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Material Selection Analysis of the Robot Arm Based on ANSYS

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Abstract

When materials selecting, the engineering process involves three different steps: selecting a suitable material, specifying a shape or design for the engineering problem, and determining the necessary manufacturing processes to create the design. The material selection process begins with identifying the desired attributes of the engineering problem, such as looking at the density, strength, or cost of the material for example. ANSYS to be as a finite element analysis software has powerful features in structural analysis. Based on ANSYS material analysis function, this paper selects two materials, and analysed which material is most suitable for this arm. The analysis is done with several of forces applied on under arm of the robot arm. The solution for the total deformation and equivalent von misses is analysed.

Keywords

ANSYS, Deformation, Equivalent Stress, Yield stress.

1. Introduction

Finite element method as a numerical method is widely used as a calculation method in the field of engineering analysis, since the mid-20th century, it gets widely developed with its unique advantages of computing, and now there are many different finite element methods, and thereby there produce some finite element commercial softwares which are very mature and professional. With the rapid development of computer technology, a variety of engineering softwares have been widely used. [1] ANSYS software with its multi-physics field coupled analysis function has become mainstream of CAE software applications and it is widely used in the engineering analysis. At the same time ANSYS software has powerful features dealing with thermal analysis, thermal analysis has always been the important applications of ANSYS.

Deformation and stress analysis are the primary task in designing the structure such as robots. These are needed for the maintenance and investigation of such structural failure. There are many methods to determine stress in structures subjected to various loads applied. It is required to investigate the stability, strength and rigidity of structures. Robotic arm are generally made out of four different types of materials: wood, plastic, metal or composites. These different materials vary with the function, size, cost, and weight of the robot design requirements.

Robots also come in various sizes as well, whether the body type is round, oval, square, or other shapes. When choosing materials, it is important to know how easy the material is to machine and shape into the arm. This paper analysed the differences between Aluminium and Acrylic for designing the robot.

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2. Material Analysis Theory of ANSYS

2.1. Finite Element Basis

Finite Element Method has proven to be a valuable tool for the analysis of advanced materials and structures, particularly for parametric structural analysis at the design stage. In this work, FEM structural analysis was carried out using ANSYS software.

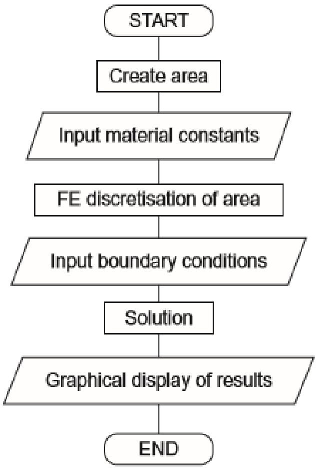

Fig 1. Flowchart of the structural analyses by ANSYS

Material properties can be divided into several different subsections, including mechanical, thermal, electrical, optical, environmental, general, and several other subsections.

In mechanical properties, the first property is the elastic modulus, which is the slope of the linear elastic line on the stress-strain curve and describes a materials response to compression or tension loads. The elastic modulus, or Young’s modulus, is important in knowing how much a material will deform.

The next property is strength, which varies in definition depending upon the material. Strength is defined by looking at the stress, which is defined as the amount of force per surface area that the material can withhold.

Equivalent (Von Misses) stress is a value used to determine if a given material will yield or fracture. It is mostly used for ductile materials, such as metals.

There are two different types of deformation, elastic and plastic. Elastic deformation will automatically reverse itself when external forces are removed. Imagine a rubber band no matter how stretch it, once let go of one end it will 'snap' back to its original shape. Plastic deformation is a permanent deformation. To reverse it, an additional external force needs to be applied to return the object to its original shape.

When squeeze the middle of a plastic bottle, it compresses and stays deformed even when let go. Have to add pressure to the inside or squeeze the opposite direction to return it to normal.

All objects will begin experiencing elastic deformation at first, but once the stress on the object exceeds a certain amount, it will experience plastic deformation. When that switch happens, the object has reached its yield stress.

Young’s Modulus is a measure of the ability of a material to withstand changes in length when under lengthwise tension or compression. It gives a measure of the flexibility of a material. The mathematical definition of Young’s modulus (specifically, the tangent modulus) is,

$$E = (\partial\sigma / \partial\varepsilon)_T \tag{1}$$

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The stress level σ is below the proportional limit for the material. The quantity ε is the mechanical strain caused by the stress σ. Young's modulus is related primarily to the forces between atoms in a material. Values for Young's modulus for Aluminium and Acrylic are given below.

Poisson's Ratio is the ratio of transverse contraction strain to longitudinal extension strain in the direction of stretching force.

