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Modelling and Structural, Analysis of a 6-DOF Robot Spray Coating Manipulator

P. Madhuraghava[1], D. Fakruddin Basha[2], V.Subhash Reddy[3], N.sunil[4]
1.Assistant Professor in Mechanical EnggDept., SREC, Nandyal.
2. UG Student in Mechanical EnggDept., SREC, Nandyal.
3. UG Student in Mechanical EnggDept., SREC, Nandyal.
4. UG Student in Mechanical EnggDept., SREC, Nandyal.
Corresponding author: P. Madhuraghava

---***ABSTRACT***---
This *paper presents Structural Analysis of a 6-DOF Robot Spray Coating Manipulator for automobile application using NX-CAD and ANSYS APDLsoftware. In automobile most products manufacture from metallic materials require some form of painted finish before delivery to the customer, the technology for applying these finishes varies in complexity from simple manual methods to highly sophisticated automatic techniques.When accomplished manually, the result in many health hazards to the human operator these include fumes and mist in the air, noise from the nozzle, fire hazards and potential cancer hazards. The feature of many robot spray-coating applications is that the manipulator must be designed and analysis to process a variety of part styles, each with its unique configuration. The advantages and disadvantages of using robots in a paint finishing system are discussed. A robot can also carry more weight than dedicated equipment or humans thus allowing them to carry paint-delivery equipment, such as colour changing valves, on their arm and close to the applicator. In this analysis, the robot manipulator isanalysed. Analysis are made to get the position and orientation of manipulator.Also the spray coating manipulator strength and environment conditions are analysed with various loading conditions and Position and orientation of end effector are analysed by forward kinematic.Measurement and observation of robot manipulator are made on NX-CAD and ANSYS APDL software.*

Keywords: NX–CAD, ANSYS APDL, Structural Analysis, Spray Coating Manipulator.

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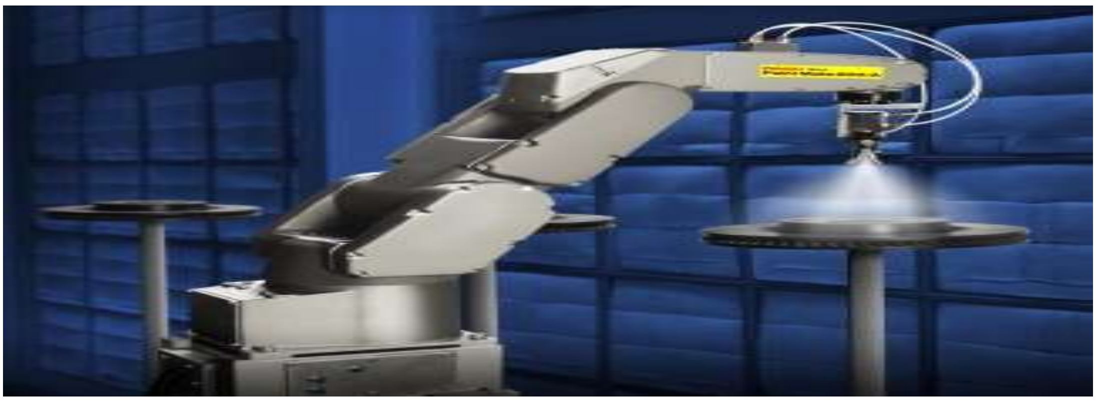
I. INTRODUCTION

Industrial paint robots have been used for decades in automotive paint applications from the first hydraulic versions - which are still in use today but are of inferior quality and safety - to the latest electronic offerings. The newest robots are accurate and deliver results with uniform film builds and exact thicknesses. Originally industrial paint robots were large and expensive, but today the price of the robots have come down to the point that general industry can now afford to have the same level of automation that only the big automotive manufacturers could once afford.

The selection of today's paint robot varies much more in size and payload to allow many configurations for painting items of all sizes. The prices vary as well as the new robot market becomes more competitive and the used market continues to expand. Painting robots generally have five or six axis motion, three for the base motions and up to three for applicator orientation. These robots can be used in any explosion hazard Class 1 Division 1 environment.



