Calculus and modelling of a load-bearing structure design for the enlargement of the working space in a production line

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The chosen subject of this paper is focused on finding a solution for optimizing the working space for the IRB 4600-40/2.55 robot, manufactured by ABB, using a gantry structure being mainly formed of two translating axis (X and Y axis), with a suspended mounted system, with one of the purposes being to be used in the extraction of raw products from plastic injection machines (Fig. 1).

1. Introduction

The gantry structure represents a translating like axis mechatronic system associated with industrial robots in different cell types, with the role of increasing available working space on a rigid path and adapting the robot to the requests of the technological process it's used in.

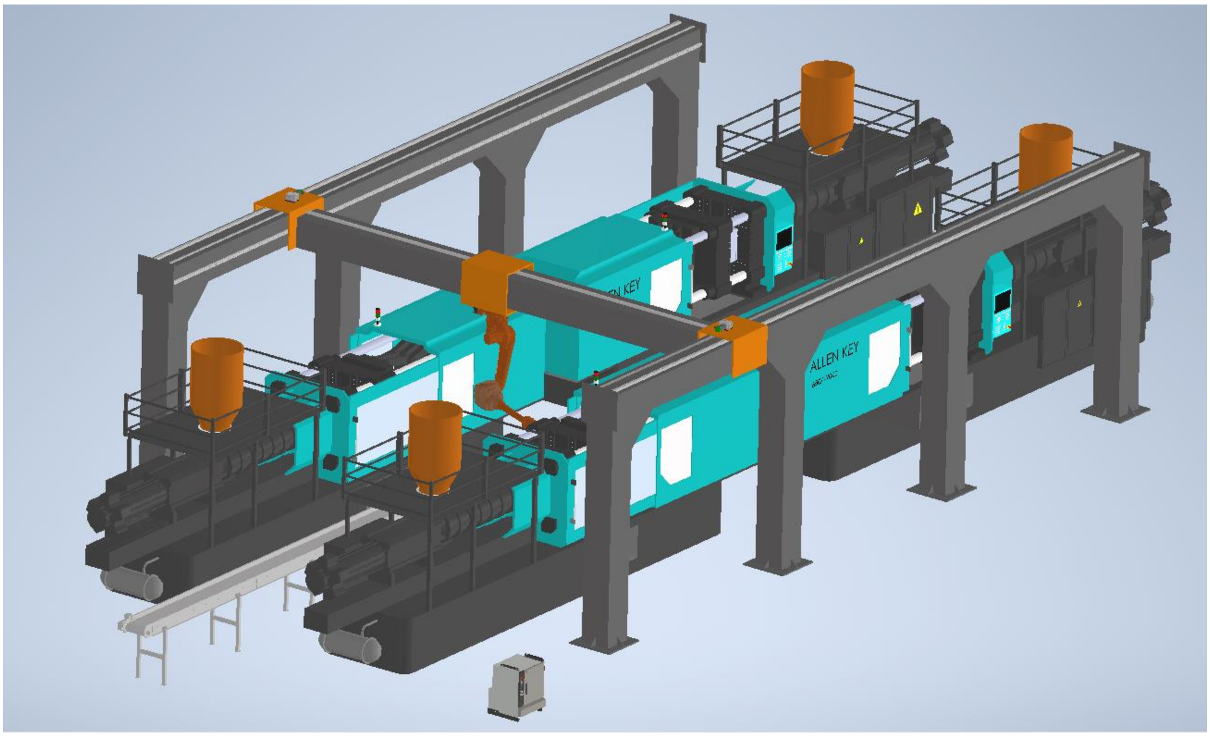

Fig. 1. 3D modelling of the cell

2. Actual state

Plastic injection machines are heavyweight industrial equipment with high demanding allocated space, like so having the need of a considerable amount of space. For extracting raw products resulted in the process of injection it is necessary to associate an industrial robot programmed to do this exact process. The association of this kind of robot (and more often of a solution to increase the working space for this robot) can lead to a significant increase of the ground space required, space that is already a problem with this type of machines, because of the space that they require (example Fig. 2).

