CAD MODELING AND FINITE ELEMENT ANALYSIS OF AN INDUSTRIAL ROBOTIC ARM

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ABSTRACT

The design process of an industrial robot starts by identifying the requirements of the customers. The requirements mostly are: application of the robot, working space, reach, accuracy, repeatability, resolution, degree of freedom and payload. They are useful in industrial application such as painting, assembling, positioning, inspection, machining, welding etc. In this paper, CAD model of KUKA industrial robot was developed first in Solidworks software followed by finite element analysis in ANSYS Mechanical workbench of its arm and gripper which are main load bearing elements and prone to failure under critical loading conditions. Using this estimation it is possible to choose between the simulation time and the desired percentage of accuracy in the results.

Keywords: CAD Modeling, Finite element analysis, Industrial robot, Robotic arm

1- INTRODUCTION

To be competitive in a changing market it is necessary to deliver reliable products in the shortest period of time possible. Before the advancement of personal computers, only few institutions were able to perform Finite Element Analysis (FEA), making the design process extensive and exclusive in the automobile and aeronautic industries. Nowadays the use of this tool has become a routine in different areas of engineering. FE methods have become the standard techniques for evaluating the physical performance of structural systems in various engineering applications.

In the concept realization phase of the mechanical design process, it is necessary to evaluate if the model can resist loads applied to it. In order to analyze the structure, static and dynamic calculations are performed. The time required to evaluate complicated structures is extensive, even though computational tools are utilized.

In order to perform FEA it is not sufficient to just run the simulation in any FE available software, it is more important to understand the method behind the analysis. There are certain parameters which control the accuracy of the FEA, such as: model simplification, mesh size, element type and accuracy percentage. By understanding the impact of the parameters mentioned above, it is possible to run the simulation efficiently.

The main goal of this paper is to automate the FEA process in ANSYS Workbench and prove the advantages of having a parametric design of a model. This thesis also aims to create a generic framework which can import developed CAD models automatically and evaluate mesh size in order to establish fast analysis without compromising the accuracy of results.

2- DESIGN PROCESS OF INDUSTRIAL ROBOT

The design process of an industrial robot starts by identifying the requirements of the customers. The requirements mostly are: application of the robot, working space, reach, accuracy, repeatability, resolution, degree of freedom and payload. The application varies on the industry, some examples of applications are the following: painting, assembling, positioning, inspection, machining, etc. The working space is the volume where the robot can position the end effectors. Reach is defined as the longest length the robot can position the end effectors in the working space; it is measured from the first axis of rotation until the last one. The accuracy is measure by how close the robot gets to the desired position.

The repeatability of the robot is the ability to repeat certain movements and to come back to previous established positions. The working space is divided into small distances, the resolution is how divided the working space is, this will determine all the points which the robot can be positioned. One important requirement of the robot is the degree of freedom, this will determine the working space of the robot and the possible independent movements the structure can do. The load the robot can carry is called payload.

2.1 CAD Modeling

The advent of Computer aided design (CAD) software's replaced the manual drawings performed by the drafters with 2D or 3D graphical representation of physical objects. In industrial design and product design CAD software's are used to model 3D (solid, Surface, Sheet metal) components or 2D drawings of physical components. These 3D models are extensively used in the engineering design process like FEM analysis to evaluate and analyze various concepts.

Advanced CAD software's have the capability to perform analysis of different aspects of the product such as FEM, Manufacturing, etc and have the features which can make it possible to integrate with other CAX software's. In the present work, CAD modeling has been performed using solid works software.

2.2 ANSYS Software

Treatment of engineering problems basically contains three main parts: create a model, solve the problem and analyze the results. Ansys, like many other FEA programs, is also divided into three main parts namely the processors which are called pre-processor, solution processor and post-processor. The Ansys pre-processor allows users to build geometry, define materials and generate element mesh. The Ansys processor allows users to solve problems by applying loads and obtaining solutions. The Ansys post-processor allows visualization and listing of results in a tabular form or as printouts. Ansys offers a comprehensive software suite that spans the entire range of physics, providing access to virtually any field of engineering simulation that a design process requires. Organizations around the world trust Ansys to deliver the best value for their engineering simulation software investment.