Every metallic material will be painted at the final stage of production in order to protect it from *corrosion*. In an automobile industry, the finished metals are painted with different colours for attracting the customers. In olden days, this painting process was done by two methods such as spray coating and immersion & flow coating methods.

Spray Coating method:
In the spray coating method, a *spray gun* is used to coat the paints on a metal. It is done manually by the well skilled human labours. This process can be performed by three different ways, namely:

- Airless spray method.
- Air spray method.
- Electrostatic spray method.

Immersion and Flow Coating methods:
The operation of immersion and flow coating methods are almost similar to each other. Both these methods are very simple techniques in the painting process. In the immersion method, a metal is dropped into a paint tank and taken out. The surplus of paints is sent back to the tank. The metals that are to be painted are placed on top of the paint tank in the flow coating method. In this process, the paint is made to flow on the metal for painting.

II. BACKGROUND

The history of robots has its roots as far back as ancient myths and legends. Modern concepts were begun to be developed when the industrial revolution allowed the use of more complex mechanics and the subsequent introduction of electricity made it possible to power machines with small compact motors. After the 1920 the modern formulation of a humanoid machine was developed to the stage where it was possible to envisage human sized robots with the capacity for near human thoughts and movements, first envisaged millennia before. The first uses of modern robots were in factories as industrial robots simple fixed machines capable of manufacturing tasks which allowed production without the need for human assistance. Digitally controlled industrial robots and robots making use of artificial intelligence have been built since the industrial robot is defined as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes. The field of robotics may be more practically defined as the study, design and use of robot systems for manufacturing. Typical applications of robots include welding, painting, assembly, pick and place (such as packaging, palletizing and SMT), product inspection, and testing; all accomplished with high endurance, speed, and precision. The most commonly used robot configurations are articulated robots, SCARA robots, Delta robots and Cartesian coordinate robots, (aka gantry robots or x-y-z robots). In the context of general robotics, most types of robots would fall into the category of robotic arms.

III. REASON FOR USING ROBOT IN PAINTING OPERATION:

The spray coating method is the harmful process in the painting operation. It causes a lot of dangers to the human workers such as:

- Production of fire during the combination of flammable paint and air.
- Emission of toxic fumes and mist in the environment.
- Possibility of cancer disease.
- Noise from the spray gun nozzle will cause hearing problems.

To get rid out of all the above hazards, the Spray Painting Robot was introduced to perform this process. This robot attaches a spray gun on its wrist and acts like an end effector. The operation is programmed by a human with the help of teach – through methods. A robot must have several necessities such as two or more program storage, continuous path control, manual lead through programming method, and hydraulic drive system for carrying out this process. This type of robots is mostly used in automobile industries for painting the exterior and interior parts of a car.

Before using a robot in the spray painting application, some of the significant parameters should be checked for achieving consistent quality of painting like air & fluid pressure, flow rate, specific gravity, viscosity, appropriate temperature, and more. Most importantly, it should be cleaned sequentially for gaining high consistency.

