and high structural rigidity.

The theoretical difficulties need to be rethink, because the design of parallel manipulators differs greatly from the one utilized for serial link manipulators. In the other hand Due to its features It might become a solution a better solution for solving many industrial problems, especially on machining process[9][10].

In fact, not all the industrial task requires 6-DOF or 4-DOF since as for some simpler tasks

2-DOF translation is sufficient.

From this point, we will describe structure and mechanism of system that we want design and we will continue this chapter by some useful geometric description about the velocity, singularity, calibration, and workspace that we use them in our system.

II.1 Introduction:

In recent years, two degrees of freedom (DOF) rotational or translational are employed for a large variety of specific tasks. They are used as robot wrists, machining tool heads, and even joints for bio-inspired robots.

Since last recent years, two degrees of freedom (DOF) rotational or translational are employed for a large variety of specific tasks. They are used as robot wrists, machining tool heads, and even joints for bio-inspired robots.

A gadget needs adequate mobility and rotary capabilities to meet these unique job requirements. Therefore, it is of fundamental necessity to choose an architecture and geometry with the necessary platform mobility. In truth it is a complicated issue to choose a certain suitable configuration with respect to numerous elements.

Some of these concerns include the transfer and disconnection of the movement axis, the potential of collisions between links, in addition the existence of uniqueness in the workplace .Mechanism kinematics analytical models may play a major role in addressing all these problems, as well as implementing a high efficiency approach for control.

The arrangement of parallel kinematic of the connections actually gives more rigidity and lower motion, thereby reducing the inertia effects. Parallel robots thus offers greater dynamic performance, which is interesting for processing that has high speed. But this last highlight some of the flaws of serial kinematics in which the axes support each other in series, including the joints and actuators of some industrial machine tools. That is why we make us discuss some geometric description point in parallel robots 2DOF. [10].

II.2 Structure and mechanism description:

The Figure II.1 displays a kinematic drawing of a 2-DoF PKM setup appropriate for use to the machine tool. There are two vertical columns with ball screws, LM guides and sliders on the two equal sides. Each peg is built like parallelogram as a four-bar mechanism to keep the tool platform in continuous orientation and to ensure the PKM needed rigidity and to symmetry the construction.

The leg ends are connected by revolving joints to the tool platform and slider. Each slider is powered by a separate servomotor. By separate actuation of the sliders, the special position of the tool platform in the plane is achieved. The legs are long and rigid also light or can be designed light mass, and hence may be utilized in machine tools. this PKM provides a wide working space because all connections are single DOF-type, [11].

The motion of the slider dependent of the rotation of servomotor (stepper). This actuation allow slider to move up and down in order to actuate the end-effector related by legs with it. We can also control this movement by the control of servomotor acceleration and velocity as we like. That is the way to use this mechanism for moving platform in the workspace. That we can move on.

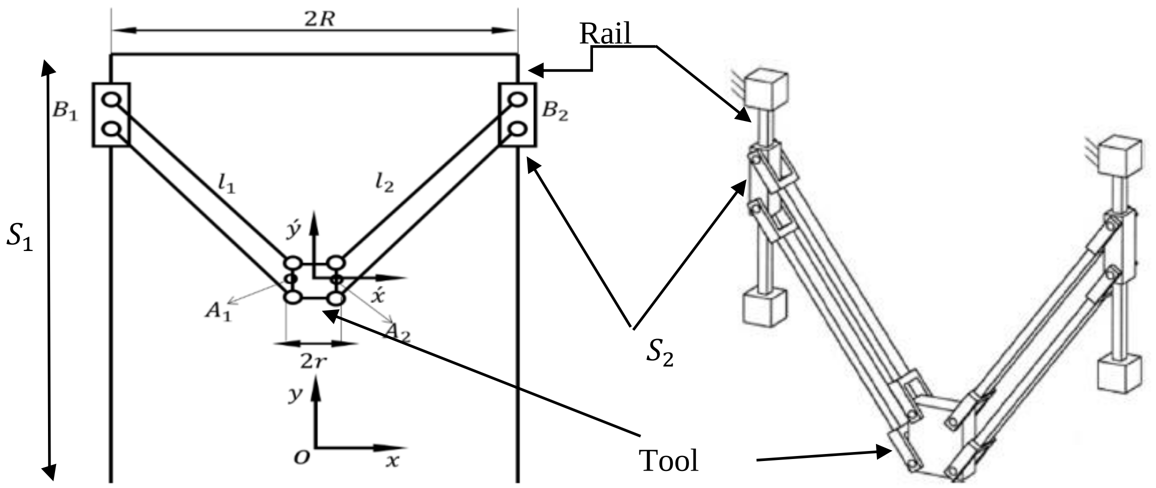


Figure II.1 - The kinematic model of a 2-DoF PKM

II.3 Geometric modelling:

Direct and inverse geometric model's resolution is a principal problem in robotics and its study.

It must to the inverse geometrical model of parallel robots, make the possible finding of articular configuration making it possible to place the platform of the manipulator in the configuration that we want. This type of modelling solution does not pose generally any problem.

The direct geometric model of fully parallel kinematic mechanism considered a complex problem, it difficult to compare it with the inverse geometric model for the serial manipulator. Thus, a lot of research has been done to solve the following problems:

- The rapid search for a solution from a known configuration.
- Research of the maximum number of real solutions.
- The simplification of the model by adding additional sensors.

II.4 Kinematic study:

Position and velocity analysis are part of the kinematics of a 2-DoF PKM. The position analysis may be performed using two distinct approaches are vector method and geometric method [12][13].

II.4.1 Position analysis

From the Figure II.1 we can simplified the chain model as a link A_iB_i $(i = 1\ or\ 2)$. This figure presented the base coordinate system O_{xy} is attached to the base with its y-axis vertical through the center point of the distance between B1 and B2. A moving coordinate system O_{xy} is fixed on the moving platform r_{Ai} and r_{Bi} are the position vectors of the joint positions A_i and B_i, respectively. 2r is the moving platform width and 2R is the width between the two columns. The position vector of the origin O' with respect to the coordinate system O_{xy} is defined as:

$$r_{O'} = [x\ \ y]^T \tag{II-1}$$

The position vector of joint position A_i in $O'_{x'y'}$ is:

$$A_1 = (-r\ ,0) \quad \rightarrow \quad r'_{A_1} = [-r\ \ 0]^T \tag{II-2}$$

$$A_2 = (r\ ,0) \quad \rightarrow \quad r'_{A_2} = [r\ \ 0]^T \tag{II-3}$$

Then the position vector of A_i in the base coordinate system O_{xy} can be expressed as:

$$r_{A_i} = r'_{O'} + r'_{A_i} \tag{II-4}$$

We put $y = q$ than, the position vector of joint position B_i in O-xy is:

$$B_1 = (-R\,, q_1) \quad \rightarrow \quad r_{B_1} = [-R \;\; q_1]^T \tag{II-5}$$

$$B_2 = (R\,, q_2) \quad \rightarrow \quad r_{B_2} = [R \;\; q_2]^T \tag{II-6}$$

Thus, the constraint equation associated with the i[th] kinematic chain can be written as:

$$r_{A_i} - r_{B_i} = l_i n_i, \qquad i = 1\,, 2 \tag{II-7}$$

Where l_i is the length, n_i is the unit vector of the i^{th} link.

$$l^2 = (y - q_1)^2 + (x + (R - r))^2 \tag{II-8}$$

$$l^2 = (y - q_1)^2 + (x - (R - r))^2 \tag{II-9}$$

Solving (II-7) and the two last equations, the position of slider namely q_1 and q_2 can be expressed as follow:

$$q_1 = y \pm \sqrt{l_1^2 - (x - r + R)^2} \tag{II-10}$$

$$q_2 = y \pm \sqrt{l_1^2 - (x + r - R)^2} \tag{II-11}$$

For the configuration shown in Figure II.1, the inverse solutions of the kinematics are:

$$q_1 = y + \sqrt{l_1^2 - (x - r + R)^2} \tag{II-12}$$

$$q_2 = y + \sqrt{l_1^2 - (x + r - R)^2} \tag{II-13}$$

From equations (II.10) and (II.11), the solutions for the direct kinematics of the manipulator can be expressed as:

$$AY^2 + By + C = 0 \tag{II-14}$$

$$(a^2 + 1)y^2 + 2(ab + ya - q_1)y + (q_1^2 + b^2 + 2yb + y^2 - l^2) = 0 \tag{II-15}$$

Where:

$$a = \frac{q_1 - q_2}{2(R - r)} \qquad b = \frac{q_2^2 - q_1^2}{4(R - r)} \qquad c = \frac{l_1^2 - l_2^2}{4(R - r)} \qquad y = (R - r) \tag{II-16}$$

$$x = ay + b + c$$

The most important equation that we arrive them are II.7 and II.13 because they described the solutions $q_i(i = 1\,,2)$ as the **direct and inverse kinematics** of the manipulator in closed form.

For a more detailed explanation, the position of the actuators or sliders on their respective rails, q_i may be solved for a given position of the tool platform, p (see Figure III.1 above), If the values of q_i meet the next condition, the given location of the tool platform p is said to be attainable:

$$0 \leq q_i \leq S_i \quad \text{For } i = 1\,,2$$

II.5 Singularity analysis:

Parallel robots Singularities have been studied primarily for basic concerns such as definition, categorization, and identification. [14].