3- DESIGN DATA CALCULATIONS

3.1 KR 90 R3100 EXTRA (KR QUANTEC EXTRA)

Maximum versatility and flexibility. More streamlined. More compact. More robust. The reduction of the moving mass enables the all-rounder of the KR QUANTEC extra series to set new standards in precision, performance, energy efficiency and availability. With a payload capacity of 90 kg, the KR 90 R3100 extra forms a highly cost-effective entry-level class of its own for reaches of up to 3,100 mm.

Fig. 1: Industrial KUKA Robot (courtesy: www.kuka.com)

Loads

Payload	90 kg
Supplementary payload	50 kg

Working envelope

Max. reach	3095 mm

Other data and variants

Number of axes	6
Repeatability	±0,06 mm
Weight	1092 kg
Mounting positions	Floor, ceiling
Controller	KR C4
Protection class	IP 65

4- FEA OF AN INDUSTRIAL ROBOTICARM

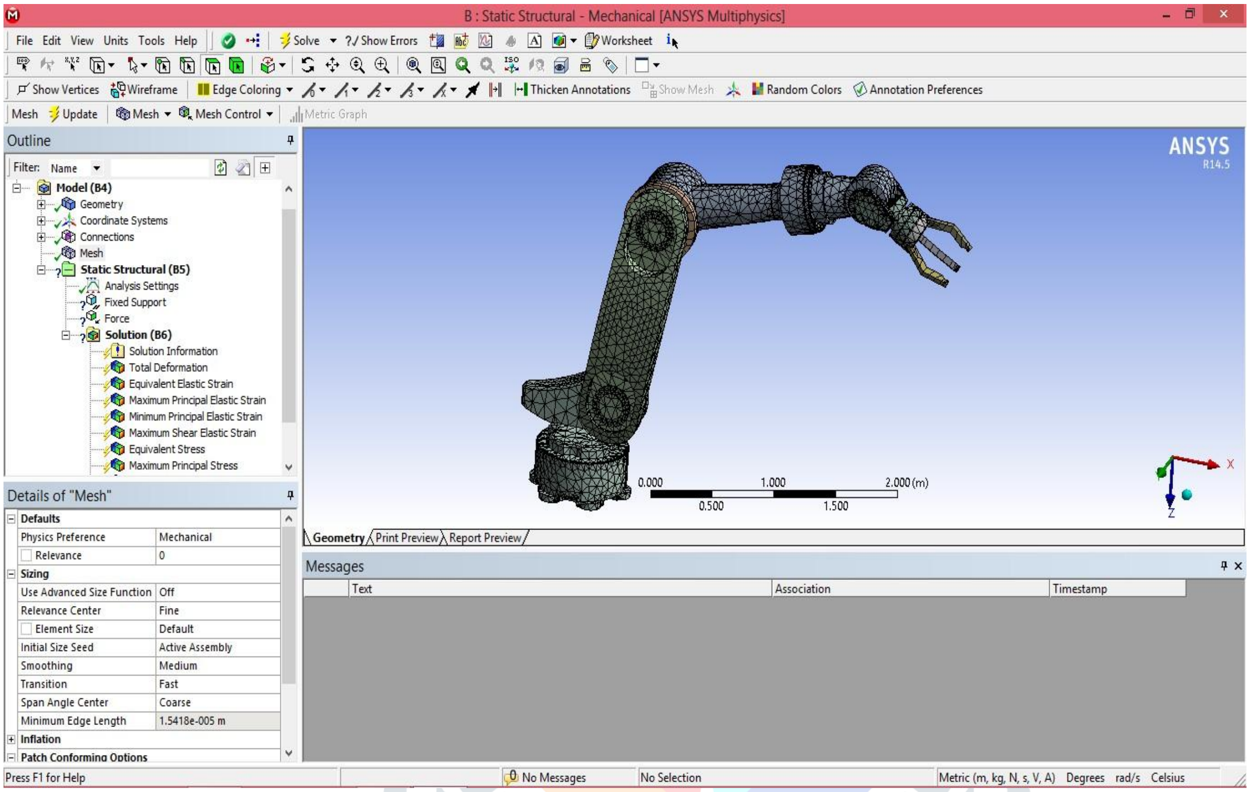

Fig. 1: Mesh model of an industrial robot

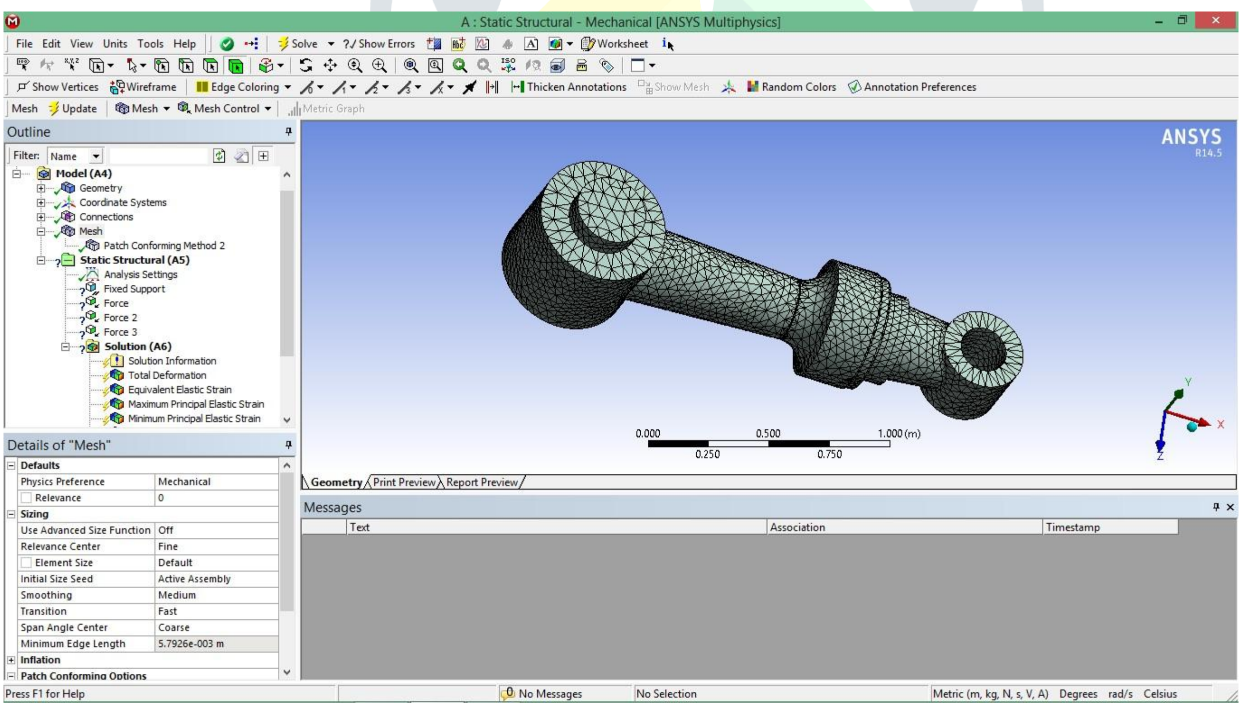

Fig. 2: Mesh model of industrial robotic arm

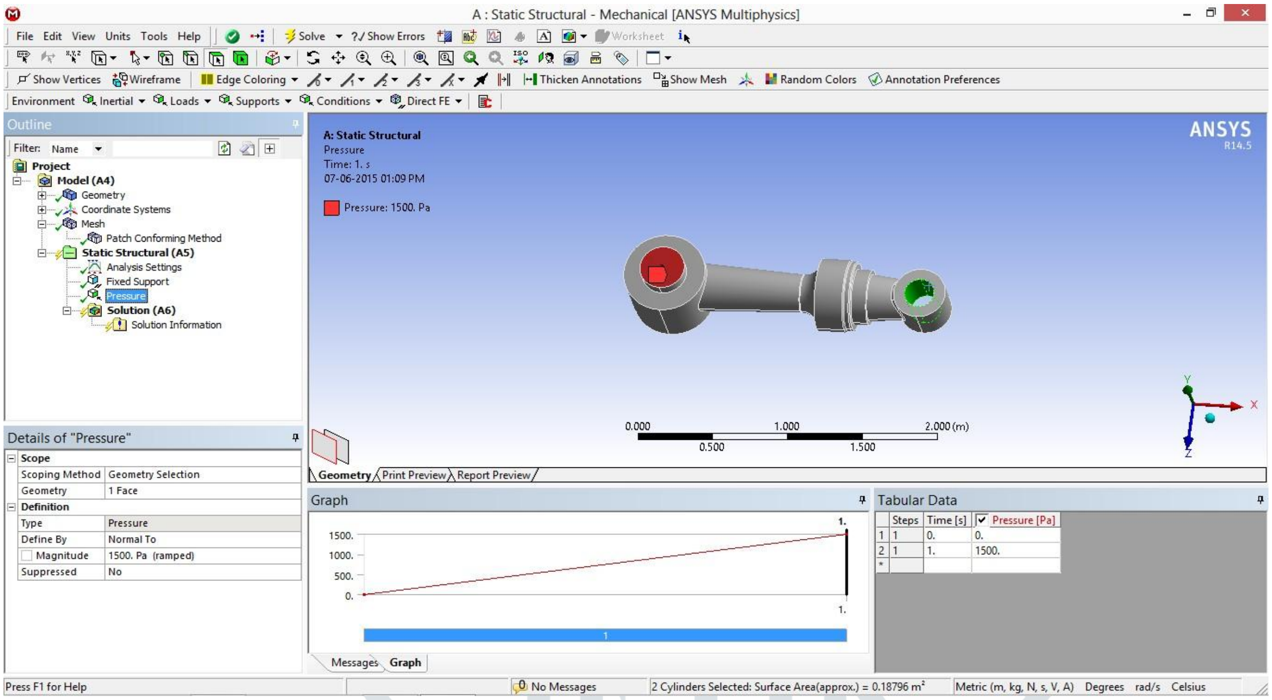

Fig. 3: Application of Static load

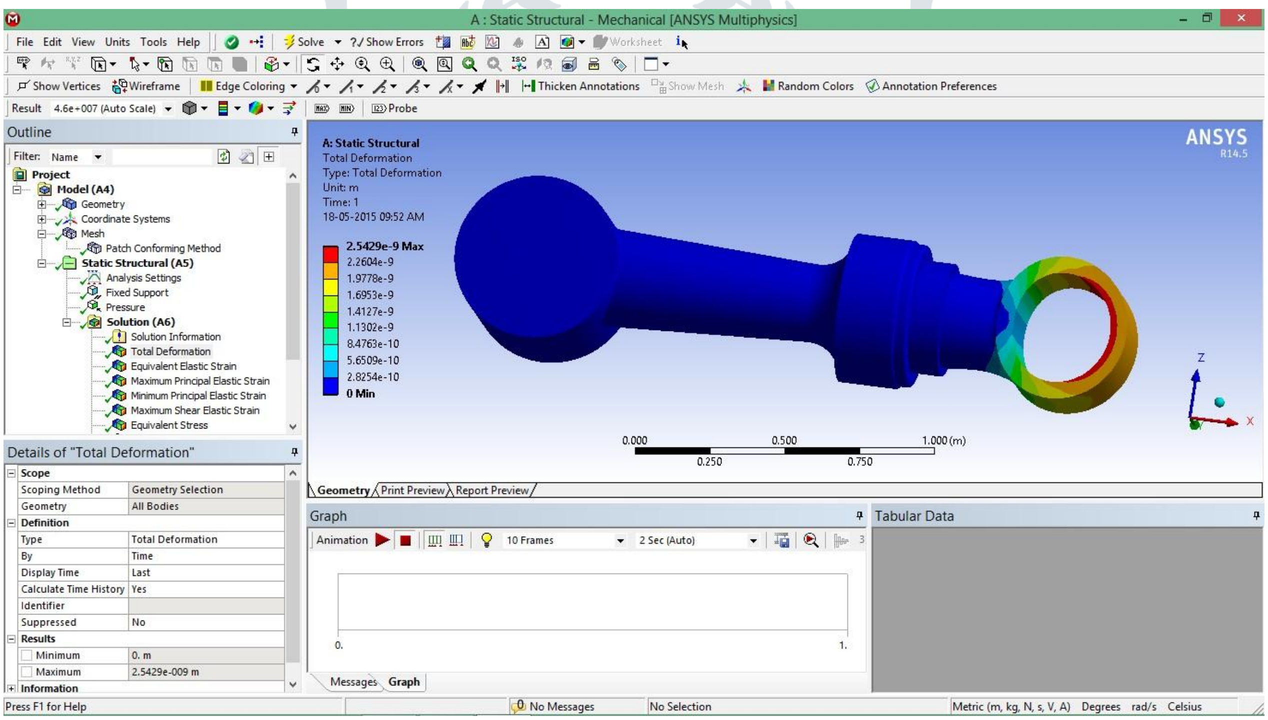

Fig. 4: Maximum principal elastic strain in an industrial robotic arm

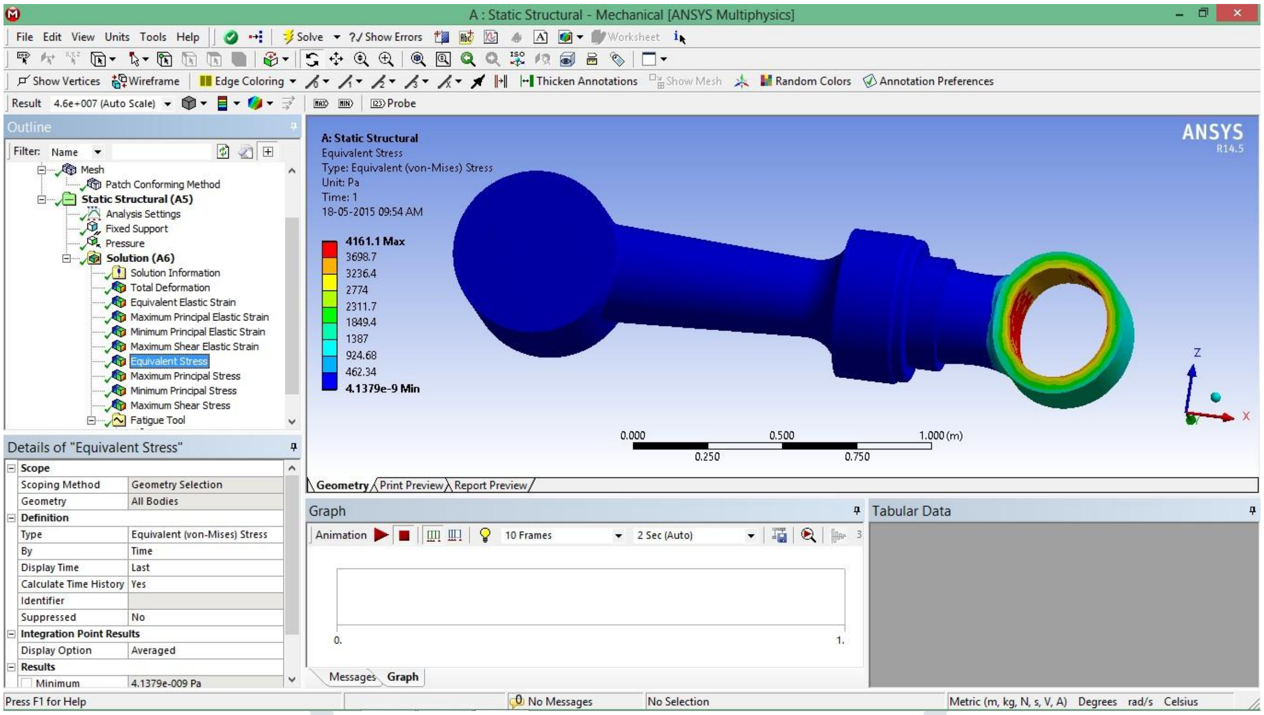

Fig. 5: Von misses stress in an industrial robotic arm

