DETERMINATION OF THE STRESS AND STRAIN STATE IN THE MOUNTING SOLUTION OF PARALLEL ACTING INDUSTRIAL ROBOT

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The present work aims to evaluate the stress and strain state in the case of the mounting plate of a parallel actuation robot. In this study, an analysis based on the finite element method will be used, more precisely a transient regime analysis. To provide the necessary input data for recreating the robot kinematics, offline simulation and programming of the industrial cell, performed for the purpose of assembling electronic components in mobile phone cases was carried out. Therefore, based on the cyclograms of movement obtained after the realization of a program necessary to obtain a work cycle, the robot can be recreated cinematically. The robot kinematics can be realized after defining all the kinematic couplings in ANSYS Code. Also, the purpose of this study, in addition to verify such a structure intended to support a DELTA-type robot, was also to design a modular structure made of aluminum profiles and stiffening elements in addition to components such as the conveyor having an active role in running an industrial application.

KEY WORDS: Paralel acting robots, Robot kinematics, Transient analysis, Industrial cell design, Offline programming

1. Introduction

In order to achieve the integration of robots with parallel actuation within an industrial cell, it is necessary to realize and design a structure for the location of the base of these robots. This topic of designing such a DELTA robot mounting solution is quite sensitive, as the stresses to which the structure is subjected must be evaluated. In the case of any mechanical structure subjected to the action of some forces (in our case inertial and overturning moments), deformations occurred can affect the positioning precision but also the accuracy with which the robot can accomplish a trajectory described in the program; consequently, the achievement of a certain type can be compromised of application. Also, one of the main aims of this study was the creation of an industrial cell dedicated to the assembly operations of various electronic components within mobile phones. All elements of the assembly cells have been selected or designed in order to obtain a variant of such a fully automated cell.

Based on the simulation and offline programming of the robotic assembly cell, the data related to the movement of the numerically controlled axes will be extracted, and these data will be further used in the transient analysis

2. Current state

The modeling of the cell as well as its simulation was completely realized in the ABB-Robot-Studio software. The motion data of the ABB-IRB-360 (DELTA) robot was obtained based on offline simulation and used in the analysis of its base mounting structure.

A parallel actuation robot made by the ABB corporation is the type of industrial robot that is included in the automation cell used for the assembly process of electronic components. This robot is the fastest in its class, and from the standpoint of carrying capacity and the range of motion that determines the working area, it can carry out all the tasks necessary for the suggested application.

In Figure 1, the main objective of the work can be observed, namely the exploitation of robots with parallel acting to increase the degree of automation of the production of smart phones.

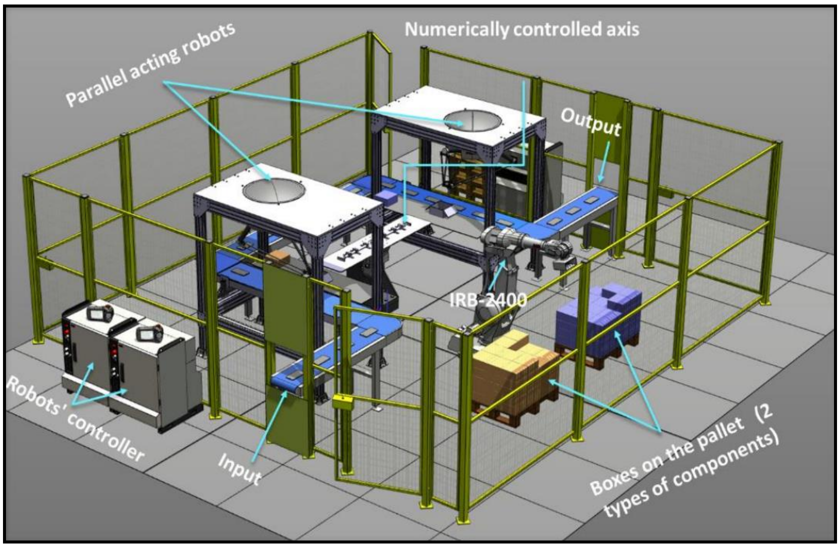


Figure 1. Design of the industrial cell

3. Design of structural elements

For the suspension of the DELTA robots, a structure made of aluminum profiles of different sizes was designed, with stiffening elements. At the structure level, additionally a conveyor serving the transportation parts for the DELTA robots has been added.