Therefore, in addition to it is much more complex structure in terms of its dynamics, kinematics, planning and control, a parallel manipulator also has, other singularities different of the usual end-effector singularities like the direct kinematic singularities, inverse kinematic singularities, and joined singularities, and can be recognized by the controller Jacobian

For example, at the point when one of the links is horizontal, the controller encounters an inverse kinematic singularity, i.e. J is singular for a certain pose of the tool platform $(y - q_i) = 0$ for any $i = 1\,,2$ (it can be called stationary singularity).

Each leg is orthogonal to its rail at this case, as a result the mechanism loses one or more degrees of freedom . When J becomes solitary on the other hand, the mechanism gains one or more degrees of freedom. The uncertainty singularity is a term used to describe such singularities.[15] [16].

When we want recognize singularities, we will be taking the derivatives of equations (II.10) and (II.11) with respect to time gives

$$\dot{q}_1 = \dot{y} - \frac{x - r + R}{\sqrt{l_1^2 - (x - r + R)^2}}\dot{x} \tag{II-17}$$

$$\dot{q}_2 = \dot{y} - \frac{x+r-R}{\sqrt{l_1^2-(x+r-R)^2}}\dot{x} \qquad \text{(II-18)}$$

The last equation can be rearranged in matrix form as:

$$\begin{bmatrix}\dot{q}_1\\ \dot{q}_2\end{bmatrix} = J^{-1}\begin{bmatrix}\dot{x}\\ \dot{y}\end{bmatrix} \qquad \text{(II-19)}$$

Where $J^{-1}$is the Jacobian inverse expressed as

$$J^{-1} = \begin{bmatrix} -\frac{x-r+R}{\sqrt{l_1^2-(x-r+R)^2}} & 1 \\ -\frac{x+r-R}{\sqrt{l_1^2-(x+r-R)^2}} & 1 \end{bmatrix} \qquad \text{(II-20)}$$

Direct kinematic singularities occur when one link of a chain and a link of the other chain are collinear. Since $l_1+l_2 > 2R$ combined singularities in this manipulator shown in Figure cannot occur. Figure shows one example of each kind of singularity. In practical applications, singularities are avoided by limiting the task workspace. Because e these singularities lead to lost controllability and debasement of the regular solidness of the controllers, that why they should be stayed away from in the undertaking workspace.

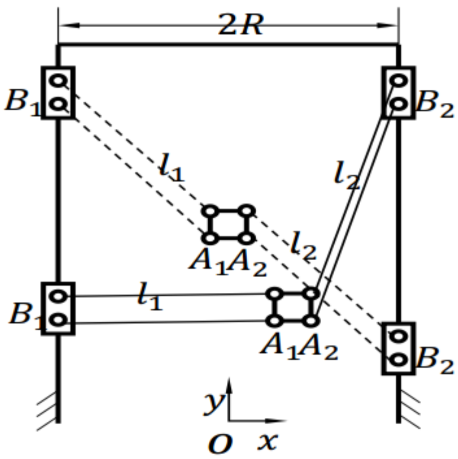


Figure II.2- Singular configurations

II.6 Workspace

The workspace of a mechanism is one of important factors dominating its kinematic performance. Especially, since parallel mechanisms suffer from smaller workspace, compared to serial ones, it is very important to analyze the size and the shape of their workspace in the viewpoint of industrial applications[17][18][19].

In contrast to a traditional machine tool, the workspace of a 2-DoF PKM is complicated in shape. Because of the constant orientation TCP (tool center point) of the mechanism, the workspace possibility of this PKM is a two-dimensional space.

The workspace for the 2-DOF planar parallel manipulator is defined as a plane area generated from the workspace of the moving platform's reference point O' by derived.

As a result, the accessible workspace of this point (O’) is the intersection of the sub workspaces associated with the two kinematic chains, as seen in Figure II.3.

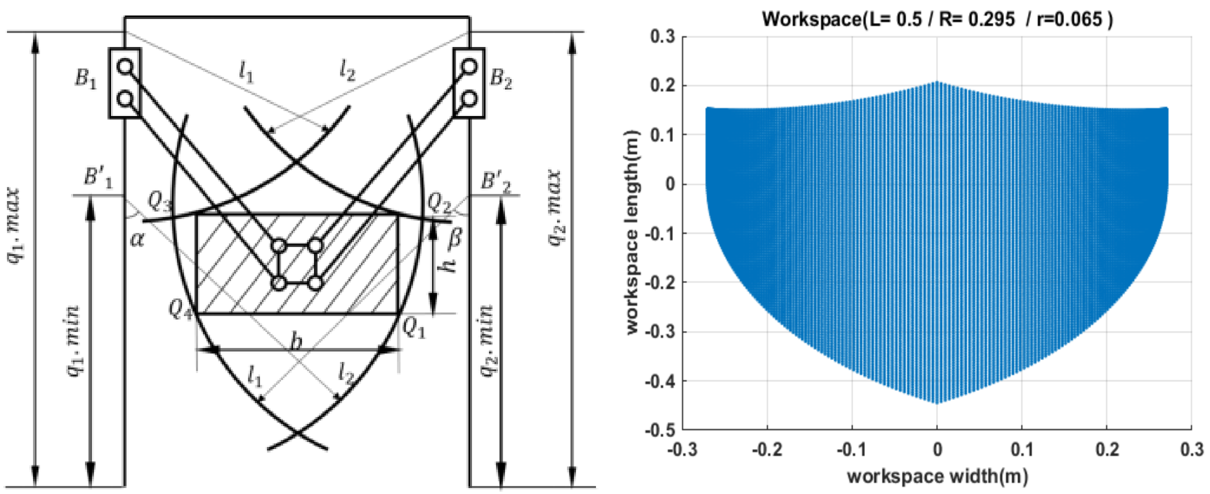


Figure II.3 - Manipulator workspace

The slider position is calculated using inverse kinematics equations and its limitations are verified.

We can be rewritten these equations as (II-8) (II-9).

II.7 Workspace Optimization:

The workspace size of a mechanism like this should be maximized, because parallel mechanisms on average have a smaller workspace than serial ones. However, designing the mechanism with the maximum workspace in mind may result in undesired kinematic properties like poor dexterity and/or stiffness. As a result, while improving a workplace, a qualitative evaluation should be carried out.

II.7.1 Performance indices

II.7.1.1 Global Conditioning Index (GCI)

The Parallel Kinematic Model dexterity, also known as the global conditioning index (GCI) considering as the first performance index used as an objective function to be maximized. it’s the capacity to apply pressures and moments in any directions during machining, or to alter the position and orientation of the tool platform arbitrarily. The GCI examines the dexterity (or Jacobian condition number) PKM over the whole workspace, with the equation:

$$GSI = \frac{\int_{Wc}\left(\frac{1}{K(J)}\right)dW}{\int_{Wc}dW} \tag{II-21}$$

Where d W is differential workspace of the mechanism, and is the condition number of the Jacobian J. at a given moving platform position within the workspace.

II.8 Conclusion

The choice of architecture and geometry is of important standard for satisfy some specific actions of the different parts of the robot. The inverse and direct geometrical model of parallel robots used for solve some problems posed on this type of PKM Taking into account the difficulty of the direct geometric model of fully parallel kinematic mechanism.

The main part of this description is to kinematic study; it is mean position and velocity because they help us to find the useful workspace size that we work on. In addition, because we want to save the ability controllability of the regular solidness of the controllers, we should avoid problems of singularities that may cause damage to the system. From that, we had to try study and optimize the workspace and knowing the specific indexes it used.

III Chapter III: Dynamic Modeling of 2Dofs Parallel Robots

Dynamic models of parallel robots have been of widespread interest in the past decade. Whereas, it was difficult to find an adequate solution to the system but it can be easily computed now for its application as control algorithms. Despite the multiplicity of methods applied or applicable to integrating dynamic parallel robots, their results are not currently easy to process.

There is a method usually used to solve these problems, which is to cut the closed chain mechanism in the passive joints and to address the dynamics of the robot in the first. After this, the closure requirement is mitigated either by using Lagrange multiples or applying the default working principle of d’ Alembert through the average of some Jacobite matrix.

As any chapter, this began by a small introduction have an entry of basics modelling needed, than a short discussion of simplifying hypothesis in order to simplify this activity(modelling) of this robot (2dof), next we will calculate and find the motors and end-effectors acceleration equations and mass matrix, forces and Coriolis vectors using the principle of virtual work.

III.1 Introduction

The whole dynamic model, which accounts for the masses and inertias of all the connections, leads to extremely intricate solutions. As a result, certain simplifying hypotheses must be employed for orientation and control reasons. Such simplifications are used in the dynamic model of the 2dof robot to avoid all this complication.

III.2 Simplifying hypothesis

The pattern becomes more complicated in parallel robots due to the mobility of the forearms. We can make this problem easier by ignoring their rotating inertia. Due to the use of lightweight materials in their construction, this assumption is not very restrictive. As a result, the force between the movable plate and the arm is directed in the direction indicated by the forearm's orientation. In parallel, the robot model is built on the virtual working method, which simplifies the following hypothesis:

- Forearm rotational inertias are ignored.
- The effects of elasticity and friction are ignored.
- For analytical reasons, the weights of the forearms are best separated into two sections, half at the lower end (the traveling plate) and half at the top end (motor mass).