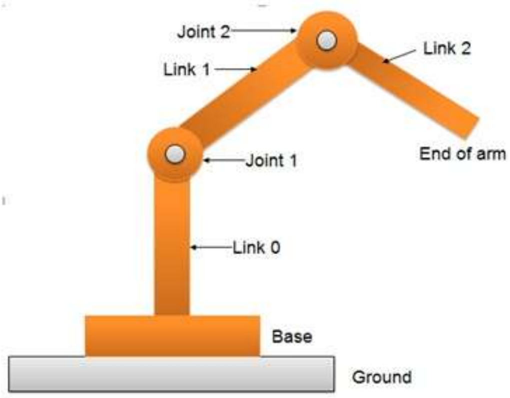
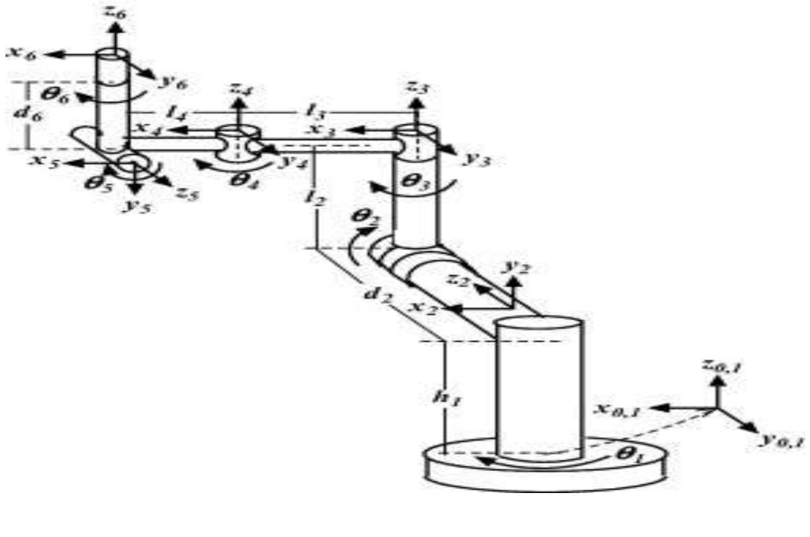


Fig:Structure of robot manipultorFig:Structure of robot manipultor

Industry-specific robots perform several tasks such as picking and placing objects, movement adapted from observing how similar manual tasks are handled by a fully-functioning human arm. Such robotic arms are also known as robotic manipulators. These manipulators were originally used for applications with respect to bio-hazardous or radioactive materials or for use in inaccessible places.



INVERSE KINEMATICS

A series of sliding or jointed segments are put together to form an arm-like manipulator that is capable of automatically moving objects within a given number of degrees of freedom. Every commercial robot manipulator includes a controller and a manipulator arm. The performance of the manipulator depends on its speed, payload weight and precision. However, the reach of its end-effectors, the overall working space and the orientation of the work is determined by the structure of the manipulator.

IV. KINEMATICS OF A ROBOTIC MANIPULATOR

A robot manipulator is constructed using rigid links connected by joints with one fixed end and one free end to perform a given task (e.g., to move a box from one location to the next). The joints to this robotic manipulator are the movable components, which enables relative motion between the adjoining links. There are also two linear joints to this robotic manipulator that ensure non-rotational motion between the links, and three rotary type joints that ensure relative rotational motion between the adjacent links. The manipulator can be divided into two parts, each having different functions: Arm and Body – The arm and body of the robot consists of three joints connected together by large links. They can be used to move and place objects or tools within the work space Wrist – The function of the wrist are to arrange the objects or tools at the work space. The structural characteristics of the robotic wrist include two or three compact joints.