The design of the assembly dedicated to the location of the IRB-360 robot is also based on the possibility of calibrating the robot. Thus, the distance between the aluminum profiles is a concern to allow the movement of the robot segments to the points dedicated to its calibration. Within the structure of the location of the robot base, there are also elements with an active role, such as the belt conveyor for transporting objects, a camera for detecting the position and orientation of objects, etc.

In Figure 2, one can observe the virtual prototype of the support structure, but also the method of fixing the robot.

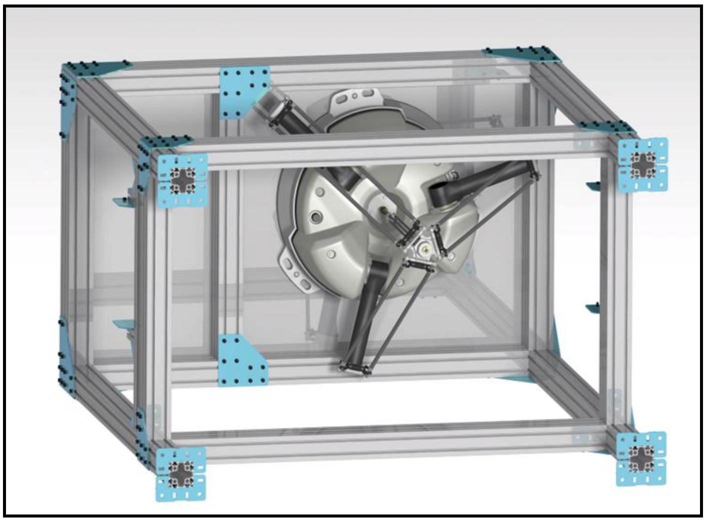


Fig 2. Mounting structure for IRB 360

The technical drawings of the structure taking into account the gauge dimensions and other dimensions of interest were obtained based on the 3D structure modeled in CATIA V5.

In Figure 3, one can observe the 2D technical drawings that have the role of facilitating the assembly part of the designed structure.