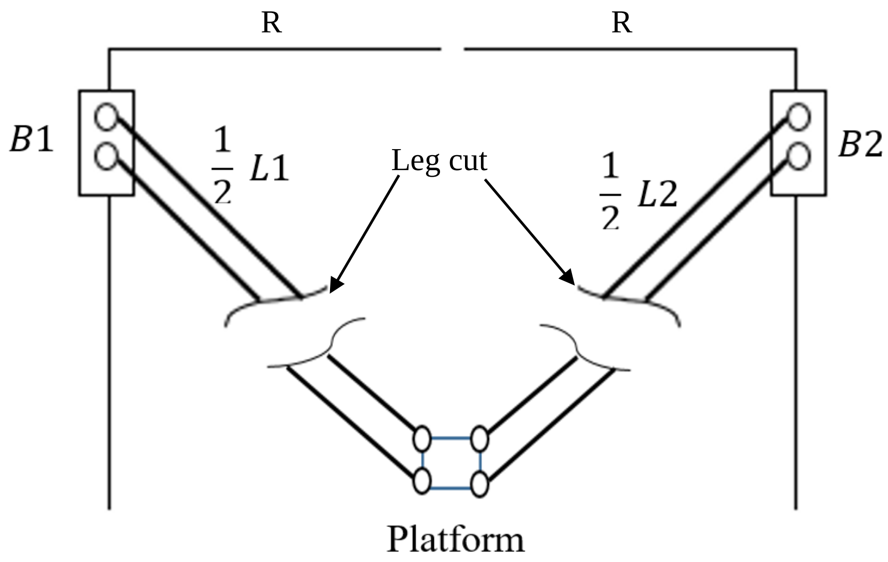


Figure III.1: dividing masses

The parallel robot is made out of parallelogram rods. The dynamic model's complexity is increased by these parallelograms. Similar approaches earlier offered can be used to simplify the dynamic problem. The concept is to ignore the rotational inertia of the parallel bar and separate the bar masses into two parts, focusing on the two joint ends. As a result, half of the mass of the rods is concentrated at the higher end (the engines), while the other half is concentrated at the lower end (the movable platform). This simplifying assumption reduces the handler to just two parts: the motors and the mobile platform. The cursor's and the moving platform's comparable masses may therefore be expressed as:

$$M_{nac} = M_1 + 2M_b \tag{III-1}$$

$$M_{mot} = M_2 + M_b \tag{III-2}$$

While M_{nac}, M_{mot} are the corrected masses of the nacelle and of each engine respectively, M_1 the Initial mass of the nacelle, M_2 the mass of an engine and Mb the mass of a bar.

The determination of the mass matrix of the robot is essential for decoupling the various axes in the overall robot control [20].

III.3 The acceleration of end-effector and motors:

We can find the expression of $\ddot{x}$ as a function of $\ddot{q}$ by deriving the direct kinematic model with respect to time we get[21]:

$$\ddot{x} = J\ddot{q} + \dot{J}\dot{q} \tag{III-3}$$

Starting from the term velocity of a slider, we can derive the term acceleration by deriving it:

$$\ddot{q_1} = \ddot{y} - \left(\frac{(2x - 2r + 2R)(x - r + R)}{2\sqrt{(l_1^2 - (x - r + R)^2)^3}} + \frac{1}{\sqrt{l_1^2 - (x - r + R)^2}}\right) * \dot{x}^2 - \left(\frac{(x - r + R)}{\sqrt{l_1^2 - (x - r + R)^2}}\right)\ddot{x} \tag{III-4}$$

$$\ddot{q_2} = \ddot{y} - \left(\frac{(2x + 2r - 2R)(x + r - R)}{2\sqrt{(l_2^2 - (x + r - R)^2)^3}} + \frac{1}{\sqrt{l_2^2 - (x + r - R)^2}}\right) * \dot{x}^2 - \left(\frac{(x + r - R)}{\sqrt{l_2^2 - (x + r - R)^2}}\right)\ddot{x} \tag{III-5}$$

In the other hand, we have the jacobian matrix derivative as follow:

$$\dot{J} = \begin{bmatrix} -\left(\frac{(2x - 2r + 2R)(x - r + R)}{2\sqrt{(l_1^2 - (x - r + R)^2)^3}} + \frac{1}{\sqrt{l_1^2 - (x - r + R)^2}}\right)\dot{x} & 0 \\ -\left(\frac{(2x + 2r - 2R)(x + r - R)}{2\sqrt{(l_2^2 - (x + r - R)^2)^3}} + \frac{1}{\sqrt{l_2^2 - (x + r - R)^2}}\right)\dot{x} & 0 \end{bmatrix} \tag{III-6}$$

III.4 Dynamic modeling of parallel robot 2DOF

For an articulated manipulator, its rigid body dynamics is given by the following equation:

$$\tau = M(q)\ddot{q} + C(\dot{q}, q) + G \tag{III-7}$$

Where M is the positive definite inertia matrix, C vector including the centrifugal and Coriolis effects, and G vector containing the terms of gravity.

III.4.1 The principle of virtual work

To get equations, several works employed the concept of virtual work (III-7). Virtual labor δW carried out by all external forces F on the body during virtual displacement ,δr, is equal to zero in line with the constraints imposed on the body under this notion of balance.:

$$\delta W = \sum_{i=1}^{n} F_i . \delta r_i = 0 \tag{III-8}$$

In equation (III-8), only the external forces are taken into account, Internal factors such as tension and forces of are disregarded since they do not do any virtual labor. Traditionally, the idea of work has been employed to solve static issues. The force (force of inertia) coming from the acceleration an of the body mass m is included in the force (force of inertia) for a system that is not at rest (III-8). The d'Alembert concept refers to the expansion of virtual work to dynamic circumstances. (III-9) is an expansion of (III-8) that includes the force of inertia:

$$\delta W = \sum_{i=1}^{n} (F_i - m_i a_i).\delta r_i = 0 \quad \text{(III-9)}$$

III.4.2 Dynamic modeling with the principle of virtual work

From the kinematic model, we know that the Jacobian matrix. The connection between the speed of the actuators and the speed of the mobile platform is described by a two by two matrix. We may generate from equation (II-20) :

$$\delta x = J\delta q \quad \text{(III-10)}$$

Let be $\tau = [\tau_1 \quad \tau_2]^T$ the actuator force vector and $\delta q = [\delta q_1 \quad \delta q_2]^T$ the corresponding virtual displacement vector. Let be $Fe_N = [F_x \quad F_y]^T$ external factors that acted on end-effector. The platform that moves can only move according to x-axes and y-axes. Suppose that $\delta x = [\delta d_x \quad \delta d_y]$ and the virtual displacement that corresponds vector. The following equation may therefore be obtained using the virtual work concept:

$$\tau^T.\delta q + G_m^T.\delta q + Fe_N^T.\delta x - f_m^T.\delta q - f_N^T.\delta x = 0 \quad \text{(III-11)}$$

Where G_m represents the force of gravity of the motors. f_m, f_N are the vectors of the inertial force of the motors and the nacelle. Which:

$$G_m = M_{mot}.g.[1 \quad 1]^T \quad \text{(III-12)}$$

$$f_m = \overline{M_{mot}}.\ddot{q} \qquad f_N = \overline{M_{nac}}.\ddot{x} \quad \text{(III-13)}$$

$$\overline{M_{mot}} = \begin{bmatrix} M_{mot} & 0 \\ 0 & M_{mot} \end{bmatrix} \qquad \overline{M_{nac}} = \begin{bmatrix} M_{nac} & 0 \\ 0 & M_{nac} \end{bmatrix} \quad \text{(III-14)}$$

Replacing equation (III-10) in (III-11) gives:

$$(\tau^T + G_m^T + Fe_N^T.J - f_m^T - f_N^T.J).\delta q = 0 \quad \text{(III-15)}$$

We can get this equation since it applies to any virtual shift q :

$$\tau^T + G_m^T + Fe_N^T.J - f_m^T - f_N^T.J = 0 \quad \text{(III-16)}$$

Taking the transposition of equation (III-16) and rearranging with replacement of the forces of inertia gives:

$$\tau + G_m + J^T.Fe_N - \overline{M_{mot}}.\ddot{q} - J^T.\overline{M_{nac}}.\ddot{x} = 0 \qquad \text{(III-17)}$$

By substituting equation (III-3) for (III-17) and if there are no external factors leading to:

$$\tau = (\overline{M_{mot}} + J^T.\overline{M_{nac}}.J)\ddot{q}^T + \left(J^T.\overline{M_{nac}}.\dot{J}\right).\dot{q} - G_m - J^T.Fe_N \qquad \text{(III-18)}$$

Equation (III-18) represents the equation of the inverse dynamic model of linear parallel robot generated by the principle of virtual work. The mass matrix of our machine is given by:

$$M = \overline{M_{mot}} + J^T.\overline{M_{nac}}.J \qquad \text{(III-19)}$$

In addition, vector comprising centrifugal and Coriolis effects:

$$C = J^T.\overline{M_{nac}}.\dot{J} \qquad \text{(III-20)}$$

Moreover, vector containing gravity terms:

$$G = (-G_m - J^T.Fe_N) \qquad \text{(III-21)}$$

because the motors have a rotational and translational actuation we can find the relation of torque in terms of screw lead (slider) and efficiency because these tow last indexes depending of the parameter of sliders. So the torque equation given as follow:

$$\Gamma = \frac{\tau.p.n}{2\pi} \qquad \text{(III-22)}$$

Where τ is the motor force, p screw lead (the distance that the slider take on one rotation) and n efficiency (dependent of the screw type).