When the atoms of a material are pulled apart by a force applied in a certain direction, there is a corresponding contraction of the material in the lateral direction, perpendicular to the applied force. Poisson's ratio μ is the magnitude of the ratio of the lateral strain in the direction of the applied force. For a force applied in the x-direction, Poisson's ratio may be written as follows,

$$\mu = -\varepsilon y/\varepsilon x \quad (2)$$

The quantity εy is the mechanical strain in the y-direction when a force is applied in the x-direction, and εx is the mechanical strain in the x-direction (the direction of the applied force). The negative sign is introduced because the strain in the transverse direction will be a contraction (negative strain) if the force causes an elongation (positive strain) in the x-direction. Numerical values of Poisson's ratio for Aluminium and Acrylic are given below. [7]

3. Model

In this section, the analysis is done with several of force applied on the under arm of the robotic arm. The force that using for the deformation is 0.5N, 2.5N, 4.5N, 6.4N, 6.5N. Two different materials were selected as the testing samples. The selection reason of Acrylic and Aluminium is because those are popularly used in the industry. The reason to select these is to see how the yield stress plays a role in the design of robot arm. The solution for the total deformation and equivalent Von Misses is analyzed. The values used for the material analysis,

Aluminium	Acrylic
Density- 2710kg/m^3	Density- 1180kg/m^3
Young's Modulus- 69×10^9Pa	Young's Modulus- 3.2×10^9Pa
Poisson's Ratio- 0.32	Poisson's Ratio- 0.37

3.1. Total Deformation of Underarm (Aluminium) and Results

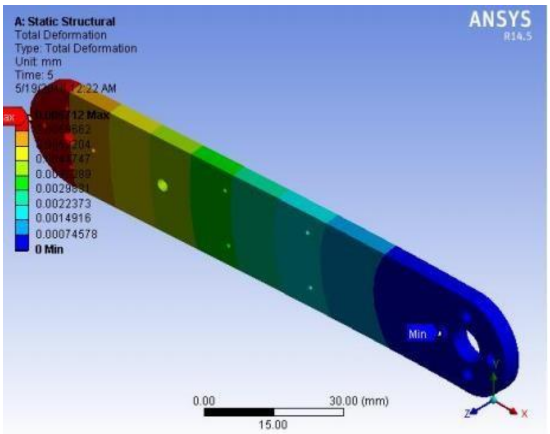

Fig 2. Total Deformation of under arm

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Table 1. Results of Stress Deformation

Force(N)	Max total deformation(mm)
0.5	5.1631e-004
2.5	2.5815e-003
4.5	4.6468e-003
6.4	**6.6087e-003**
6.5	6.712e-003

3.2. Equivalent Stress of Underarm (Aluminium) and Results

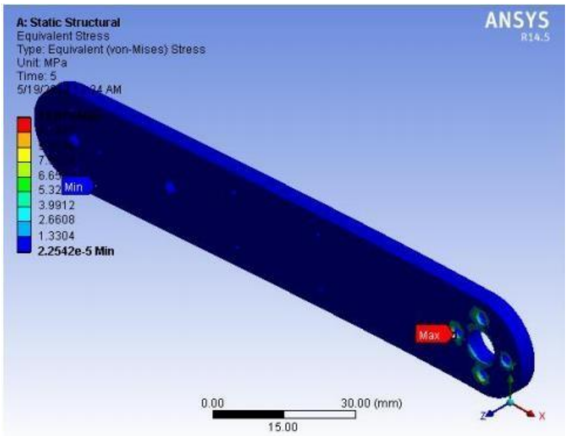

Fig 3. The Equivalent Stress of under arm

Table 2. Results of Equivalent Stress

Force(N)	Max Equivalent Stress(MPa)	Min Equivalent Stress(MPa)
0.5	0.921	1.73e-006
2.5	4.605	8.67e-006
4.5	8.289	1.56e-005
6.4	11.789	2.21e-005
6.5	11.974	2.25e-005

The simplified results is listed in the Table 1 and Table 2, where the bold character show the maximum force that the robotic arm can support before it will begin to break.

The value of the maximum stress for applied force is compared with the yield strength of the material of part affected. If the value of the maximum stress is higher, this means that the structure cannot stand the applied force. The maximum force that the Aluminium underarm can stand is the bold value in the tables since when the next force is applied the maximum stress occur on the part begins to get a higher than the material strength itself.