V. ROBOTIC MANIPULATOR ARM CONFIGURATION

Manipulators are grouped into several types based on the combination of joints, which are as follows:
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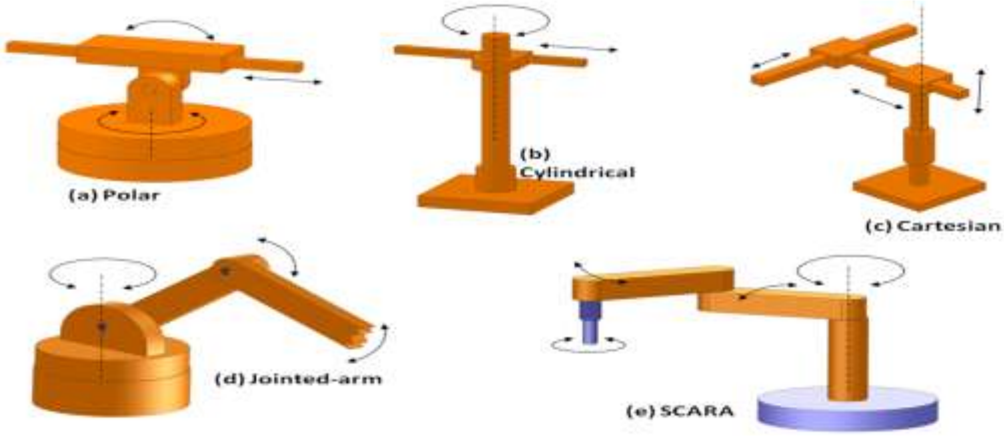
Cartesian geometry arm – This arm employs prismatic joints to reach any position within its rectangular workspace by using Cartesian motions of the links.
Cylindrical geometry arm – This arm is formed by the replacement of the waist joint of the Cartesian arm with a revolute joint. It can be extended to any point within its cylindrical workspace by using a combination of translation and rotation.
Polar/spherical geometry arm – When a shoulder joint of the Cartesian arm is replaced by a revolute joint, a polar geometry arm is formed. The positions of end-effectors of this arm are described using polar coordinates.
Articulated/revolute geometry arm - Replacing the elbow joint of the Cartesian arm with the revolute joint forms an articulated arm that works in a complex thick-walled spherical shell.
Selective compliance automatic robot arm (SCARA) – This arm has two revolute joints in a horizontal plane, which allow the arm to extend within a horizontal planar workspace. The TH650A SCARA Robot by TM Robotics is a great example to demonstrate pick and place functionality of robotic manipulators:

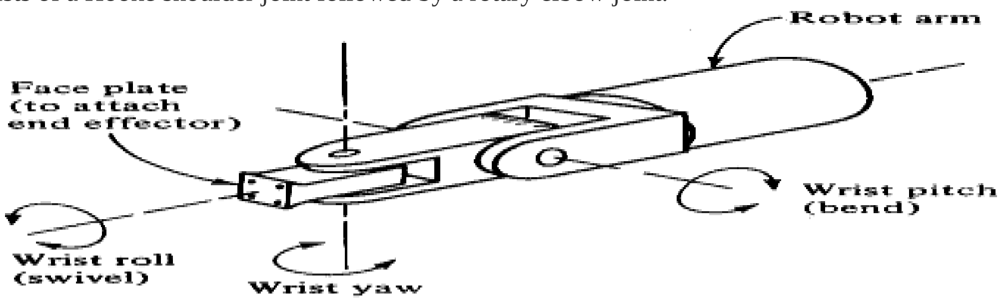


VI. WRIST CONFIGURATION

The two main types of wrist design include:

- Roll-pitch-roll or spherical wrist
- Pitch-yaw-roll.

The spherical wrist is more common because of its mechanically simpler design. It has 6 degrees of freedom, and consists of a Hooke shoulder joint followed by a rotary elbow joint.



VII. Manipulator Design and Analysis

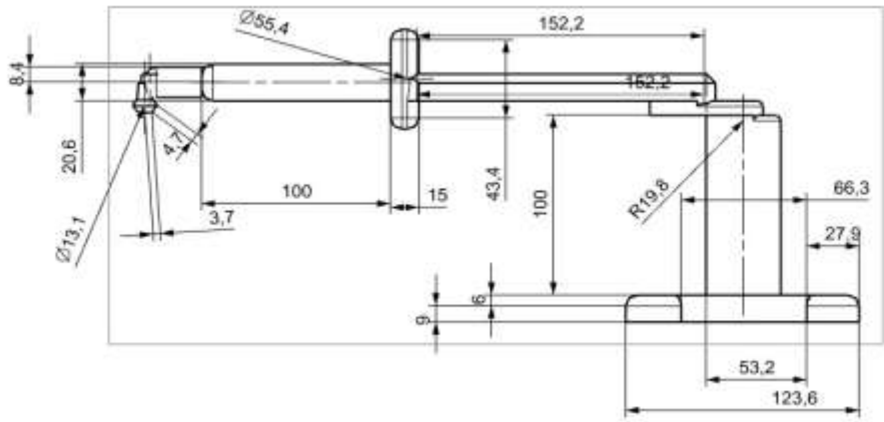
- Defining theProblem
- Identifying the purpose of aconstruction
- Identifying specificrequirements