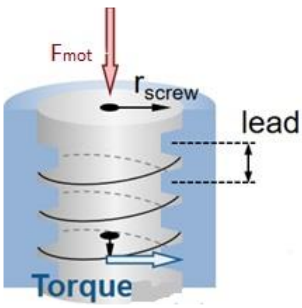


Figure III.2 – Representation of motor Force and torque.

III.5 Conclusion:

In this chapter, the 2dof parallel robot's decoupled control has been shown. A simplified initial dynamic model of the robot was built to this aim and before the construction of its mass matrix. According to the virtual work concept, the suggested approach employs the robot Jacobian matrix to project the forces operating at the operational point onto the joint space.

All of that has the benefit of providing explicit answers for the robot mass matrix, Coriolis and centrifugal forces, and gravity contribution. All of these aid in the determination of motor forces and torques, as well as providing a simple method for studying rigid body dynamic modeling.

IV Chapter IV: Results and discussion

Simulation is an essential step that takes place after mathematical modelling of any system, regardless of its level of complexity. Simulations are carried out to find out the effectiveness of the system and its portability in reality.

To make this simulation it should be use a simulator software to extract the results and apply it on the robot, and from these simulators MATLAB Simulink and ANSYS that we will use them.

In this chapter, we will simulate a parallel robot 2dof, by means of the inverse geometric model that gives the relationship of the position of the two motors in terms of the position of the end-effector. Then we simulate the speed of the two motors. Then the acceleration of the two motors acceleration. As these three steps take place simultaneously in real time. Finally, extracting the force applied to the movements. Using virtual work method and compare the result forces between MATLAB and ANSYS. We also study the effect of external forces, gravity and weight of movements and the moving platform by changing one of the variables each time.

IV.1 Simulation schematic of parallel robot 2DOF

The dynamic simulation of the robot is an important step to study the effect of the various forces. For this purpose, we simulated the PKM using the MATLAB SUMILINK program, where we started from a specific path that the robot must move to arrive to reach the dynamic model. Generally, the diagram is a composed two principal paths called subsystems and three function.

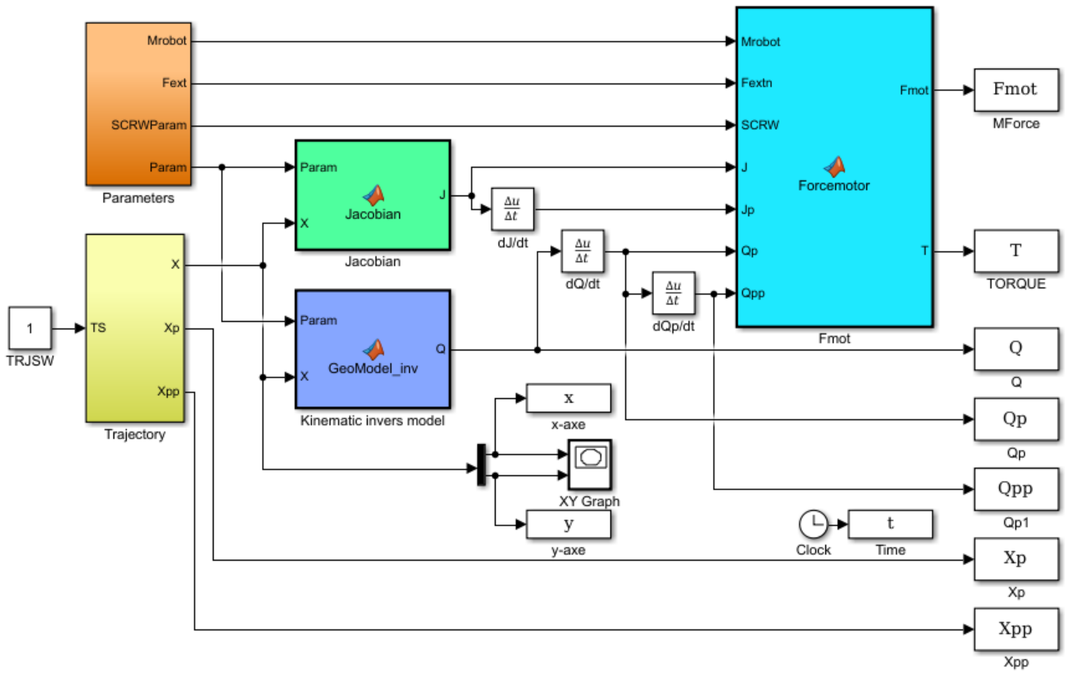


Figure IV.1 – Global simulation model using SIMULINK

IV.1.1 Parameters schematic

This subsystem is intended for entering the parameter on this parallel manipulator, which are the dimensions and masses of the parallel manipulator formed for it, and the external forces applied to the end-effector.

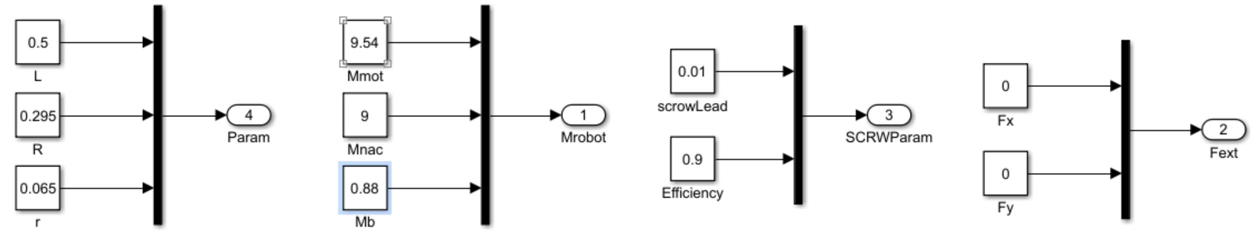


Figure IV.2 - Parameters schematic sub-system

Parameter table

Geometric parameter (m)	Mass robot (Kg)	Screw parameter	Extern forces (N)
L =0.5	Motor mass= 9.54	Screw lead = 0.01(mm)	Fx= 0
R = 0.295	End-effector mass= 9	Efficiency =0.9	Fy= 0
r = 0.065	Bar mass= 0.88		

The values in this table are used on the schema block for obtain the result dynamic forces and torque it’s mean the dynamic model results.

IV.1.2 Trajectory schematic

In fact, this sub-system cannot be found in parallel robots because they are computer-controlled where trajectory and velocity information is sent to them. For example in CNC machines a G-code file containing the trajectory and speed is sent but in this case we set this block in order to create some trajectories to perform this simulation.

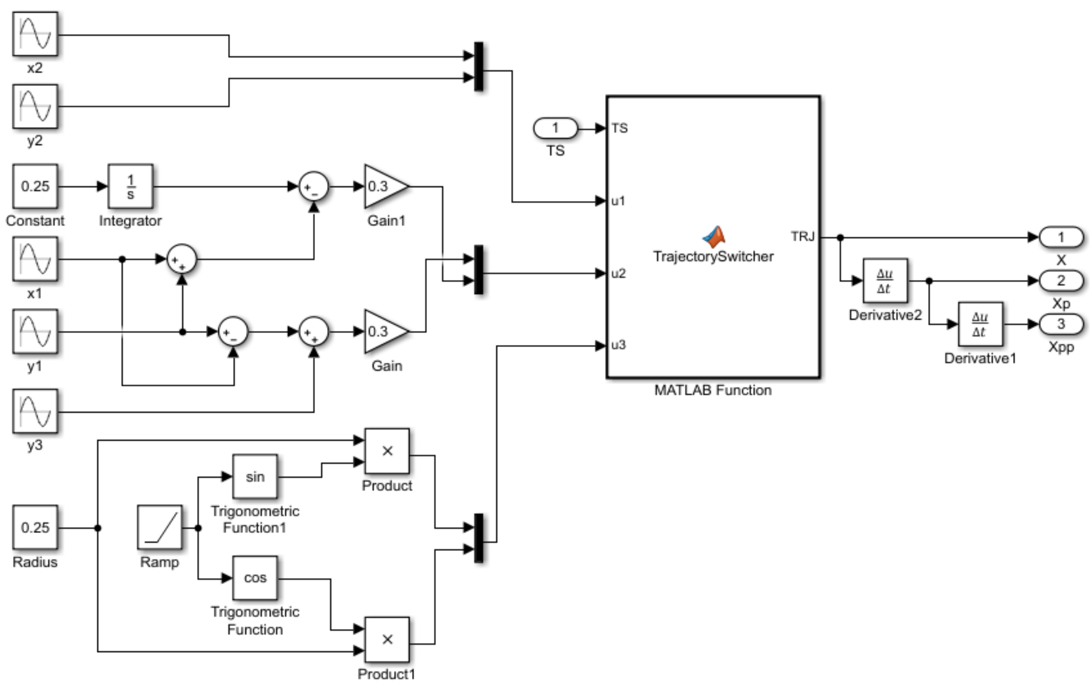


Figure IV.3 - Ttrajectory sub-system schematic

IV.2 Results and graphs discussion

In order to calculate the forces applied to the two motors B1.B2 (Figure II.1) and the resulting torque of both motors, we used the equation abo

IV.2.1 Trajectories

These graphs represent a set of different trajectories that were constructed for both the geometric and dynamic models of parallel robot 2DOF, but the first graph was chosen randomly and from that study was started.