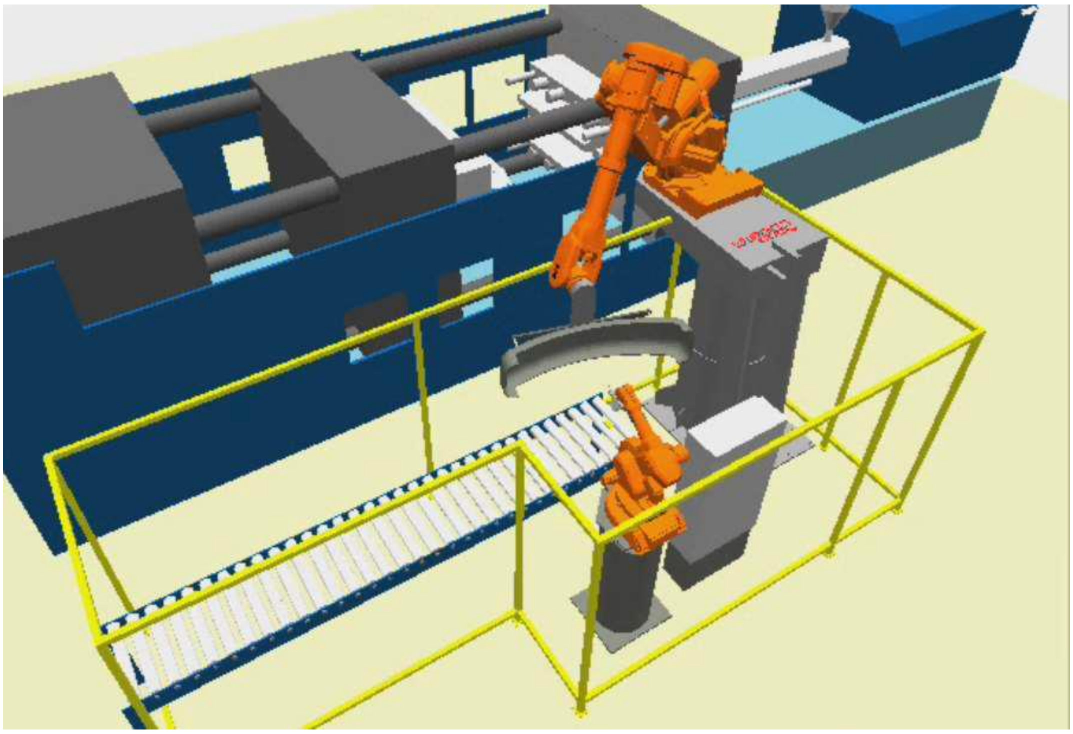

Fig. 2 Virtual simulation of a plastic injection process

In the production factories most of the time you can find one or more of this type of machines, every each one of them requiring a solution to extract the final product, fact that by cumulating leads to a significant issue referring to the space management available in the enclosure.

