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Static and Dynamic Analysis of Articulated Robotic Arm for Domestic Purposes

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A B S T R A C T

The articulated robotic arm is getting huge importance due to its high precision work in carrying out heavy task. This project is related with the modeling and analysis of an articulated robotic arm which can be utilized for painting tasks. For designing and simulation of the articulated robotic arm SOLID EDGE software is used. The finite element analysis was carried out using ANSYS software workbench to study the model of a robotic arm with different dimensions and various loading conditions. The results of the analysis are reviewed for selecting the best structure parameter and also approving good feasibility of the articulated robotic arm.

Keywords: SOLIDEDGE, ANSYS, factor of safety, stress distribution, deformation analysis

1. INTRODUCTION

Robot is a machine which can execute various tasks quickly and its precision is also very good. So it is largely used in the manufacturing industry for producing good quality products in less time with precision. These machines minimize or eliminate the human factor to gain various advantages in processing speed, capacity and quality. They are safe to use around human operators as they have a controllable speed limit for operation and are limited as to how much force they can generate. They operate continuously through repetitive movement cycles as instructed by set of commands called program Traditional industrial robots must not be confused with a newer robotic technology called collaborative robots. The main structure of an industrial robot is the arm. The arm .is a structure made of links and joints. Links are rigid components that move through space in the range of the robot. The joints, on the other hand, are mechanical parts that connect two links while allowing translational (prismatic) or rotational (revolute) movement. The configuration of these two components classifies the different types of industrial robots. The most important part of the robot is the end-of- arm-tool (EOAT), or end effector. The EOAT is the component that manipulates the product or process by moving or orienting. They perform special operations such as welding, measuring, marking, drilling, cutting, painting, cleaning, and so on. Most of the company produce huge robotic arm at high cost. So many small and medium scale industries cannot afford such components. We have to design a compact robotic arm at affordable cost.

2. METHODOLOGY

According to their requirements, the material must be selected which must be suitable for carrying maximum payloads. The methodology provide us the sequence operations carried out in this project by chronological order. The experimental analyses is compared with the ANSYS analyses to check the accuracy of the computational software and the program for articulated robotic arm is generated to get output for the different payload conditions. Finally, discuss the result obtained by ANSYS and conclusion is given.

3. MATERIAL SELECTION

Robots are mostly built of common materials. The operating environment and strength required are major factors in material selection. There are a wide variety of metals and composites available in the market these days. Selection of materials and the cost study to design an economic model is a completely different and deeper area of engineering. The materials are chosen in such way that they satisfy our payload bearing capacity requirements and not too expensive. Steel, cast iron and aluminium are most often used materials for the arms and base of robots. Selection of materials is a completely different study.

3.1 GREY CAST IRON

To design robotic manipulator parts cast iron is selected. Grey cast iron is characterised by its graphitic microstructure, which causes fractures of the material to have a grey appearance. It is the most commonly and most widely used cast material based on weight. Grey cast iron has good tensile strength and shock resistance than steel, but its compressive strength is comparable to high carbon steel. Most cast irons have a chemical composition of 2.5–4.0% carbon, 1–3% silicon, and the remainder iron.

4. CAD MODELING

Computer-aided design (CAD) is defined as any action that includes the effective use of the computer to create, modify or study an engineering design. SOLIDEDGE software is utilized to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. Each individual parts of robotic arm is designed and assembled by SOLIDEDGE software.

5. FINITE ELEMENT ANALYSIS

The arm geometry with the FE model, boundary conditions, and payload conditions are the input information for FE analysis. The direction and location of each payload input to the component define the payload conditions. The finite element method was adopted to solve various links under stress due to the payload conditions. The advantage of simulation is less time, cost and easier comparison to experiment method. Assembly of the robotic arm is converted into STEP or IGS file format so that it can be imported to the software. ANSYS software uses the static structural toolbox to calculate component stresses and deformation. Complete robotic arm is analysed by providing various payloads and tested for stability and factor of safety.

6. RESULT & DISCUSSION

6.1 STATIC STRUCTURAL ANALYSIS

Here the painting robotic arm has been designed using specialized software. Ideal robotic arm is designed for optimal weight, can withstand the highest levels of allowable stresses while carrying different payloads, has an efficient performance index and reduce the overall manufacturing and operational costs of a robot. The main target is to decrease the mass of the structure and lowering its physical distortions to enhance the stiffness of the design model we chosen or any static model by applying different force condition. The weight conditions, number of links in the robotic arm to be designed is assumed and some further external circumstances are well-defined earlier. This work validated the mechanization of ideal design process in terms of a 4-degree-of- freedom industrial robotic arm. The outcomes gotten from the ANSYS software with mesh size of 0.05 are significantly decent where analysis on total deformation and maximum shear stress are done. Like this, with the help of finite element model analysis (ANSYS), the extreme data of the different aspects can be figured out which can cause to failure of the model design.