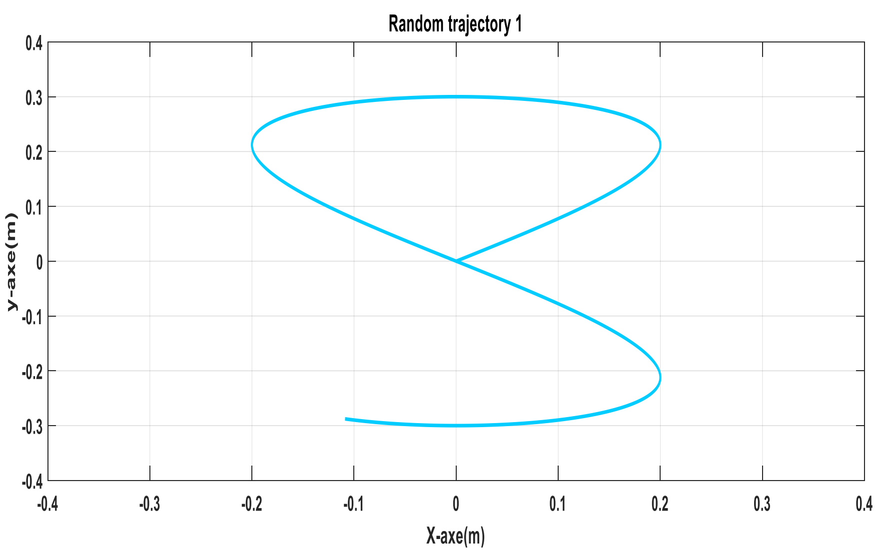


Figure IV.4 – 1st Random trajectory of end-effector

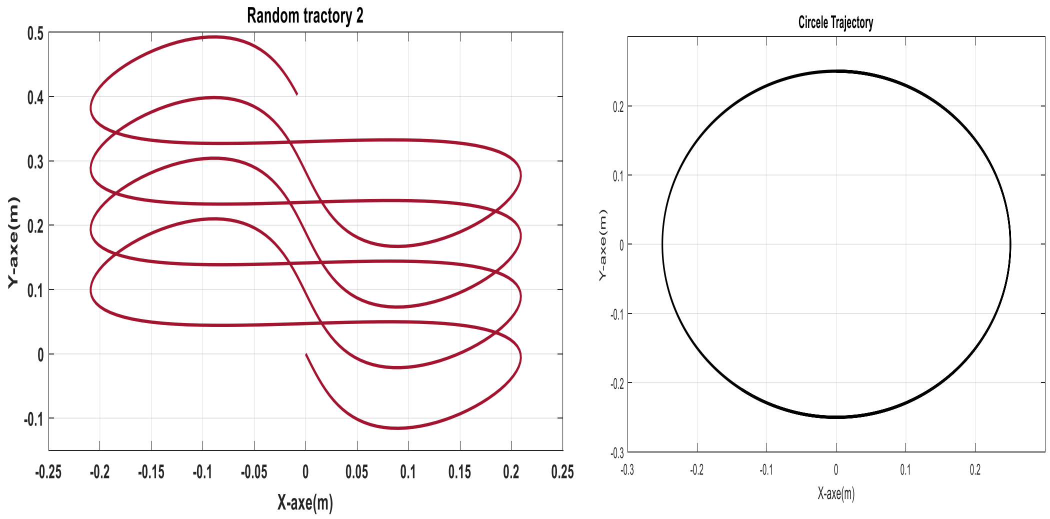


Figure IV.5 – 2nd Random and Circle trajectories

IV.2.2 End-effector velocity and acceleration

The end-effector velocity is the first derivative of the position vector, and is shown as two cosine paths because two pairs of sine blocks are positioned to form a two-dimensional path. As shown in Figure IV.3.

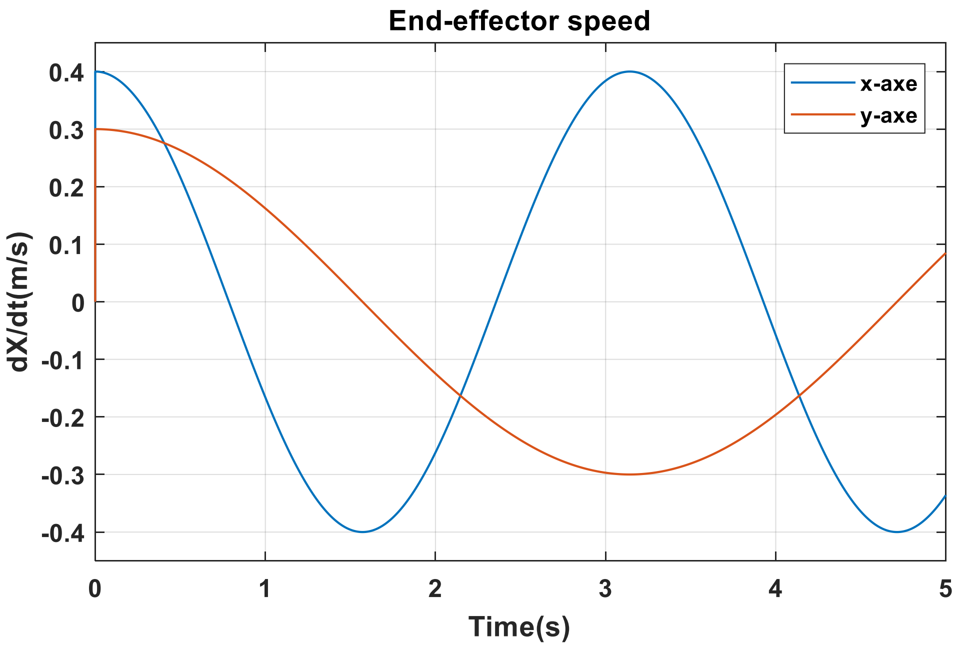


Figure IV.6 – End-effector velocity graph.

The graph represents the acceleration of the final effector on the x-and y-axes and is the second derivative of the position vector. It also appears that it represents the trigonometric function Sine.

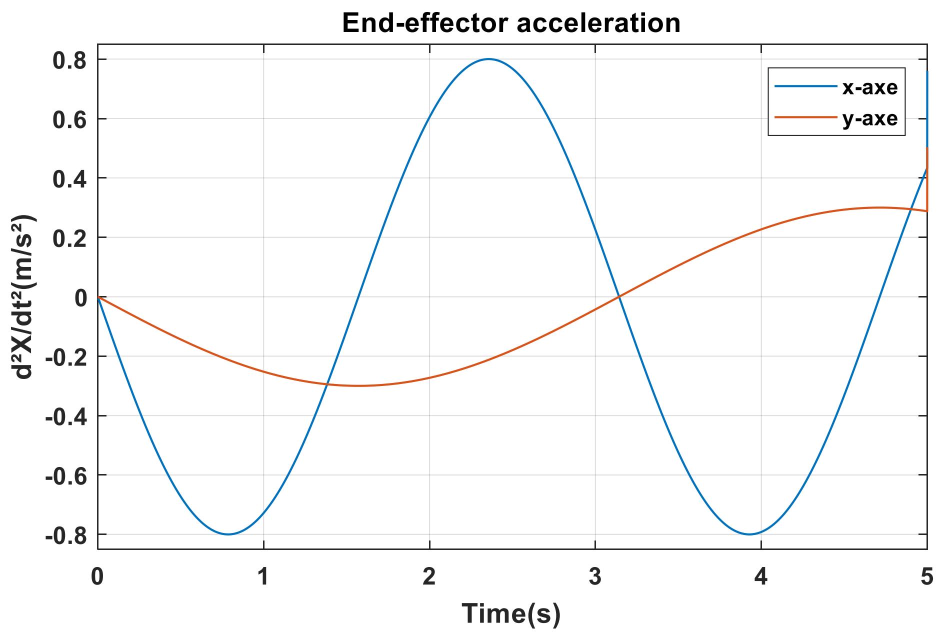


Figure IV.7 – The end-effector acceleration in X and Y-axes

IV.2.3 Motors position, velocity and acceleration

The position of sliders q1 and q2 changed in terms of the time according the first trajectory like the following figure, the motor B2 move firstly and B1 actuate the second after few second.