The need to determine what problem you are trying to solve before you attempt to design

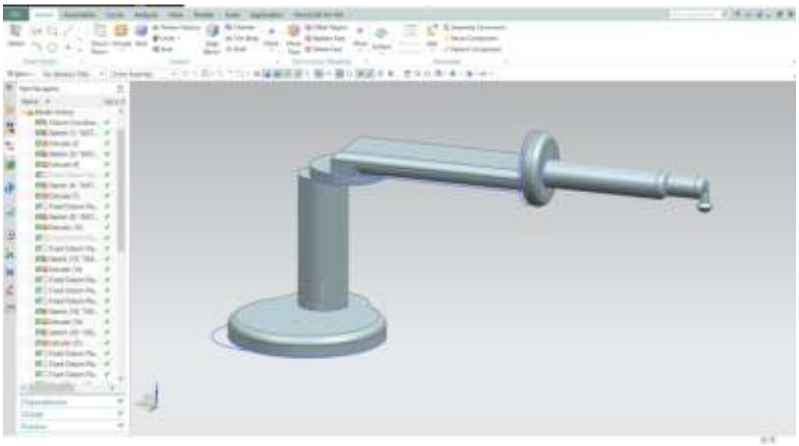
This is the main body of the robot; it consists of the links, the joints, and other structural elements. The weight of the robot is roughly 20kg. The robot is equipped with an operating system Base OS. The Base OS control every aspect of the robot, such as motion control, development and execution of application programs communications. The Robot can also be equipped with optional software for application support. The IRB1410 ABB Robot has a payload of 5kg and a working envelop (reach) of about 1.44m.

VIII. MANIPULATOR DESIGN PARAMETERS

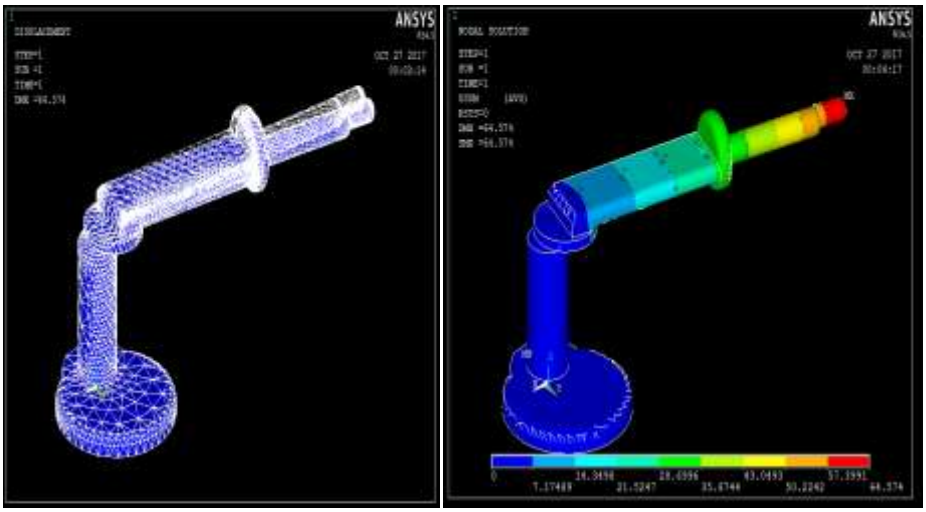
Type of material: Aluminum,
Poisson's ratio: 0.32
Young's modulus 69Gpa, Ultimate tensile strength 110Mpa, yield strength 95Mpa



