Stress Analysis of Switchover Module with Al6061-T6 and Al7075-T6 for Hybrid Locomotion Mobile Robot

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Abstract. This study presents the design and stress analysis of mobile robot switchover module (track tensioner), which helps the robot to work in hybrid locomotion mechanism. The track tensioner is a loading and unloading module that helps the locomotion system transformability while robot moves either on wheel or track mechanism. The selection of suitable material for its design, the model is therefore analysed under static loading. It was analysed under static load of 200 N on two selected materials Aluminium alloys Al6061-T6 and Al7075-T6, to determine its mechanical behaviour of models. The results concluded that the material Aluminium alloy Al7075-T6 would be more suitable material for robot design as compared to Aluminium alloy Al6061-T6.

1 Introduction

In the design of a mechanical machine element or any system, the designer should cover all the specific needs, which generally involve in the moving component that cause specific kind of motion. The component dimensions/shape, type of material, allowable load/force/pressure and type of work application. Under the stress and failure analysis of any mechanical member, it is necessary to select a proper kind of material for design and all acceptable dimension of model [1-2].

Robot is an autonomous device that performs various tasks in difference applications with preinstalled programs or with external controller by the operator guidance [3]. They are usually performed all dirty, difficult and dangerous tasks as an alternative of humans [4-5]. Mobile robots are generally used to perform various tasks from one point to another point on the ground in different applications. Therefore, the effective locomotion mechanism will give the high flexibility and manoeuvrability to mobile robot to complete all harsh and complex tasks [6-7]. Mobile robots are mostly work in such harsh environments, where the entrance of any human to perform task is not safe or unaffordable [8]. The hybrid locomotion mobile robot designed by Bakhsh [5] was used in this study.

It consists two locomotion mechanisms; wheel and track system as shown in Figure 1. The loading and unloading of wheel to track or vice versa is done with the help of track tensioner unit. In this paper the track tensioner unit is designed and its mechanical behaviour was also analysed under static external load of 200 N. The stress analysis of track tensioner unit was done for two selected materials aluminium alloy Al6061-T6 and Al7075-T6.

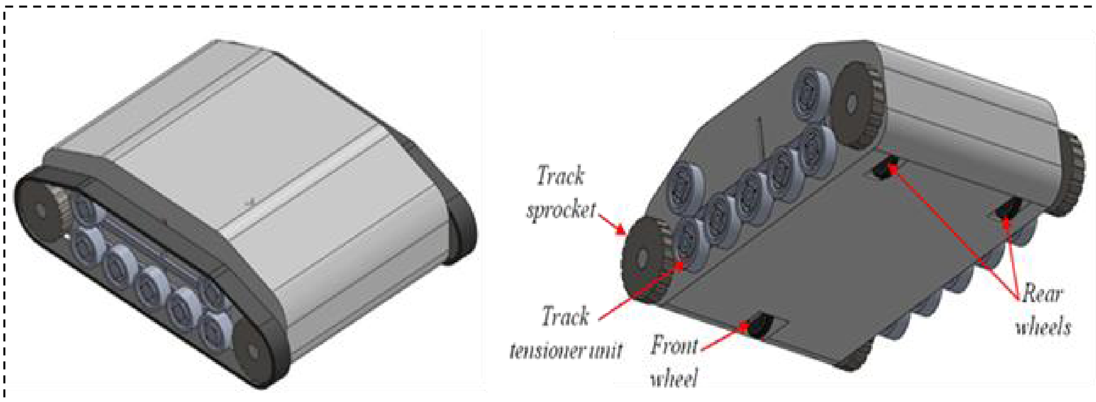

Figure 1. Wheel and Track locomotion mobile robot

2 System design

The Track Tensioner Unit is the most important part and it helps the mobile robot, to move in multi locomotion systems by its interchangeable locomotion phenomena. At smooth and plain path it moves on wheel mechanism, because at low energy consumption it gets high velocity and high manoeuvrability. But if sudden the working environment or path changed to rough and unstructured then robot change its locomotion in track mechanism. Because of this transformation of locomotion system, TTU mostly subjected to external load and stress in terms of weight of robot.

Therefore, it is necessary to analyse the mechanical behaviour of this unit under specific load conditions. So that it would be able to sustain the external applied load up to certain limit or level. This TTU is operated by means of pinion gear that is in mating with rack. The pinion gear is driven by a servo motor, which transmits the power or torque to the rack and pinion unit.

The TTU is designed in two sections or regions, both sections contains of different number of guider drum as its child components. In lower portion of TTU it contains five guider drums mounting, which produced the tension and suspension of track belt. The upper section of TTU contains two guider drums on each corner, those drums used to maintain the length of track belt during robot move on wheel locomotion system. Figure 2 shows the detail of design and dimensions for track tensioner unit and its child components, all values are given in millimeter (mm).