The analysis of total deformation and stress of the model provides the basic information regarding life span, destruction and screw-up of the design. The base portion of the modal having the most minimal estimation of stress has appeared as dull blue shading and the top portion of the modal displays the highest data of stress has appeared as red shading.

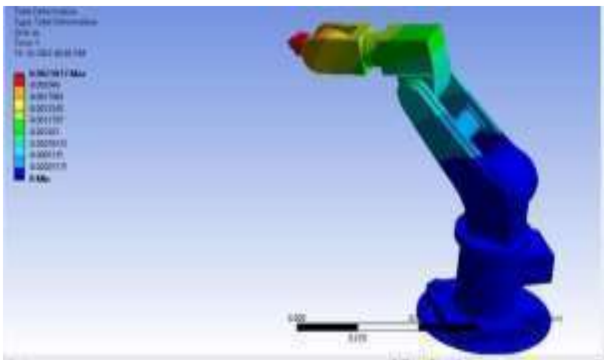


Fig-2 Total deformation at 2kg

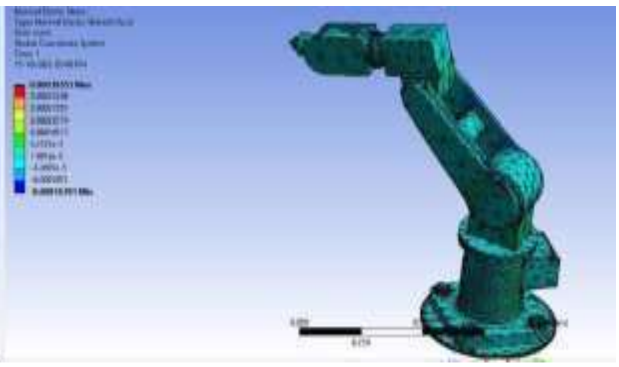
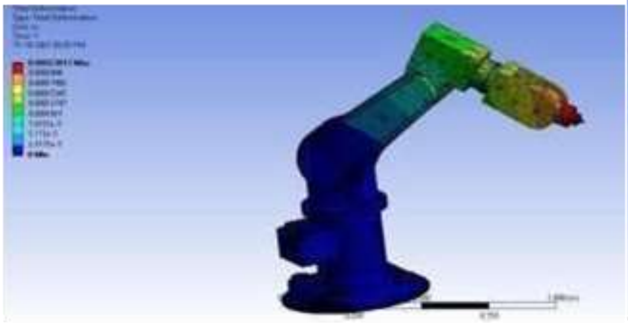


Fig-3 Stress analysis at 2kg



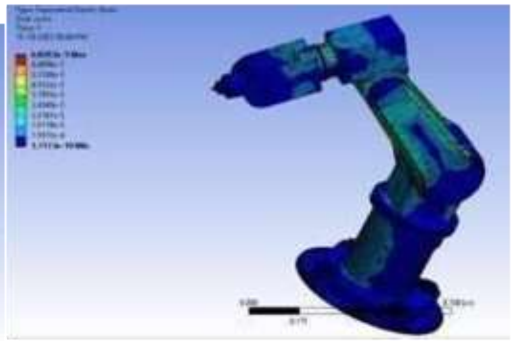
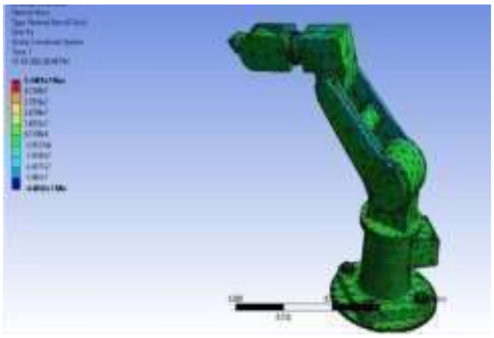


Fig-4 Deformation at 2.5 kg Fig-5 Stress analysis at 2.5 kg

Shear stress and deformation of robotic arm design for nozzle weight of 2 kg is presented in figure 2 and 3, it can be clearly seen that least deformation and stress is acted at the lower part of robotic arm and the maximum stress deformation occurred close to the nozzle. As the payload increases at the nozzle point it is clearly seen from the result that total deformation increases.