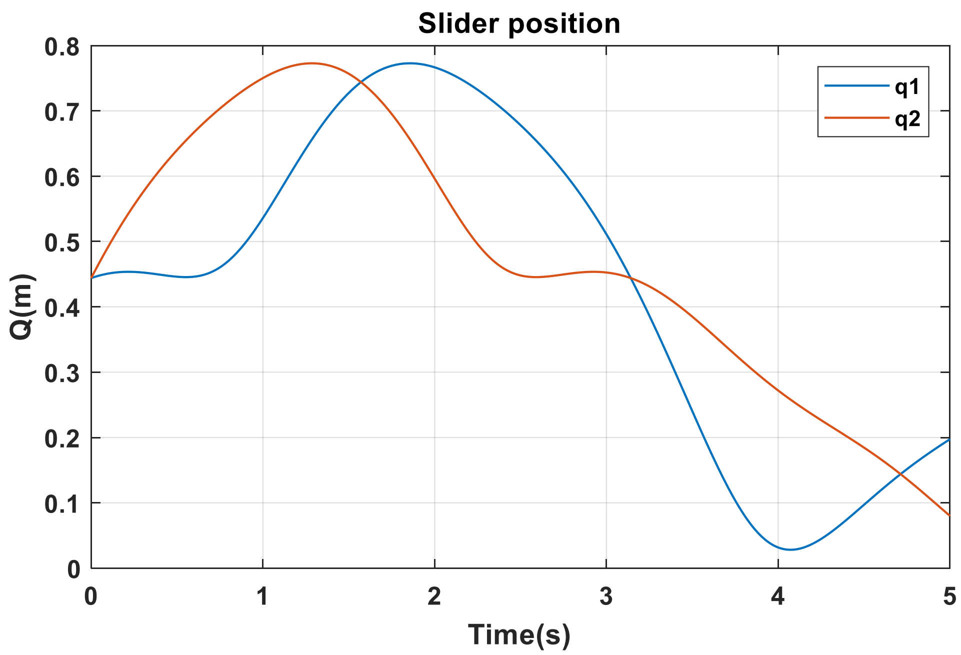


Figure IV.8 – The position vector of sliders

The velocity $\dot{q}_1$ and $\dot{q}_2$ change also according the positions and trajectory that we want design. In the zero (s), the tow sliders start moving to get the specific point that it started on.

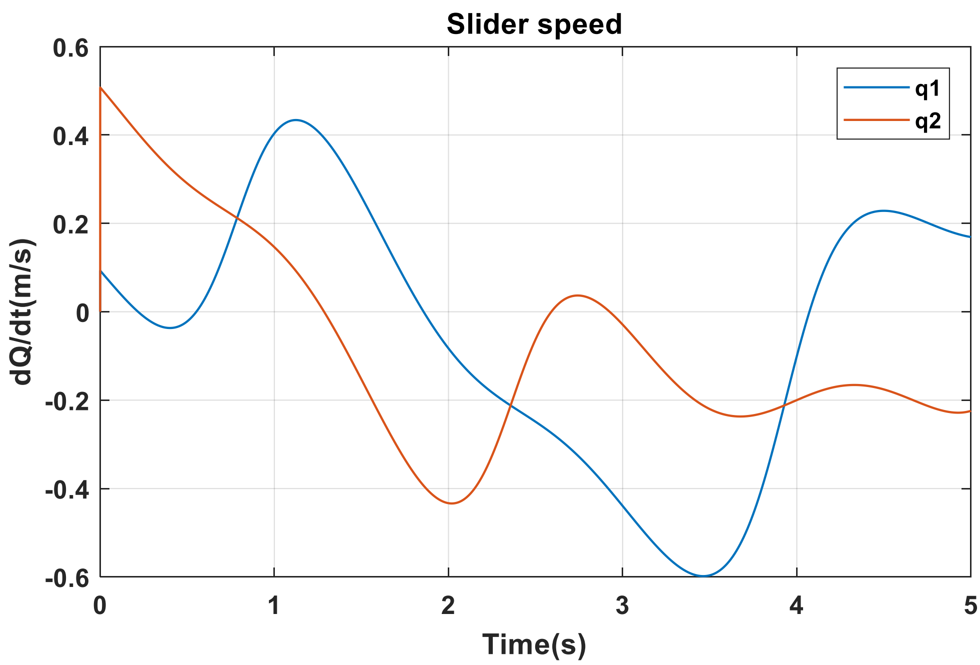


Figure IV.9 – Slider velocity graph

Here we see the slider acceleration (velocity derivative). The graph explain that the tow sliders have a harmonic acceleration according the trajectory, when the first one speed up the acceleration of (1.1 m/s² approximately) .the second one increase with a little ratio, and if the action of design be invers. they reverse their acceleration (the first decrease quickly and the second slowly) till they will be equal , next they reflect their acceleration ratio . In addition, make that until they finishing of trajectory they want but we see at the end they rise their acceleration more than beginning and still have different acceleration

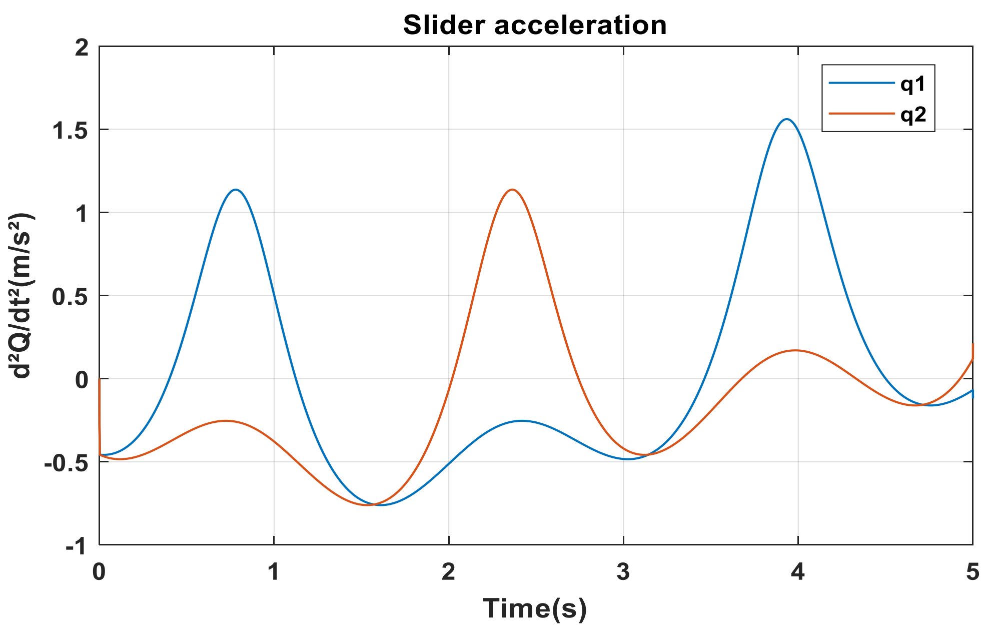


Figure IV.10 – The acceleration of sliders, which linked to motors

IV.2.1 Motors load force and torque

In order to calculate the forces applied to the two motors B1.B2 (Figure II.1) and the resulting torque both motors, we used the force and torque equations to extract the results shown in (Figure IV.11) and (Figure IV.12).

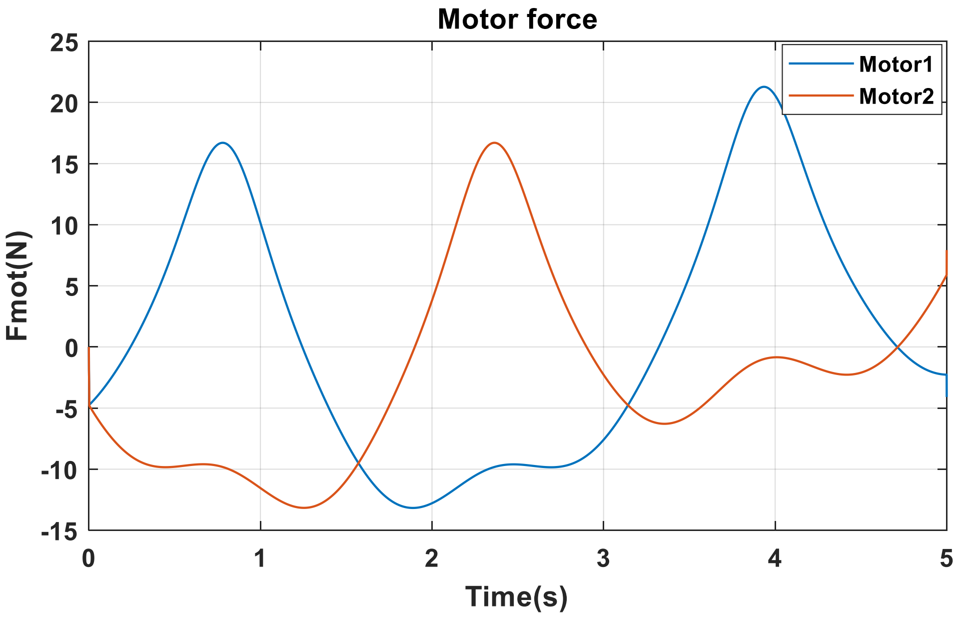


Figure IV.11 – The force load applied on motors

The forces and torques curve have the same shape, the force applied to the two motors produces the torque multiply the radius. In this case, it was assumed that the motor rotates a screw with an advance of 10 mm and an efficiency of 0.9 and the results obtained are shown in (Figure IV.12).