Mechanical structure overview

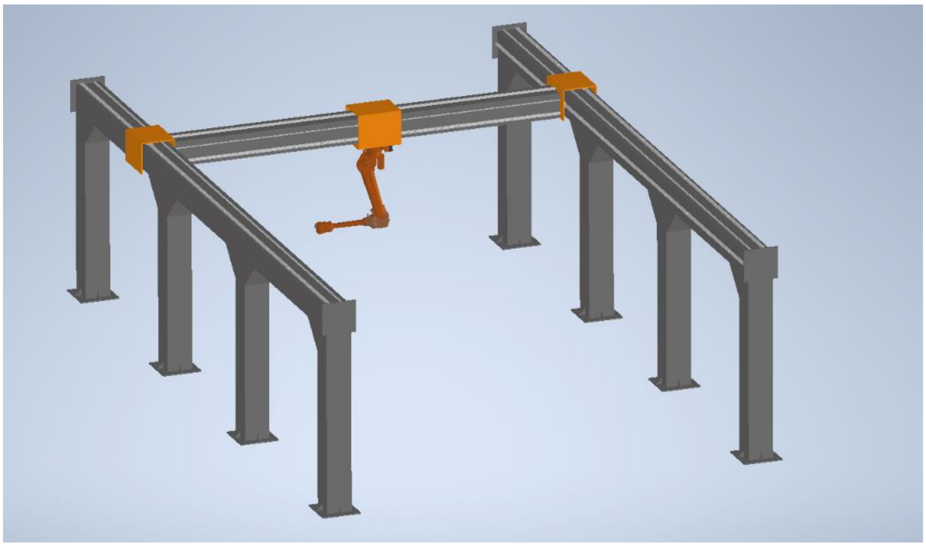

Fig.3 Isolation of the analysed structure

The constructive solution that we propose comes in the help of this sort of problems. The design and production of a structure that serves for more injection machines, working for each one of them, sequentially. This option comes with the following advantages:

- The reduction of footprint, because by eliminating the four independent structures for each machine with a single, bigger structure, it can overall lead to a better organization of the available space;
- The structure's reduction of technological complexity, the simplification of the programming algorithms and the decrease in electrical energy consumption;
- Also, we can observe a significant decrease in the matter of cost for building the entire line of production (the reduced number of robots required is ultimately leading to a lower price, some of the robots having prices between 25.000 $ and 400.000 $, and also by cutting off on the number of robots all the necessary equipment that are mandatory for an optimal execution are reduced);

Although, like any solution, we can't present only it's strong points, it must have some disadvantages too, like for example it is observed that an increase in the necessary time to effectuate the same number of process cycles by a single robot, in comparison with the time required by four robots to complete them.