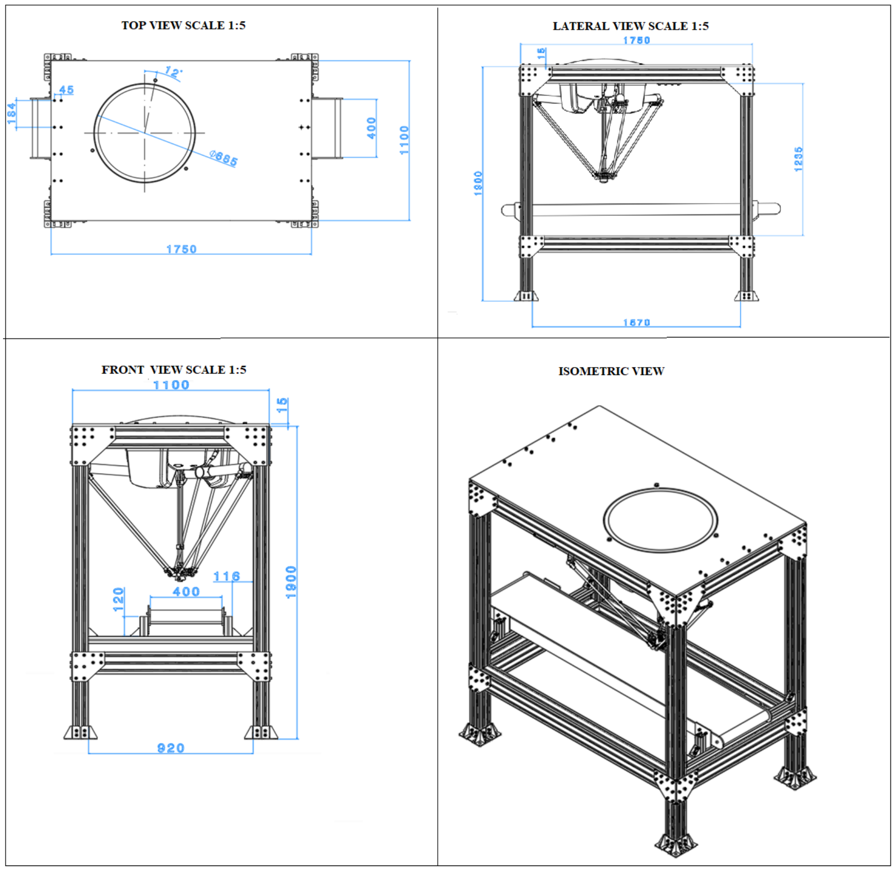


Fig 3. Technical drawings of mounting structure for DELTA type robot

3. Offline programming

In accordance with the assembly process, the robots integrated in the automation cell were programmed to achieve the duty cycles associated with the assembly of the electronic components. As a way of programming industrial robots, offline programming and simulation is used through the programming language dedicated to ABB robots called RAPID [1], [2].

Thus, the articulated arm type robot with 6 degrees of freedom has the role of facilitating the transfer of boxes with electronic components to workstations equipped with ABB IRB-360 parallel drive robots. DELTA ABB IRB-360 robots carry out the assembly process of the two types of electronic components, namely batteries and speakers.

One of the essential elements of the offline programming was obtaining the movement characteristics of the robot because these signals will be used in the finite element analysis which aims to evaluate the von Mises stresses and the deformations appearing in such a structure.

In Figure 4 one can observe the movement signals of the robot with parallel actuation, extracted from the robot controller (IRC5 Single Cabinet). These motion signals will be found as motion data on the kinematic couples recreated in ANSYS.

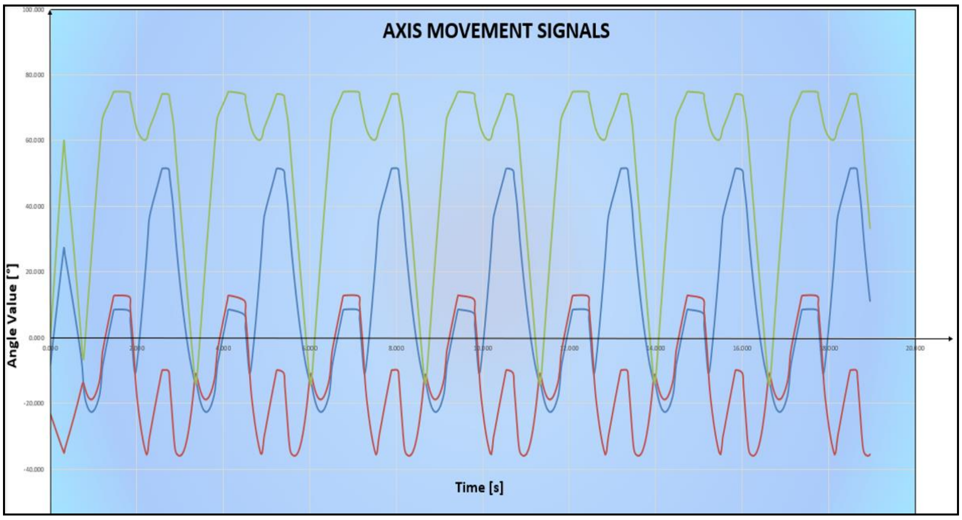


Fig 4. Axis movement signals

4. Structural analysis of modular structure for mounting the DELTA type robot

To assess the behavior of the structure that one of the robots is installed on, the authors of this study performed a transient analysis. A fundamental three-dimensional model is utilized in every FEM investigation. Since some components of the original model have a negative impact on the analysis, this fundamental model has been streamlined. In this study, a file import from CATIA V5 is the first step in the FEM analysis, which is then followed by a structure simplification based on the basic model (Figure 5).