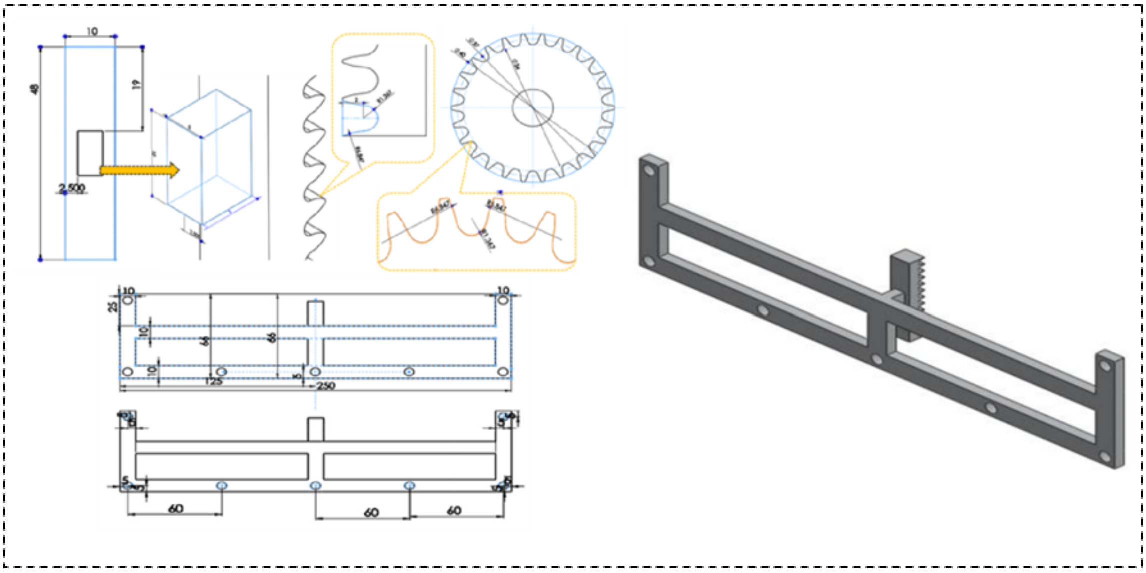

Figure 2. Track tensioner module

3 Stress analysis

Stress analysis is a very important factor for the designer and manufacturer to know the reliability of their design or product [1]. Prior to failure, ductile materials undergo significant plastic deformation, which has a major influence on damage evolution [9]. Mechanical behaviour analysis covers the model failure caused due to the application of external load or force. Therefore, it is necessary to analyse load carrying members for stress and failure due to direct loads, shear, tensional and bending.

In the principle of statics, it is to analyse the type of forces employed on each load carrying model or members. Aluminium alloys are used commonly in most of mobile robot design because of its outstanding characteristics such as; high strength, light weight, corrosion resistance and high thermal conductivity [1]. Aluminium and its alloys are being used successfully in a wide range of applications, from packaging to aerospace industries. Due to their good mechanical properties and low densities, these alloys have an edge over other conventional structural materials [10].

Aluminium alloy Al6061-T6 particular for ground transport systems, when relatively high strength, good corrosion resistance and high toughness are required in conjunction with good formability and weldability, aluminium alloys with Magnesium (Mg) and Silicon (Si) as alloying elements are used, the chemical composition of Al6061-T6 is given in Table 1 [11].

Table 1. Chemical composition of Al6061-T6 [11].

	%Si	%Fe	%Cu	%Mn	%Mg	%Zn	%Cr	%Al
Al6061-T6	0.4-0.8	0.7 max	0.15-0.4	0.15 max	0.8-1.2	0.25 max	0.04-0.35	Balance

Al7075 series are often used in transport applications, including Aircraft fittings, gears and shafts, fuse parts, meter shafts and gears, missile parts, regulating valve parts, worm gears, keys, aircraft, aerospace and defence applications; bike frames, all-terrain vehicle (ATV) sprockets, due to their high strength-to-density ratio [12], the chemical composition of this metal is illustrated in Table 2.

Table 2. Chemical composition of Al7075-T6 [12].

	%Si	%Ti	%Fe	%Cu	%Mn	%Mg	%Zn	%Cr	%Al
Al7075-T6	0.4	Max 0.2	Max 0.5	0.12-2	Max 0.3	2.1-2.9	5.1-6.1	0.18-0.28	87.1-91.4

4 Experimental setup

Firstly, the model is imported into the SOLIDWORKS simulation tool, where the material for designing is selected. The basic information related to the model was given by the tool automatically, Al6061-T6 its mass is 8.843x10-2 kg, volume is 3.275x10-5 m3 and weight is 86.67x10-2 N and Al7075-T6 its mass is 9.203x10-2 kg, volume is 3.275x10-5 m3 and weight is 90.197x10-2 N.