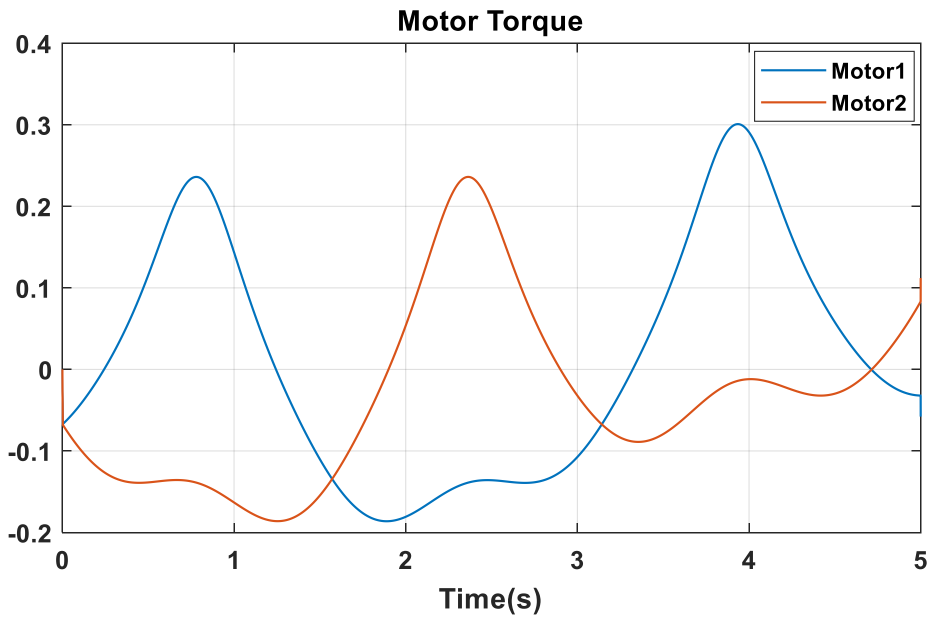


Figure IV.12 – Torque of both motors B1 and B2

IV.3 Motor force comparison between MATLAB and ANSYS

This robot was designed by SOLIDWORKS program, and in order to perform these simulations, this design was transferred to the ANSYS program. The ANSYS program was used in order to obtain more accurate results, the model that we used on this program is the direct kinematic model, than compare these results with the results obtained by MATLAB program using the inverse kinematic model. The results of this comparison are shown in (Figure IV.16) and (Figure IV.17).

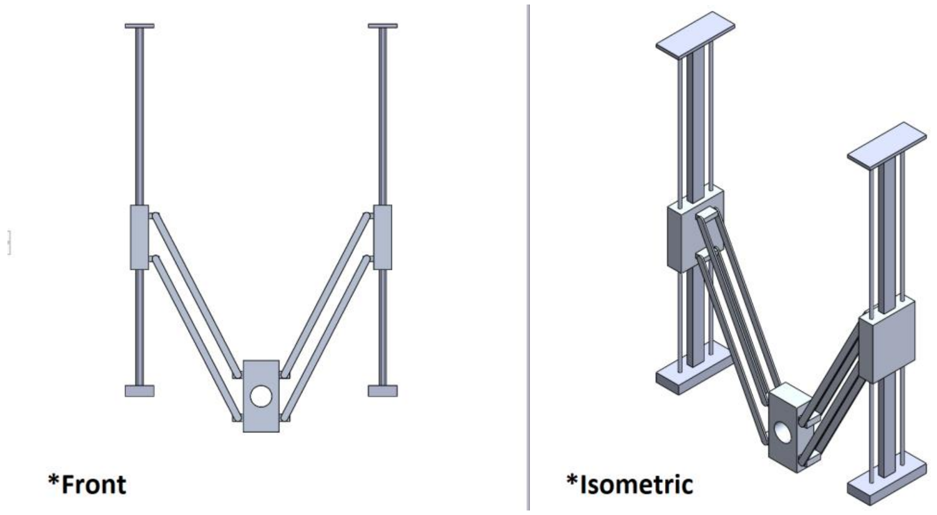


Figure IV.13 – Robot simulation with SOLIDWORKS

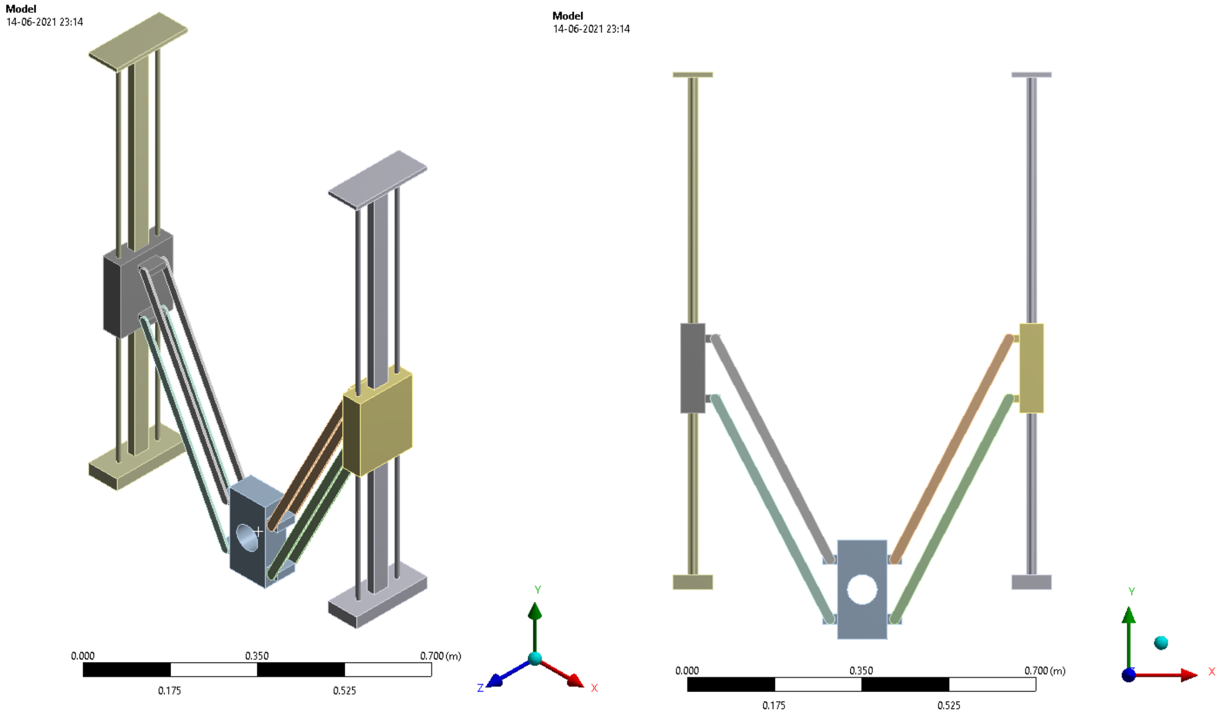


Figure IV.14 – Robot simulation with ANSYS

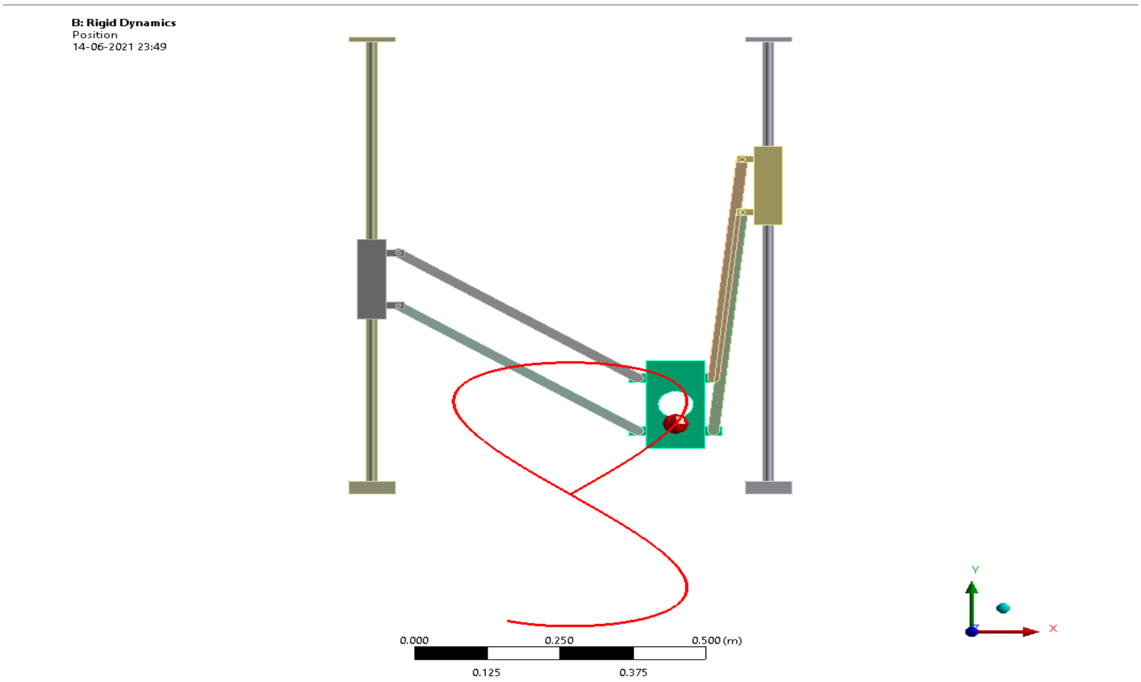


Figure IV.15 – The robot simulation of designe the trajectory (with Ansys)

First: With gravity: $g = [0 \quad 0 \quad -9.81]$ and end-effector external force: $F_{extN} = [0 \quad 0]^T$

The next figure show the first result comparison of forces between MATLAB and ANSYS, we see that the graphs M1A (Motor 1 ANSYS) and M1M (Motor 1 MATLAB) are applicable to each other, also the two other graphs (M2A & M2M) are the same with the condition that we put above.