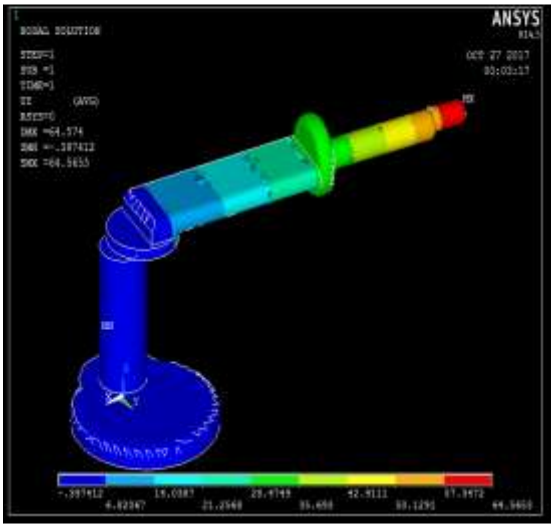
DRAWING BY NX –CAD (All dimensions are in MM)

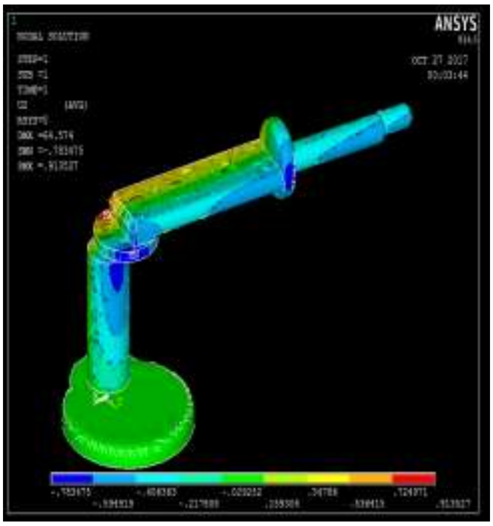


Manipulator Modelling By Using NX-Cad Software

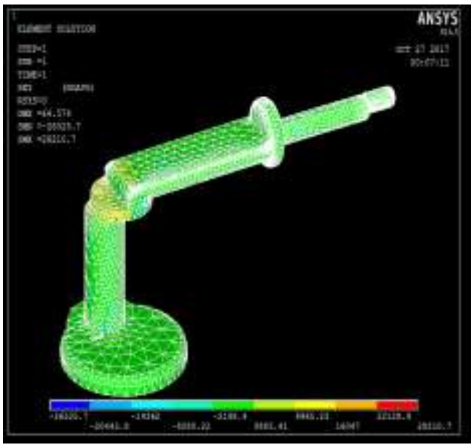


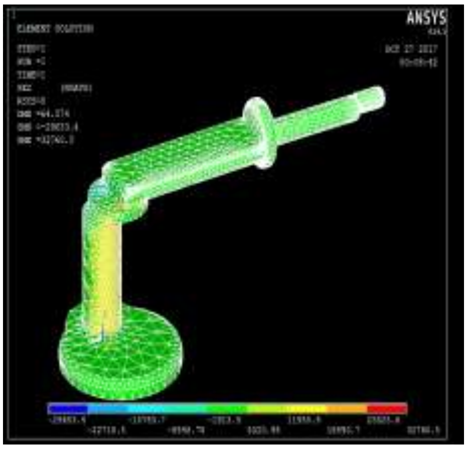
Meshing Displacement Vector Sum



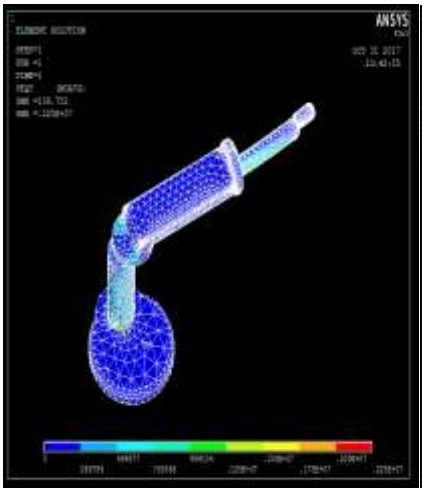