The model was tested for its failure analysis under static load condition, the load 200N applied on the rack part of TTU by means of pinion gear. The constraint details are given in Figure 3, where the point of force or load application is defined at the rack part. The downward load applied on the rack, because it requires lifting the whole body of mobile robot, while it starts moving on track mechanism. At the points where the guider drums are coupled with the TTU are supposed to be a fixed pint. In the simulation the load is applied at the top surface of rack, as the equal intensity of forces applied on the each teeth of rack.

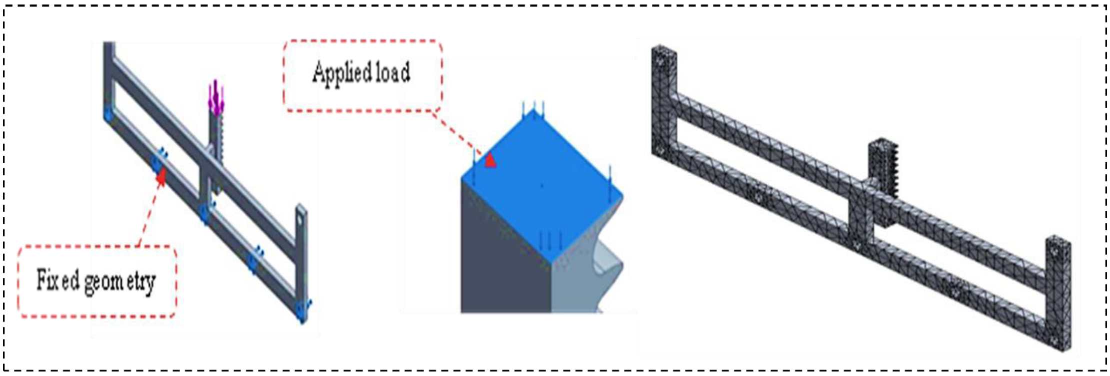

Figure 3. Track tensioner module force constraint and solid meshing

5 Results and discussion

The model undergo for its deformation by von mises stress at 200N with different deformation scale values such as 87.9314 for Al6061-T6 and 91.8219 for Al7075-T6. The simulation result gives the detail of minimum and maximum von mises stress value under the yield strength 275 MN/m2 (Al6061-T6) and 505 MN/m2 (Al7075-T6).

5.1 For Al6061-T6

The minimum value of static nodal stress is 7.838x10-2 kN/m2 at 13959 nodes and maximum value is 56.945x103 kN/m2 at 2008 nodes. The test result for resultant displacement at minimum and maximum elongation in model dimensions under the applied load. The minimum value of displacement is 0 mm at 538 nodes and the maximum value 31.646x10-2 mm at 3143 nodes. The equivalent strain results from the external load; the minimum and maximum values are 1.16279x10-9 at element 3224 and 5.49578x10-4 at element 7667 respectively. The factor of safety from its minimum to maximum range is 4.82918 at node 2008 and 3.40835x105 at node 13959 respectively. The stress-strain curve is shown in Figure 4.

5.2 For Al7075-T6

The minimum value of static nodal stress is 13.327x10-2 kN/m2 at 3237 nodes and maximum value is 60.141x103 kN/m2 at 2036 nodes. The simulation result gives the detail of minimum and maximum elongation in model. The minimum value of displacement is 0 mm at 540 nodes and the maximum value 30.328x10-2 mm at 3171 nodes. The equivalent strain results from the external load, the minimum and maximum values are 6.61454x10-10 at element 6493 and 4.81364x10-4 at element 8051 respectively. The factor of safety from its minimum to maximum range is 8.39693 at node 2036 and 3.78917x106 at node 3237 respectively. The stress-strain curve is shown in Figure 5.

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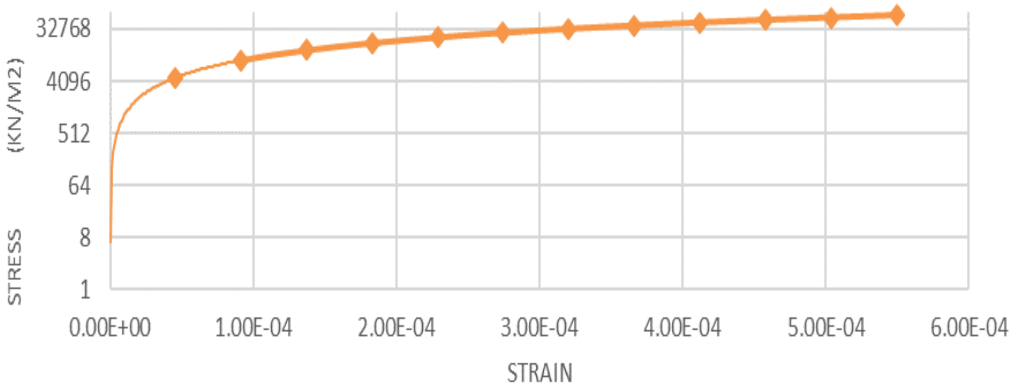