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3.3. Total Deformation of Underarm (Acrylic) and Results

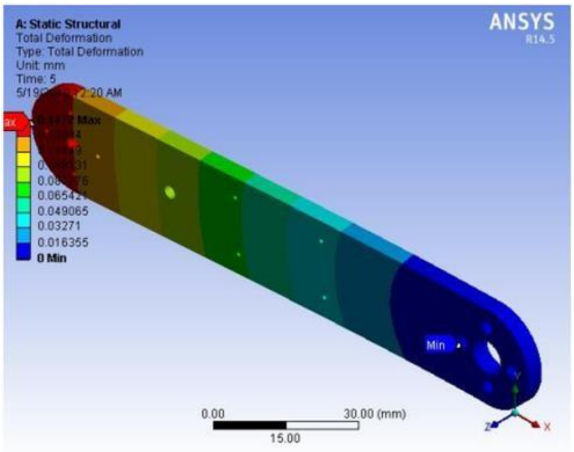

Fig 4. Total Deformation of under arm

Table 3. Results for Stress Deformation

Force(N)	Max total deformation(mm)
0.5	1.132e-002
2.5	5.66e-002
4.5	0.102
6.4	0.145
6.5	0.147

3.4. Equivalent Stress of Underarm (Acrylic) and Results

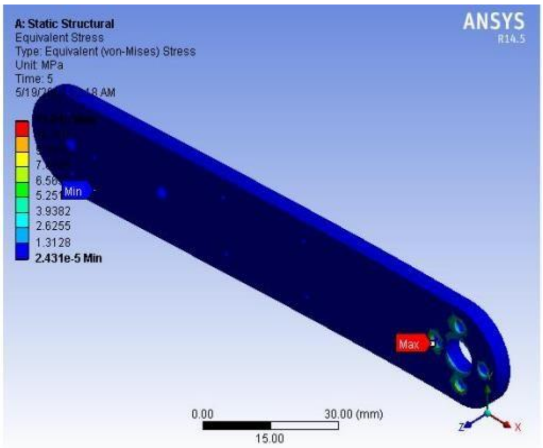

Fig 5. The Equivalent Stress under arm

Table 4. Results for Equivalent Stress

Force(N)	Max Equivalent Stress(MPa)	Min Equivalent Stress(MPa)
0.5	0.908	1.87e-006
2.5	4.544	9.35e-006
4.5	8.179	1.68e-005
6.4	**11.633**	**2.39e-005**
6.5	11.815	2.43e-005

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From Table 4, can see that when the applied force is 6.5N, the maximum equivalent stress is 11.815 MPa which is still smaller from the yield strength of the material of the underarm that is Aluminium. This proves that the performance of the Aluminium underarm for the robotic arm is better than the Acrylic underarm.

4. Results

4.1. The Combined Graph of Maximum Equivalent Stress Against Force

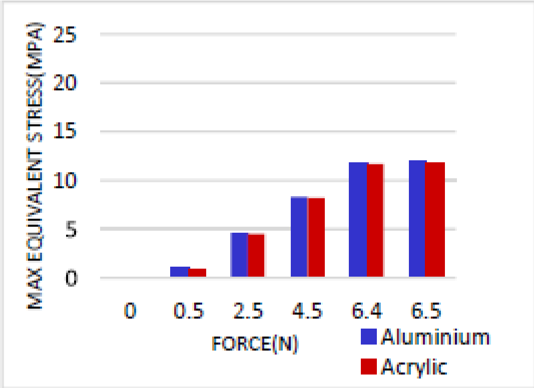

Fig 6. Equivalent Stress vs. Force

4.2. The Combined Graph of Maximum Total Deformation Against Force

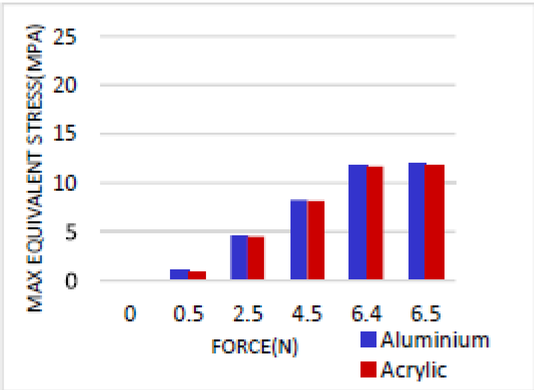

Fig 7. Total Deformation vs. Force

5. Discussion

The combined graph of maximum equivalent stress against force and combined graph of maximum total deformation against force is plotted, as Figure 6 and Figure 7. Red represents the Acrylic underarm of the robotic arm while blue represents the Aluminium underarm of the robotic arm. Both graphs shows the difference gap between red and blue line to prove that the structures of the Aluminium underarm is stronger than Acrylic underarm and also act as desired under prescribed forces. It is because the value of equivalent stress occurs on the parts when force is applied is much lesser that the Acrylic under arm.

6. Conclusion

I did material selection analysis using ANSYS software. We must consider the value of the maximum stress for the applied force is compared with the yield strength of the material of part affected. If the value of the maximum stress is higher, this means that the structure cannot stand the applied force.

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If the maximum equivalent stress is smaller from the yield strength of the material, this proves that material performance are better than other material.

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