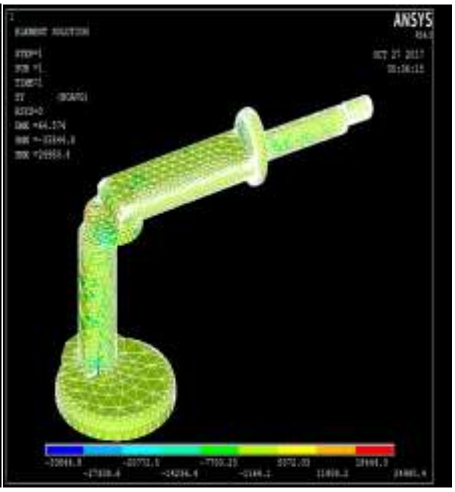
DOF In Y –Direction DOF In Z- Direction



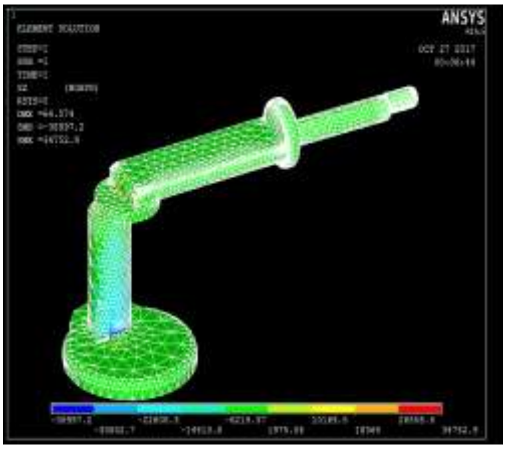


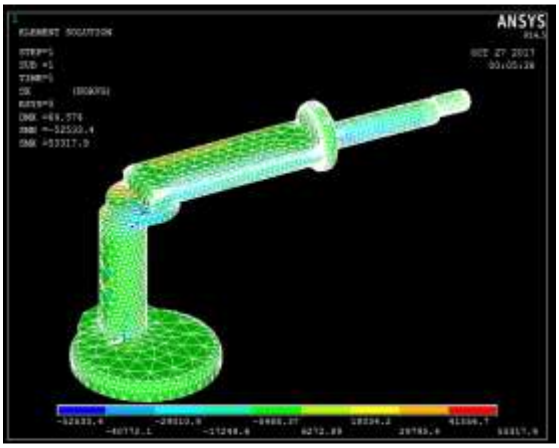
Stress In XY- Directionstress In XZ- Direction



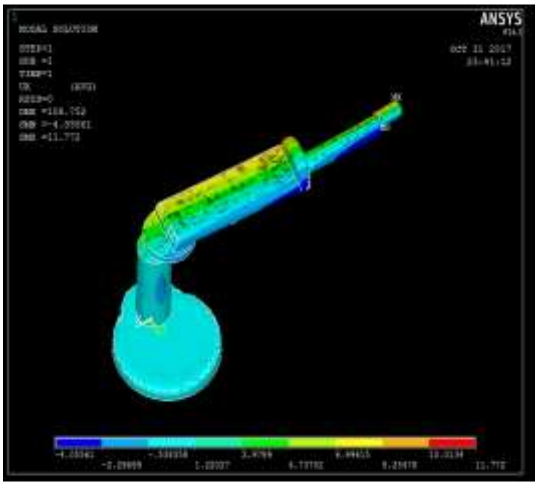


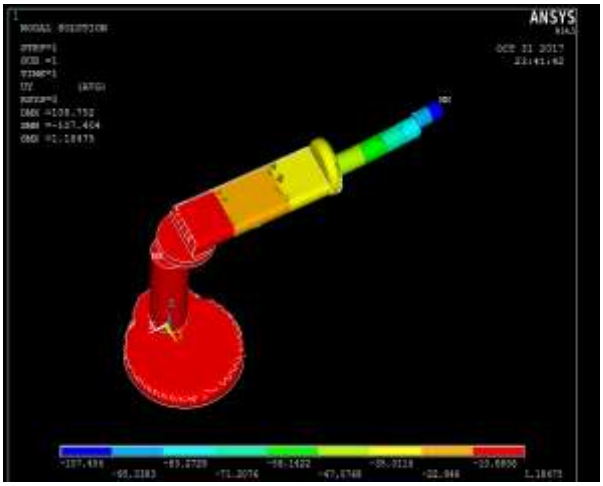
Von misses stress Stress In Y- Direction