Figure 4. Stress-Strain curve for Aluminium Al6061-T6

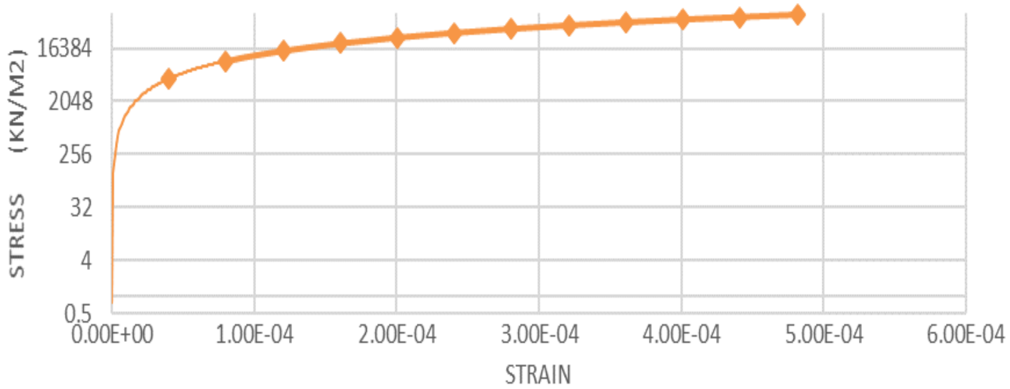

Figure 5. Stress-Strain curve for Aluminium Al7075-T6

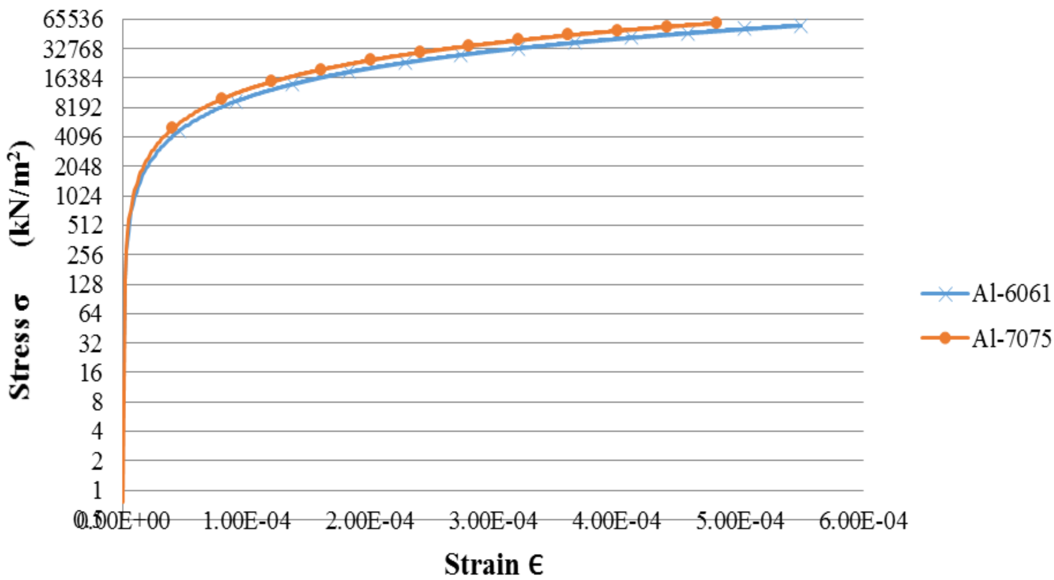

Figure 6. Comparative result

6 Conclusion

For the selection of a suitable material for hybrid mobile robot design, the Aluminium alloys Al6061-T6 and Al7075-T6 were investigated for their stress analysis. For the stability of these materials, the selected parts of mobile robot were then analysed under same load conditions. In this method of FEA, the parts were subjected to payload of 200N by defining the constraint according to their function. The results obtained from simulation were then plotted in the stress-strain curves for both materials, individually as well as comparatively. The results in Figure 6 shows that Al6061-T6 deform more as compared to Al7075-T6, because the stress induced due to the external load caused high elongation and deformation in the Al6061-T6 material. Therefore, the study has concluded that Al7075-T6 material is more suitable for this type of mobile robot.

7 Acknowledgment

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