The figure 4 and 5 shows the total deformation and stress distribution of the robotic arm at 2.5 kg. By optimizing the deformed part, the normal stress is made to distributed equally and the results show less deformation at the nozzle compared to previous case.



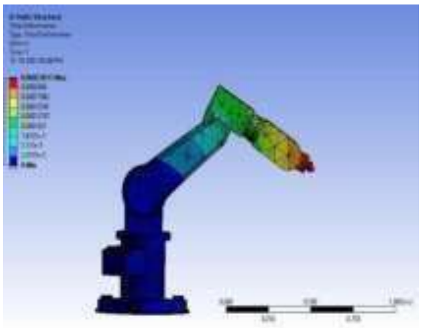


Fig-6 Normal stress at 3 kg Fig-7 Deformation at 3 kg

The figure 6 shows the normal stress distribution on the robotic arm at 3 kg. The forearm part of the robotic manipulator shows more stress distribution compared to other structures. The figure 7 shows the total deformation of the robotic arm at 3 kg.Nozzle part shows higher deformation compared to other parts. Next to nozzle, higher deformation shown by forearm and joint 2. It shows this domestic robotic arm can lift upto 3 kg without much difficulties at static condition. Hence factor of safety is 3 kg. Above such limit the arm weakens and chances of failure of nozzle increases. Thus the robotic arm is suitable for carrying load upto 30N.

Table 1-Stress,Deformation and strain results

S.NO	PAYLOAD	STRESS	DEFORMATION	STRAIN
1	1 kg	3.187 E+05	3.275 E-08	5.811E-07
2	1.5 kg	3.545 E+05	3.414 E-08	6.279 E-07
3	2 kg	7.855 E+05	4.836 E-07	8.141 E-07
4	2.5 kg	4.458 E+06	5.447 E-07	3.088E-06
5	3 kg	6.178 E+06	6.712 E-07	6.258 E-06

The forces are applied on the bodies of the robotic arm which induce stress on those bodies. The behaviour of the body upon applied payload is analysed by computing its stress. The shoulder part can carry a maximum 30 N payload safely and it is the weakest part of the robotic arm. The base and shaft can carry 50 N force safely and it is the strongest part of the entire robotic arm. The arm 1 can carry 35 N force safely and its maximum stress is observed at its fillet section.

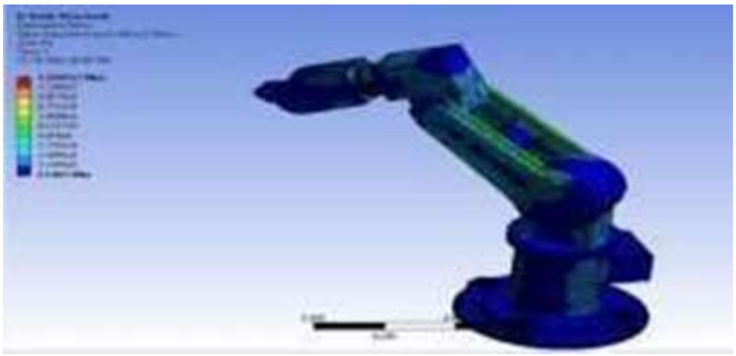


Fig-8 Equivalent stress at 3 kg

If the value of maximum stress is greater than the yield stress that means the structure will fail. The figure 8 shows the equivalent stress distribution on the robotic arm. The pressure state of a structure with particular loading is also characterized by the FE analysis results

6.2 TRANSIENT ANALYSIS RESULT

A safe payload of 30 N can be carried by arm 2 as well and the maximum stress of arm 2 is observed at the potion where it is connected with arm1. The average force acting at revolute joint 1 is nearly 40 N during the dynamic analysis of the robotic arm. Therefore, from these analyses, it is observed that the design of the robotic arm is safe for the above mentioned payloads and given angular velocities at the joints of the robotic arm.

There are two revolute joints in the robotic arm between arm 1 and collar and between arm 2 and arm1. The revolute joint between arm 1 and collar is named 'Revolute joint 1' and the revolute joint between arm 2 and arm 1 is named 'Revolute joint 2'. The joint between the shaft and base is the twisting joint. The variation of applied angular velocities of different joints of the robotic arm with respect to time is shown in chart 1. When the rotation of joints of the robotic arm is anti-clock wise, the angular velocity of the joints is taken positive and when the rotation of the joints of the robotic arm is clockwise, the angular velocity of the joints is taken negative. The maximum applied angular velocity of revolute joint 1 is 1 RPM

The rotation of revolute joint 1 is given clockwise. The maximum applied angular velocity of the twisting joint is 2 RPM. The rotation of the

twisting joint is given anti-clockwise. There is no angular velocity provided at the revolute joint 2. Force is induced in revolute joint 1 due to the rotation of revolute joint 1 and twisting joint. The induced force in revolute joint 1 is determined and its variation with respect to time can be observed from chart 2. It is observed that the average force acting at revolute joint 1 is nearly 40 N. Fluctuation of dynamic forces is observed in revolute joint 1 as the robotic arm is not dynamically balanced. The entire robotic arm is operated at a low speed which leads to very less fluctuation of dynamic force. Therefore, very low vibration can take place in the r o b o t arm .