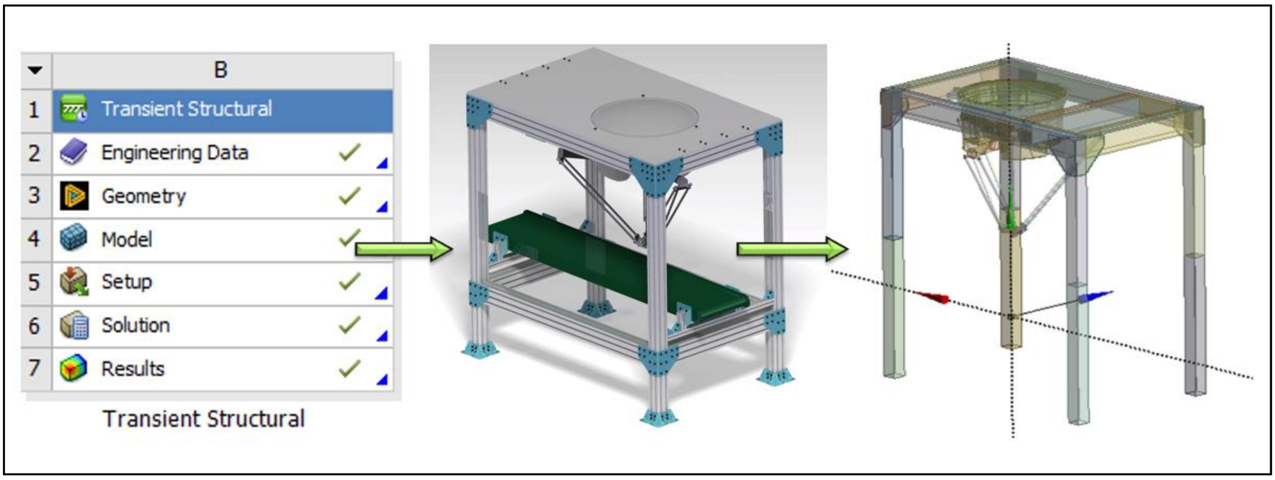


Fig 4. Simplified geometry

The next stage for performing the transient analysis is defined by recreating the kinematic couplings and simulating the robot's working cycle based on the data extracted from the offline programming and simulation software provided by ABB (Robot Studio).

In the case of the parallel actuation robot, these are three cylindrical joints (from the three segments of the RI), four spherical joints for the articulated quadrilaterals to connect the robot segments to the actuated movable element, plus six more spherical joints from the actuated movable element [3].

The definition of kinematic couples is depicted in Figure 5.