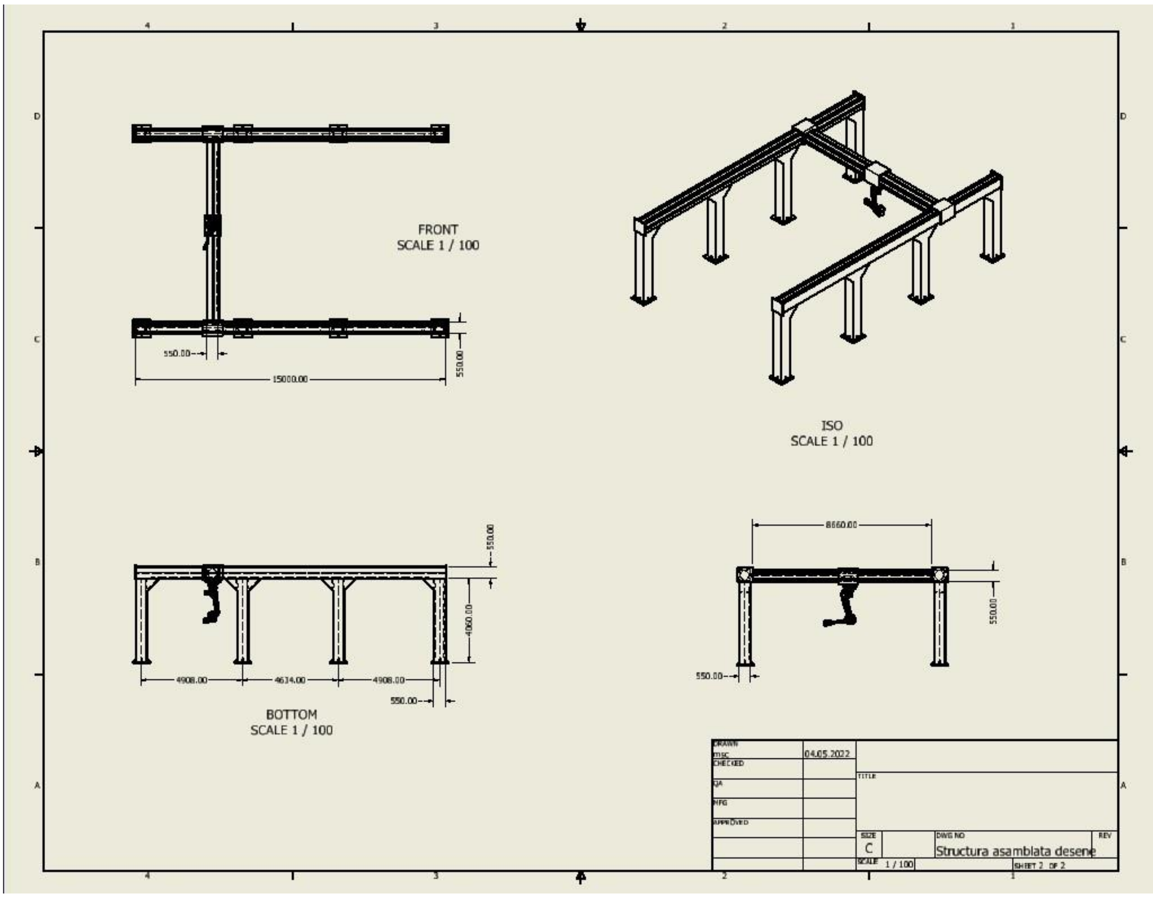

Fig. 4 Multi-view technical representation of the structure

Main specifications for the selected robot

In order to be able to design the gantry structure it has been extracted a series of technical information from the datasheet, such as the shape and the dimensions of the robot's working space, it's weight and maximum load capacity. The value and direction of the forces and moments that are developed during operation can be also extracted. This robot has been chosen because of it's capability of being suspended mounted, but also for its characteristics and applications which suits for plastic injection processes.

1.1.2 Different robot versions

General

The IRB 4600 is available in four versions and all versions can be floor mounted, inverted or tilted (up to 15 degrees around the Y-axis or X-axis).

Robot type	Handling capacity (kg)	Reach (m)
IRB 4600	60 kg	2.05 m
IRB 4600	45 kg	2.05 m
IRB 4600	40 kg	2.55 m
IRB 4600	20 kg	2.50 m

Manipulator weight

Robot type	Weight
IRB 4600-60/2.05	425 kg
IRB 4600-45/2.05	425 kg
IRB 4600-40/2.55	435 kg
IBB 4600-20/2.50	412 kg

Fig. 5. Versions, maximum payload, reach and weight for the ABB IRB4600-40/2.55

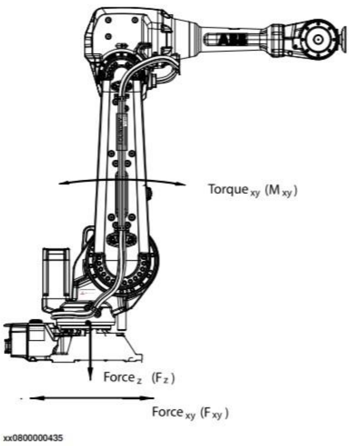

Fig. 6. Forces and moment displacements for the ABB IRB4600-40/2.55 while being reverse mounted (first view)

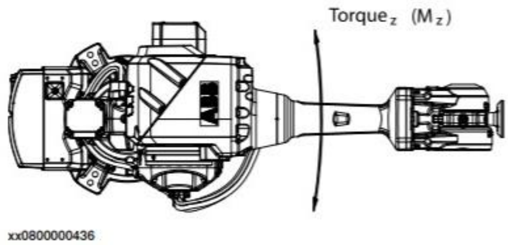

Fig. 7. Forces and moment displacements for the ABB IRB4600-40/2.55 while being reverse mounted (second view)

Maximum load in relation to the base coordinate system

Floor Mounted

Force	Endurance load (in operation)	Max. load (emergency stop)
Force xy	±3940 N	±7790 N
Force z	4350 ±2460 N	4350 ±6360 N
Torque xy	±6850 Nm	±14090 Nm
Torque z	±1610 Nm	±2960 Nm

Suspended

Force	Endurance load (in operation)	Max. load (emergency stop)
Force xy	±3940N	±7790 N
Force z	-4350 ±2460N	-4350 ±6360 N
Torque xy	±6850 Nm	±14090 Nm
Torque z	±1610 Nm	±2960 Nm