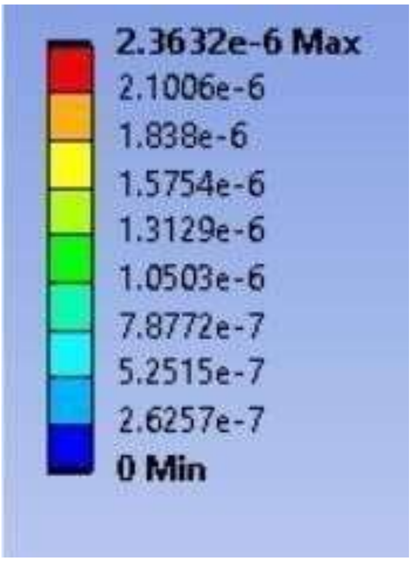


Fig-9 Equivalent stress and deformation values at 3 kg

From the obtained results, we can conclude that all the results for stress distribution are within the permissible limits i.e. they are less than the yield and ultimate stress for the materials. However cast iron Arm is giving better results as compared with the other industrial arm for the same payload. Also the results show that the structural strength of the articulated robotic arm met the working requirements and are eligible for further studies.

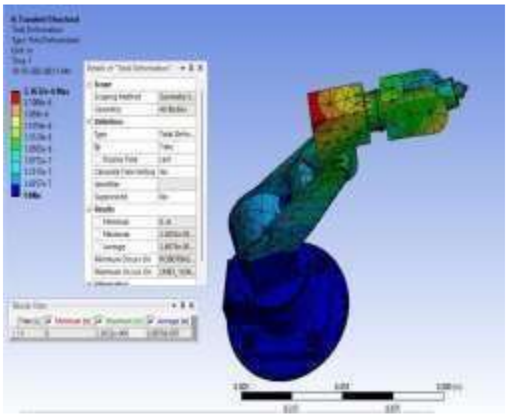


Fig-10 Total deformation at transient payload 3 kg

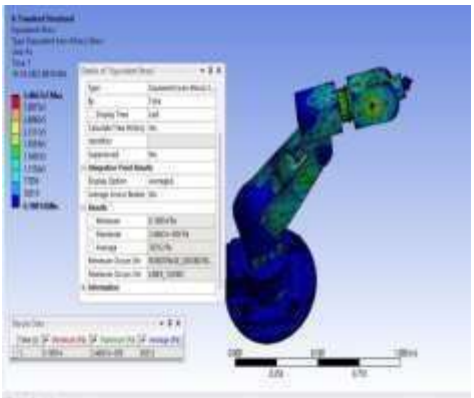


Fig-11 Equivalent stress at transient payload 3 kg

The figure 10 shows the total deformation of the robotic arm manipulator at a payload of 3 kg with various angular velocity. The results are compared with yield stress and ultimate stress of the material and it is found that robotic arm manipulator shows improved results as they lie within permissible limits. The figure 11 shows the Equivalent stress of the robotic arm manipulator at a payload of 3 kg with various angular velocity. Thus from the simulation this grey cast manipulator arm is best suited for both large scale and small scale industrial applications. As the cast iron is affordable and readily available , and the size and structure of the arm is modified economically many companies will prefer this manipulator for many applications

CONCLUSION

In the present work, the design parameters of articulated robotic arm for application were analysed using ANSYS software. The results shows that stress distribution and total deformation value of articulated robotic arm at 3 kg payload are 6.178 E+06 and 6.712 E-07 respectively. The strain distribution at the payload of 3kg is 6.258 E-06. This results value clearly shows that articulated robotic arm has more strength and less vibrating effect at the application of transient payload of 3kg at various angular velocity. There will be slightly greater deformation in case of other dimensions with same payload. The values obtained from the software shows the end effector can be applicable for the effective function of painting at maximum payload of 3 kg without any deviation. Complex and complicated duties would be achieved faster and more accurately with this design. Hence this manipulator met the working requirements and suitable for performing work at hazardous area in industries which is eligible for further studies.

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