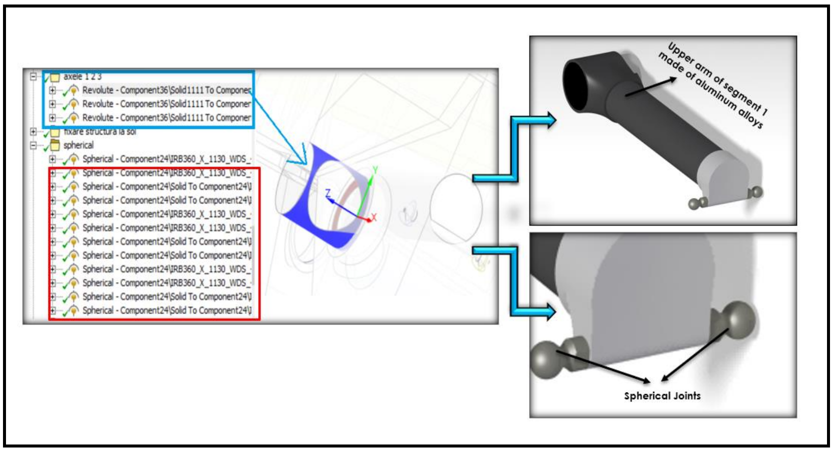
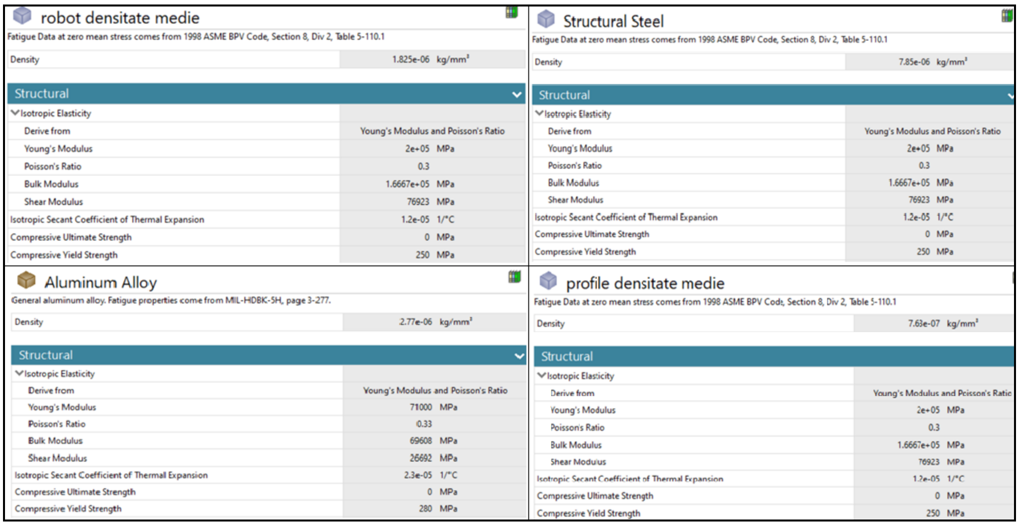


Fig 5. Joints definition

The definition of materials is very important in finite element analysis because the actual study is performed according to the data presented in the robot data sheet. In this sense, the sum of all the volumes for the partial assemblies (robot base, robot segments, actuated mobile element) must be exactly as in the data sheet. Therefore, by using the "measure inertia" function in CATIA V5, the volume of these subassemblies is calculated and, in accordance with the technical sheet, a specific density is assigned to the material from which the robot components are made. After simplifying the geometry and defining the kinematic joints, it was necessary to define and to allocate the specific materials to each element of the robot structure. In Figure 6, a. one can observe the materials that are used in the transient analysis.



robot densitate medie

Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1

Density	1.825e-06	kg/mm³
Structural		
Isotropic Elasticity		
Derive from	Young's Modulus and Poisson's Ratio	
Young's Modulus	2e+05	MPa
Poisson's Ratio	0.3	
Bulk Modulus	1.6667e+05	MPa
Shear Modulus	76923	MPa
Isotropic Secant Coefficient of Thermal Expansion	1.2e-05	1/°C
Compressive Ultimate Strength	0	MPa
Compressive Yield Strength	250	MPa

Structural Steel

Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1

Density	7.85e-06	kg/mm³
Structural		
Isotropic Elasticity		
Derive from	Young's Modulus and Poisson's Ratio	
Young's Modulus	2e+05	MPa
Poisson's Ratio	0.3	
Bulk Modulus	1.6667e+05	MPa
Shear Modulus	76923	MPa
Isotropic Secant Coefficient of Thermal Expansion	1.2e-05	1/°C
Compressive Ultimate Strength	0	MPa
Compressive Yield Strength	250	MPa

Aluminum Alloy

General aluminum alloy. Fatigue properties come from MIL-HDBK-5H, page 3-277.