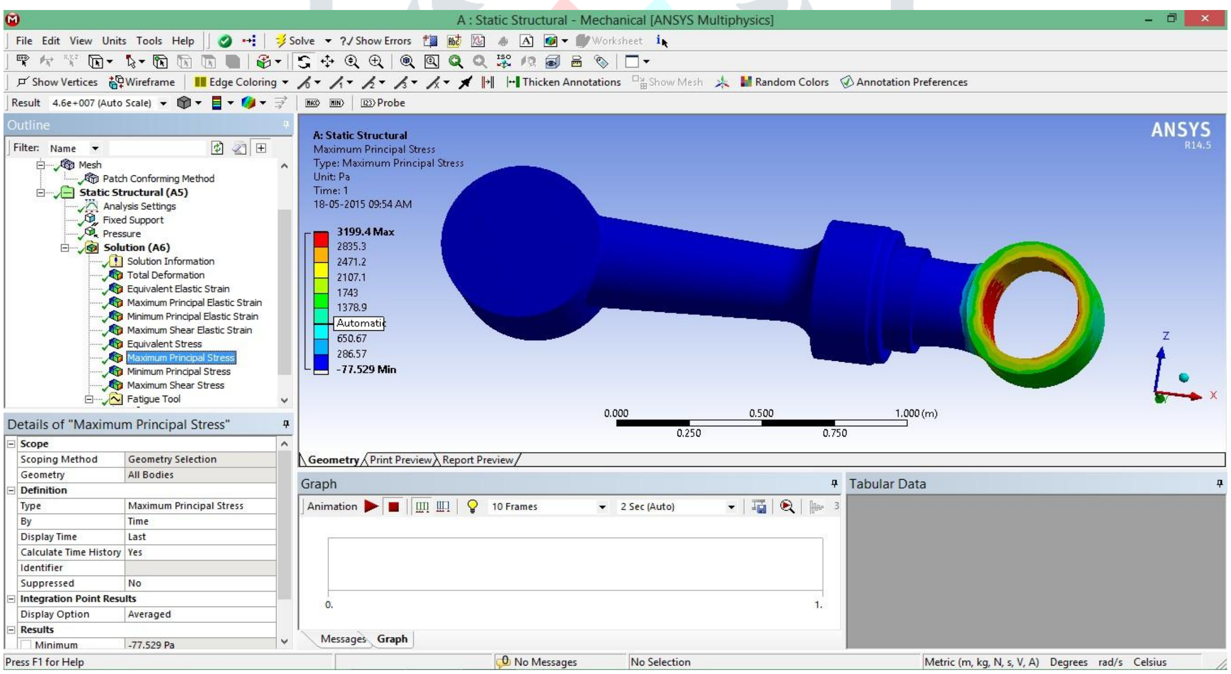

Fig. 6: Maximum principal stress in an industrial robotic arm

4.1 FEA results

Applied Pressure = 1500 Pa

Total Deformation = 2.5429e-9 Max

0 Min

Equivalent Elastic Strain = 2.0811e-8 Max

3.3124e-20 Min

Maximum Principal Elastic Strain = 1.8212e-8 Max

1.2936e-20 Min

Minimum Principal Elastic Strain = -1.4588e-20 Max

-1.2651e-8 Min

Maximum Shear Elastic Strain = 3.0642e-8 Max Von-Mises Stress = 4161.1 Max

4.1379e-9 Min

Maximum Principal Stress = 3199.4 Max

-77.529 Min

Minimum Principal Stress = 257.6 Max

-1545.1 Min

Maximum Shear Stress = 2357.1 Max

2.1172e-9 Min

Safety Factor = 15 Max

15 Min Life = 1e6 Max

1e6 Min

5- CONCLUSIONS

The following conclusions have been drawn from this work-

Two parametric CAD models of an industrial robot lower arm are constructed. These two are created by using two different modeling approaches and they are validated with the original model. The models are compared using the automated framework and it can be concluded that the mass properties are sufficiently close to each other. FEA is used to minimize repetitive work at industry performing.

The parametric model obtained with approach 1 did not give comparative Von Mises Stress results with the original CAD model of the robotic arm.

Approach 2 on the other hand has given satisfactory results in the comparison. This test further strengthens the hypothesis that parametric CAD models together with automated FEA are an efficient alternative to non-parametric CAD and manual FE processes.

Mesh evaluations have been performed in both the parametric CAD models and the functional relation between Mesh Element Size and the outputs has been estimated.

Using this FEA approach, it is possible to choose between the simulation time and the desired percentage of accuracy in the results.

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