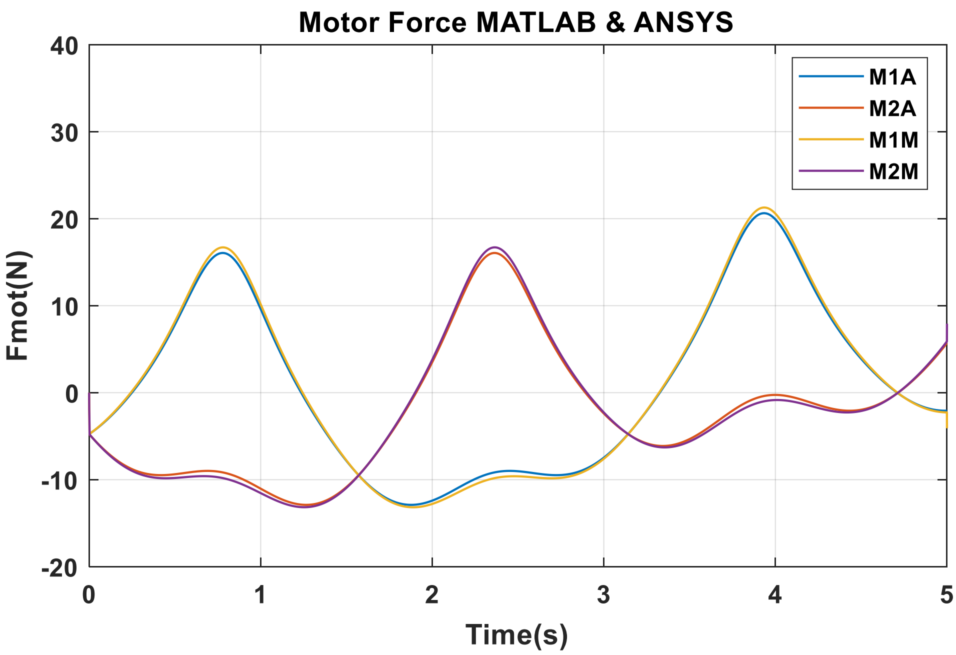


Figure IV.16 – Motor force in ANSYS and MATLAB where Y-axe force equal 0 Newton.

Second: With gravity: $g = [0 \quad 0 \quad -9.81]$ and end-effector external force: $F_{extN} = [0 \quad 20]^T$

When we compare our forces with the second condition between the two software, we see that the forces of two motors are the same on (M1A, M1M) and (M2A, M2M).

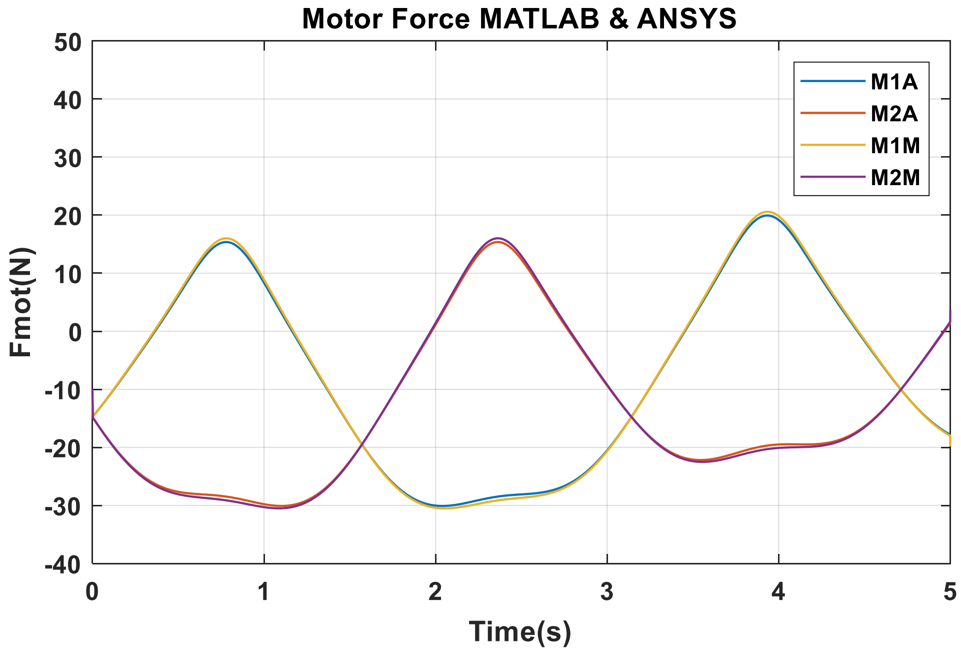


Figure IV.17 – Motor force in ANSYS and MATLAB where Y-axe force equal 20 Newton.

This comparison is completed with the same results in MATLAB and ANSYS. In order to check the validity of load forces applied at motors.

IV.4 Conclusion

When we show the result with MATLAB Simulink we certain that the simulation can help us to modelling this robot professionally, and apply it on the reality.

The simulation results show the displacement changes, velocities and acceleration values with respect to the selected slider and path, especially the relation between this kinematics and trajectory selected. Also it facilitate the analysing of forces and torques applied to the motors in order to deduce perfectly the optimal dynamic modelling or trying to reach it using this way.

General conclusion

Because rapid parallel manipulators may be developed, it is important to calculate their dynamic model in order to provide adequate control. Although a comprehensive dynamic model in closed form cannot be built, some assumptions may be made, allowing for the simulation of simplified yet efficient dynamics behavior. and that is what we explained in this research, starting from the geometric to dynamic passing through the kinematic model using the virtual work method , and this is proven when starting the simplifying hypothesis that help for calculate the each of acceleration, forces and torques of the main different parts on this robot, espiscially this PKM 2dof is parallel and like all parallel manipulators the dynamic modelling is some defficult but with this simplifying can be easy to model. from this point the importance of this project show and it can be used for Develope some of other robots.

The dynamic modeling of the parallel robot is very important, and through the foregoing, it is an essential element in the simulation of the parallel robot 2 dof, where this importance lies in the development of an initial mathematical model for the manipulator before its creation with the possibility of modifying this model easily and checking the validity of this modeling before applying it on the Reality.

Obtaining this dynamic model Through the stages in which it is in the development of the geometric model, which gives the relationship of the vevctor position of the motors in terms of the location of the coordinates of the end-effector. Then the motor model, which in turn gives the relationship of the speed of the motors in terms of the speed of the the platform(end-effector), using the Jacobian matrix, which in turn makes the system linear . And finally, the dynamic model, which gives the relationship of motors acceleration in terms of acceleration of the end-effector as well.

This model can be verified by the simulation process, where the robot parametre , the gravity as well as the weight of the parts that make up it are entered, the principal goal of this dynamic modelling is to calculate the load forces applied to the motors that are calculated in real time and the required torque can be deduced as well from the load forces , Where hypotheses were puted to simplify the model and use the virtual work model to reach the required modeling. .

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Abstract

Report title: Dynamic modelling of parallel robot two DOF.

Master: Electromechanical.

Keywords: parallel robot, dynamic, modelling, kinematic, workspace, geometric model, virtual work.

Authors: Hadjaidji Abdelmounaim, Fezzai Ramzi, Hamlaoui Chakib Abdenour**.**

Abstract:

Dynamics modelling parallel robot 2dof is the application of rigid-body dynamics to this robots. Using two modelling types: inverse (calculate the torques and/or forces), and forward (calculate the state variables accelerations). With the help of some methods one of them virtual work method. That this project used on, where we started from the geometric, than the kinematic down to the dynamic model that give the relationship between the two motors and acceleration relation of end-effector. In addition found the force that calculated by virtual work, finally the torque.

Titre du mémoire : Modélisation dynamique du robot parallèle 2 degré de liberté.

Mots clés : robot parallèle, dynamique, modélisation, cinématique, espace de travail, modèle géométrique, travail virtuel.

Résumé :

Modélisation du dynamique robot parallèle 2 degrés de liberté. est l'application de la dynamique des corps rigides à ce robot en utilisant deux types de modélisation : inverse (calcule les couples et/ou forces) et avant (calcule les accélérations des variables d'état) à l'aide de quelques méthodes l'une des la méthode de travail virtuelle utilisée par ce projet, où nous sommes partis de la géométrie, de la cinématique jusqu'au modèle dynamique qui donne la relation entre les deux moteurs et la relation d'accélération de nacelle. En plus on retrouve la force que l'on calcule par travail virtuel, enfin le couple**.**

عنوان المذكرة: النمذجة الديناميكية للروبوت المتوازي درجتين من الحرية.

الكلمات المفتاحية: روبوت متوازي، ديناميكي، نمذجة، حركي، مساحة عمل، نموذج هندسي، عمل افتراضي

الملخص:

النمذجة الديناميكية للروبوت المتوازي درجتين من الحرية هو تطبيق ديناميكيات الجسم الصلب على هذه الروبوتات باستخدام نوعين من النمذجة: معكوس (يحسب عزم الدوران و / أو القوى) والأمامي (يحسب تسارع متغيرات الحالة) بمساعدة بعض الطرق، إحداها طريقة العمل الافتراضية التي استخدمها هذا البحث، حيث بدأنا من الشكل الهندسي، ثم الحركي وصولاً إلى النموذج الديناميكي الذي يعطي العلاقة بين المحركين وعلاقة تسارع المؤثر النهائي. بالإضافة إلى ذلك، ايجاد القوة التي تم حسابها من خلال العمل الافتراضي، وأخيراً عزم الدوران.