Density	2.77e-06	kg/mm³
Structural		
Isotropic Elasticity		
Derive from	Young's Modulus and Poisson's Ratio	
Young's Modulus	71000	MPa
Poisson's Ratio	0.33	
Bulk Modulus	69608	MPa
Shear Modulus	26692	MPa
Isotropic Secant Coefficient of Thermal Expansion	2.3e-05	1/°C
Compressive Ultimate Strength	0	MPa
Compressive Yield Strength	280	MPa

profile densitate medie

Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1

Density	7.63e-07	kg/mm³
Structural		
Isotropic Elasticity		
Derive from	Young's Modulus and Poisson's Ratio	
Young's Modulus	2e+05	MPa
Poisson's Ratio	0.3	
Bulk Modulus	1.6667e+05	MPa
Shear Modulus	76923	MPa
Isotropic Secant Coefficient of Thermal Expansion	1.2e-05	1/°C
Compressive Ultimate Strength	0	MPa
Compressive Yield Strength	250	MPa

Fig 6. Materials properties

Structural steel was selected for the top plate whereas the aluminum for the robot arms. The materials chosen for the robot segments are those presented in the product manual, where it is specified that the segments of the three-robot axis must generate small moments of inertia. The meshing was controlled at a global level, as a local level. Globally, the meshing type elements have been set to be of second order, with a size of 40 mm. At a local level, the authors imposed a size of 20 mm for the meshing elements, the discretization being refined around the robot fixing holes. At the same time, it was used the sweep method with two elements, these settings having the role to ensure correct results in the shortest time [4]. The structure meshing is shown in Figure 7.

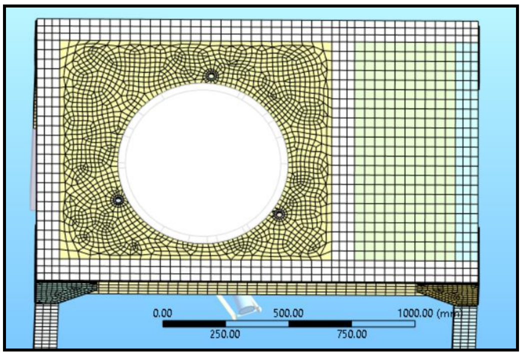


Fig 7. Controlled mesh

5. Results interpretation

Although the structure is safely to use, the integrator will take into account the calculation of the structural fatigue stress because a robot frequently repeats the same work cycle. Equivalent stress distribution is shown in Figures 8.a and 8.b, with a maximum value of 24,739 [MPa].

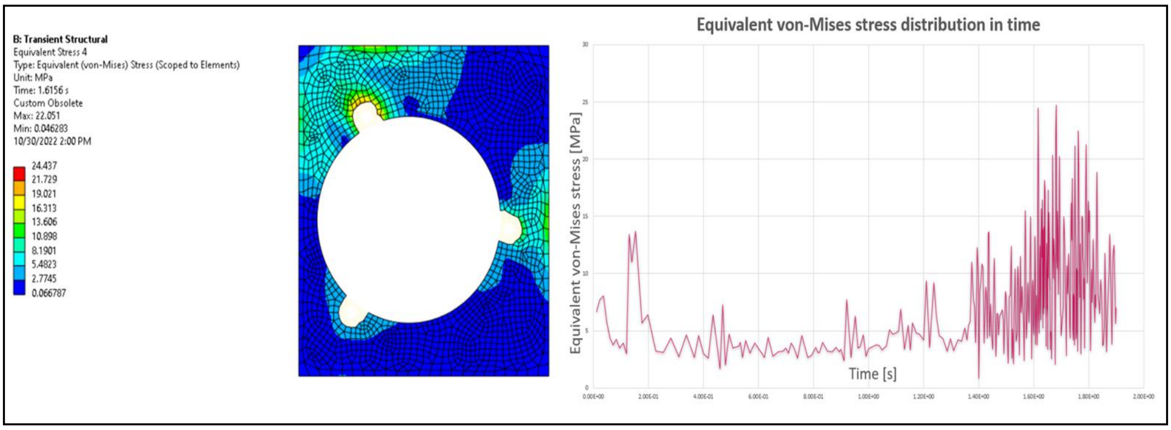


Fig 7. von Mises stress distribution

Also through this transient analysis, the value of the deformations in the steel plate on which the base of the robot is mounted, a value of 0.165 [mm] was obtained. This deformation value affects the positioning accuracy by a percentage of 32.5% if we refer to the robot specifications, and in the case of the proposed industrial application we consider that the operation of the robot is not compromised due to its mounting structure

5. References

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