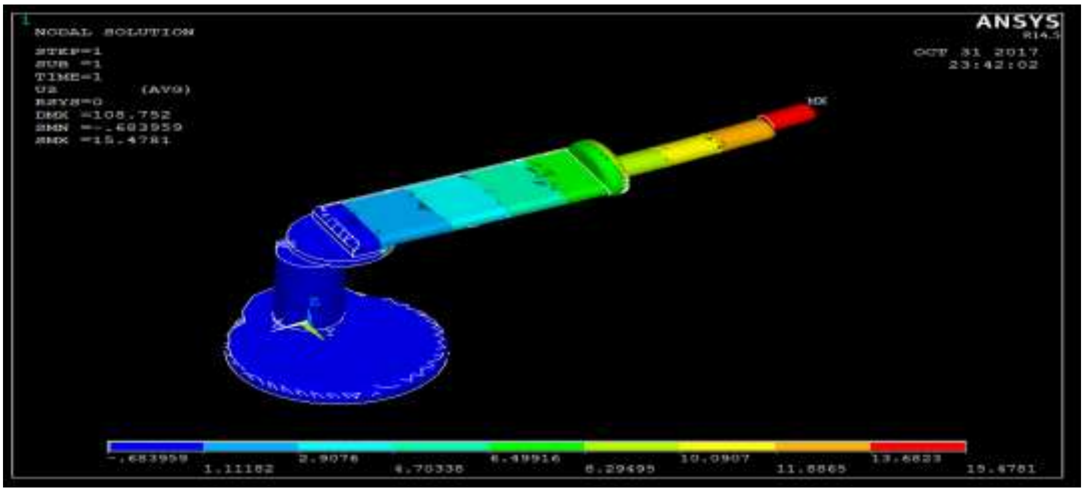


Stress In Z –Direction Stress In X- Direction





Nodal Solution In X- DirectionNodal Solution In Y-Direction



Nodal solution in z direction

IX. CALCULATIONS

POST1 ELEMENT TABLE LISTING
STAT CURRENT
ELEMENT Stress in X direction
58508 31516.
MINIMUM VALUES
ELEM 55206
VALUE -0.20376E+07
MAXIMUM VALUES
ELEM 41082
VALUE 0.18726E+07

OST1 ELEMENT TABLE LISTING
STAT CURRENT
ELEMENT Stress in Y direction
58508 -17588.
MINIMUM VALUES
ELEM 50858
VALUE -0.10121E+07
MAXIMUM VALUES
ELEM 39613
VALUE 0.12364E+07

POST1 ELEMENT TABLE LISTING
STAT CURRENT
ELEMENT Stress in Z-direction
58508 73188.
MINIMUM VALUES
ELEM 50858
VALUE -0.66145E+06
MAXIMUM VALUES
ELEM 39613
VALUE 0.62706E+06

X. ADVANTAGES OF SPRAY PAINTING ROBOT:

- High consistency, higher quality.
- potentially higher production output
- Increased labours safety
- Less power consumption
- Minimizes the use of paint

XI. CONCLUSION

The conclusion of this paper is analysis of a model before going to prototype or manufacture there is the choice to reduce the cost and time and to make a better manipulator is also possible, and results was able to boost the quality of painting, safety was improved with the usage of all the painting materials, and the cost of painting was reduced by using less paint. The integration of all the components of a typical robot was the driving factor in achieving the present paper. The benefits to the manufacturer include higher quality, fewer rejects, potentially higher production output, and fewer employee health problems.

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