Fig. 8. Values of forces and moments developed by ABB IRB4600-40/2.55

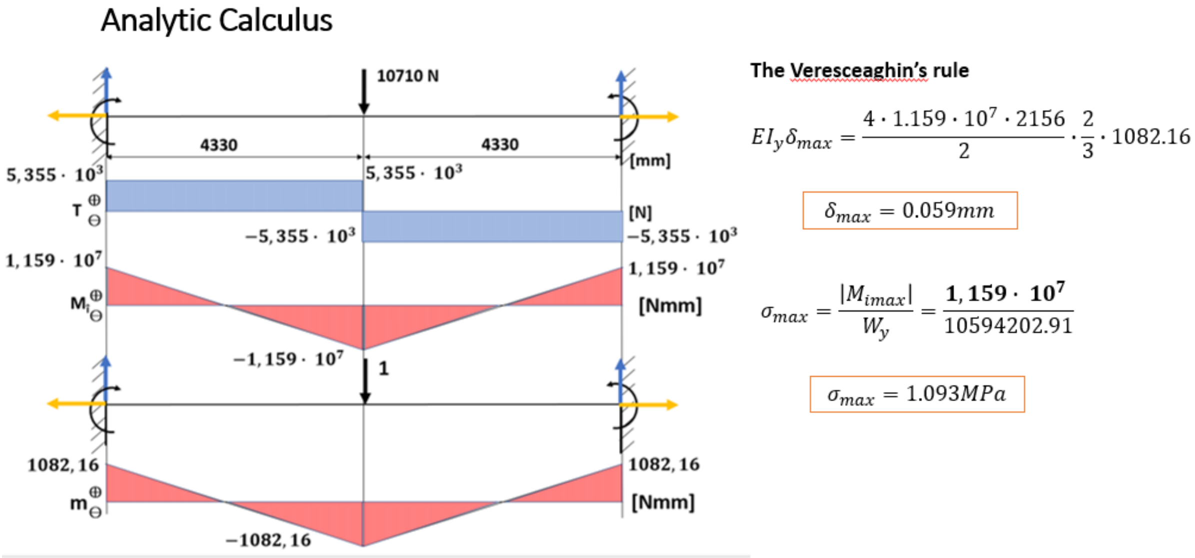

Fig. 9. Analytical calculus of the main beam and representation of diagrams [1], [3]

Simulation and analysis of the main beam in Ansys [2]:

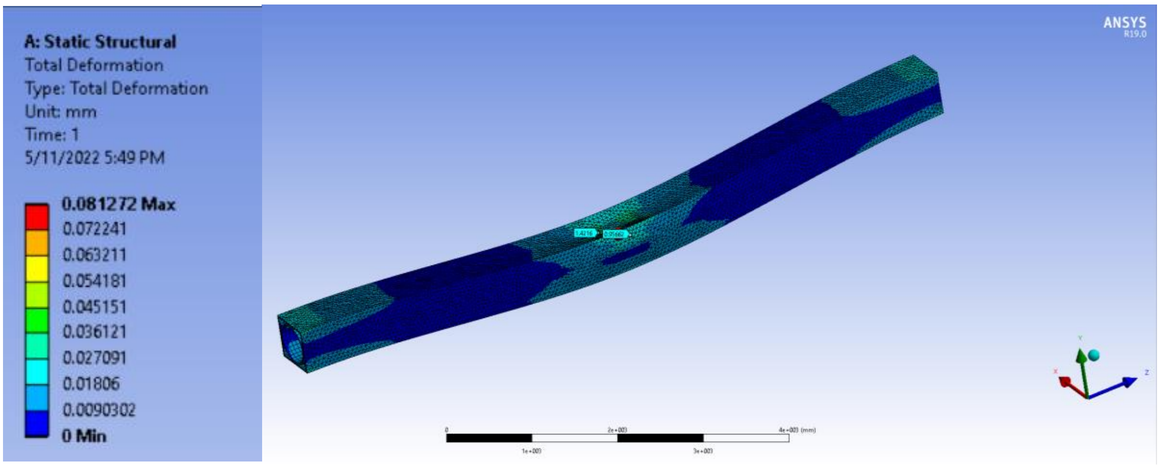

Fig. 10. Total deformation for the main beam

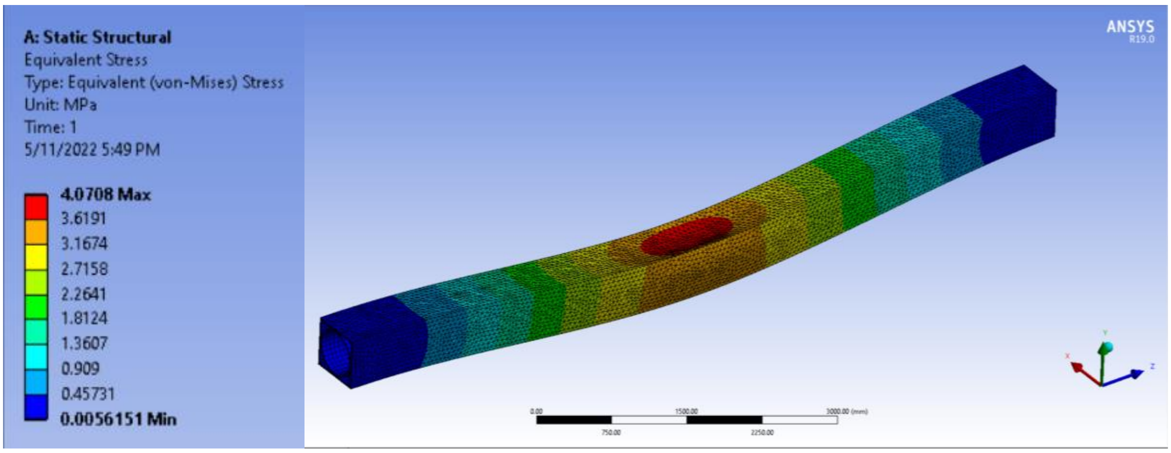

Fig. 11. Equivalent stress for the main beam

Simulation and analysis of the structure in Ansys:

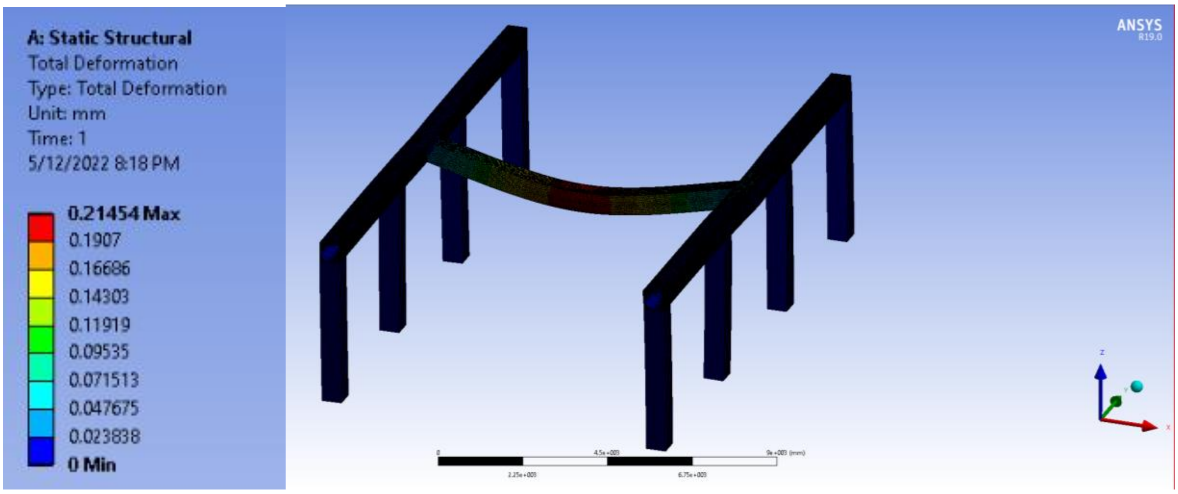

Fig. 12. Total deformation of the structure

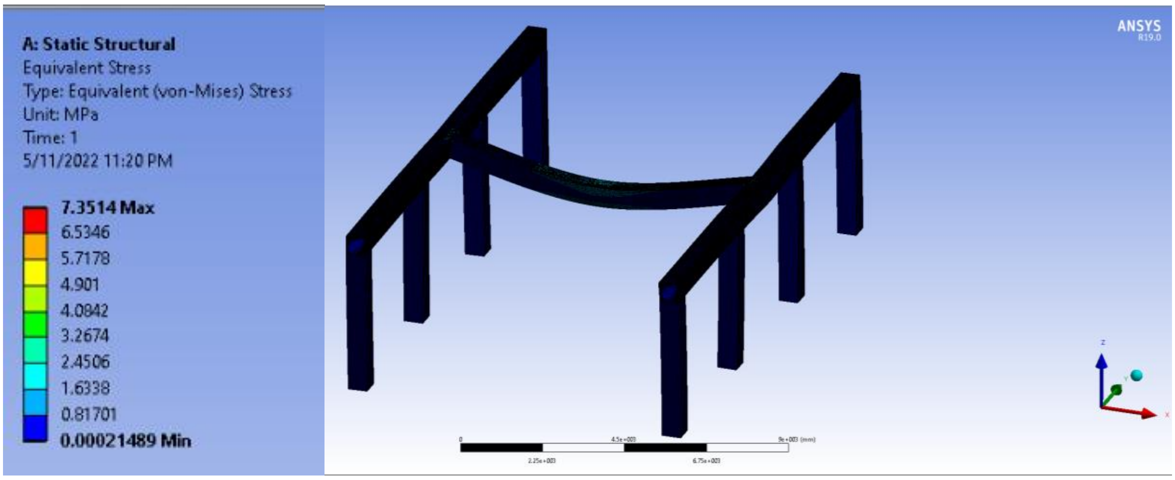

Fig. 13. Equivalent stress of the structure

The Veresceaghin's rule

$$EI_y\delta_{max} = \frac{4 \cdot 1.159 \cdot 10^7 \cdot 2156}{2} \cdot \frac{2}{3} \cdot 1082.16$$

$$\delta_{max} = 0.059mm$$

$$\sigma_{max} = \frac{|M_{imax}|}{W_y} = \frac{\mathbf{1,159 \cdot 10^7}}{10594202.91}$$

$$\sigma_{max} = 1.093MPa$$

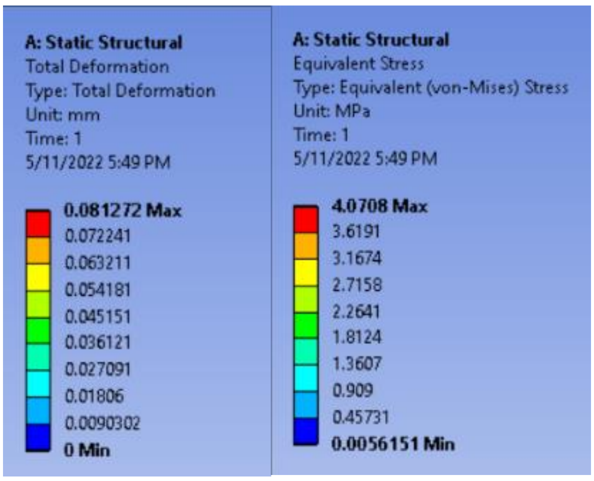

Fig. 14 Comparison between analytical result and simulation result

Conclusions

The study has reached the goals to design and simulate in as close to reality as possible of a gantry structure dedicated to a robotic cell. Comparing the final results obtained analytical (deformation 0.059 mm equivalent stress 1.093 MPa) with the results of the final element analysis (0.21454 mm total deformation and 4.0708 MPa equivalent stress), it can be observed that the values were similar, taking into consideration the total deformation and the equivalent stress of the structure. For furthermore development it could be taken into consideration the following directions of the study: thermic expansion behaviour, vibration influence over the structure, dynamic analysis and strain sensors research over real life miniature replica at a given scale.

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