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# FINITE ELEMENT ANALYSIS OF ROAD ROUGHNESS EFFECT ON STRESS DISTRIBUTION OF HEAVY DUTY TRUCK CHASSIS

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## ABSTRACT

Finite Element Method is one of the most powerful methods in numerical analysis techniques. The time consuming tasks and high costs can be reduced by using this method in the early stages of machine component design. The truck chassis is a base component of vehicles and integrates many of the truck component systems such as the axles, suspension, power train, cab and trailer. The truck chassis has been loaded by static, dynamic and also cyclic loading. Static loading comes from the weight of cabin, its contents and passengers. The movement of truck affects a dynamic loading to the chassis. The vibration of engines and the roughness of roads give a cyclic loading. The chassis used in trucks has almost the same appearance since models were developed 20 or 30 years ago, denoting that they are a result of slow and stable evolution of these frames throughout the years. The manufacturers of these chassis, in the past, and some still today, solve their structural problems by trial and error. Conducting experimental tests in the early stage of design are time consuming and expensive. In order to reduce these costs, it is important to conduct simulations using numerical software methods to find the optimum design. Determination of static, dynamic and fatigue characteristics of a truck chassis before manufacturing is important for design improvement. This paper presents the finite element analysis (FEA) of road roughness effects on stress distribution of heavy duty truck chassis.

*Keywords:* Finite element analysis; Road roughness; Stress analysis; Truck chassis

## 1. INTRODUCTION

The truck chassis is the backbone of the vehicle and is integrated with the main truck component systems such as the axles, suspension, power train, cab and trailer. The truck chassis has been loaded by static, dynamic and also cyclic loading. Static loading comes from the weight of cabin, its contents and passengers. The movement of truck affects a dynamic loading to the chassis. The vibration of engines and the roughness of roads give a cyclic loading. The existing truck chassis design is normally designed based on static analysis. The emphasis of design is on the strength of structure to support the loading placed upon it. However, the truck chassis has been loaded by complex type of loads, including static, dynamic and fatigue aspects. It is estimated that fatigue is responsible for 85 to 90% of all structural failures (MSC.Fatigue Encyclopedia, 2003). The knowledge of dynamic and fatigue behavior of truck chassis in such environment is thus important so that the mounting point of the components like engine, suspension, transmission and others can be determined and optimized.

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Many researchers have carried out studies on truck chassis. Karaoglu and Kuralay investigated stress analysis of a truck chassis with riveted joints using FEM. Numerical results showed that stresses on the side member can be reduced by increasing the side member's thickness locally. If the thickness change is not possible, then increasing the connection plate length may be a good alternative (Karaouglu & Kuralay, 2000). Fermer et al. (1999) investigated the fatigue life of Volvo S80 Bi-Fuel using MSC/Fatigue. Conle and Chu (1997) did research about fatigue analysis and the local stress-strain approach in complex vehicular structures. Structural optimization of automotive components applied to durability problems also has been investigated (Ferreira et al., 2003). Fermér and Svensson (2001) studied on industrial experiences of FE-based fatigue life predictions of welded automotive structures.

The objective of the work in this paper is mainly to focus on the application of FEA of cyclic loading on the heavy duty truck chassis. Sub-modeling techniques have been applied on the critical area in order to find the more reliable, more accurate and faster way of simulation.

## 2. MODEL OF TRUCK CHASSIS

The model is depicted in Figure 1. The model has length of 12.350 m and width of 2.45 m. The material of chassis is Steel with 552 MPa of yield strength and 620 MPa of tensile strength (Juvinall, 2006).

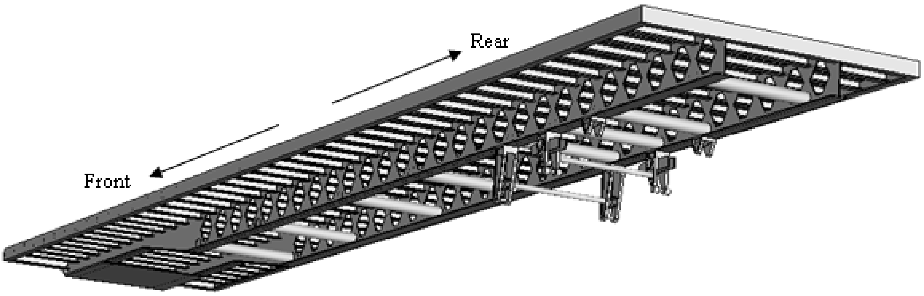

Figure 1 Model of truck chassis

The material properties of chassis are tabulated in Table 1. The truck chassis model is loaded by static forces from the truck body and cargo. For this model, the maximum loaded weight of truck plus cargo is 36,000 kg. The load is assumed as a uniform pressure obtained from the maximum loaded weight divided by the total contact area between cargo and upper surface of chassis. In order to get a better result, locally finer meshing is applied in the region which is suspected to have the highest stress.

Table 1 Properties of truck chassis material (Juvinall, 2006)

| Modulus Elasticity $E$ [GPa] | Density $\rho$ [kg/m$^3$] | Poisson Ratio | Yield Strength [MPa] | Tensile Strength [MPa] |
|---|---|---|---|---|
| 207 | 7800 | 0.3 | 550 | 620 |

### 2.1. Boundary condition of the model

There are 3 boundary conditions (BC) of the model; the first BC is applied in front of the chassis, the second and the third BC are applied in rear of chassis, as shown in Figure 2. The type of BC 1 is pinned (the displacement is not allowed in all axes and the rotation is allowed in all axes) that represent the contact condition between chassis and cab of truck. The BC 2 represents the contact between chassis and upper side of spring that transfer the loaded weight of cargo and chassis to axle. In the BC3, the displacement and the rotation is zero in all axes on all of bolts' body. This condition is called fixed constraint. The bolt in BC 3 is assumed perfectly rigid. This assumption was realized by choosing a very high modulus Young value of the bolt properties. The contact condition of BC in the object is shown in Figure 3.

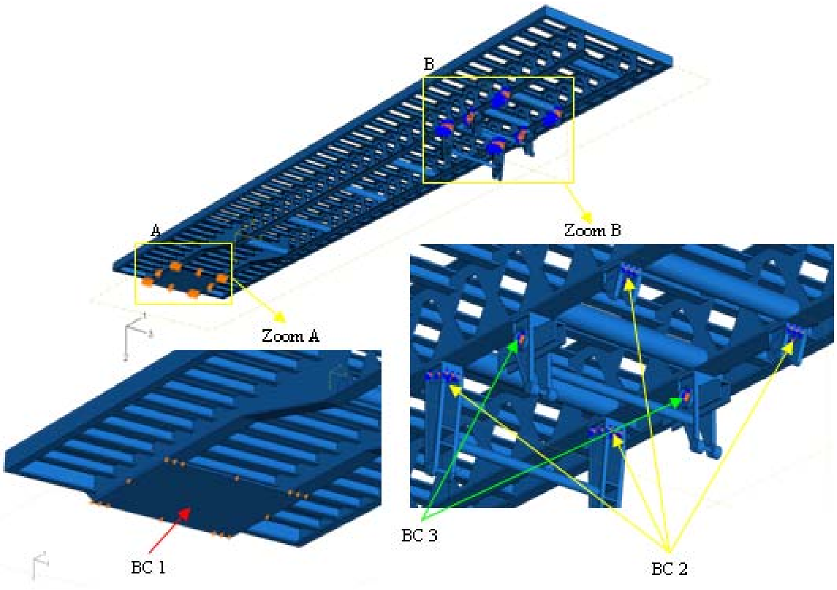

Figure 2 Boundary conditions representation in the model

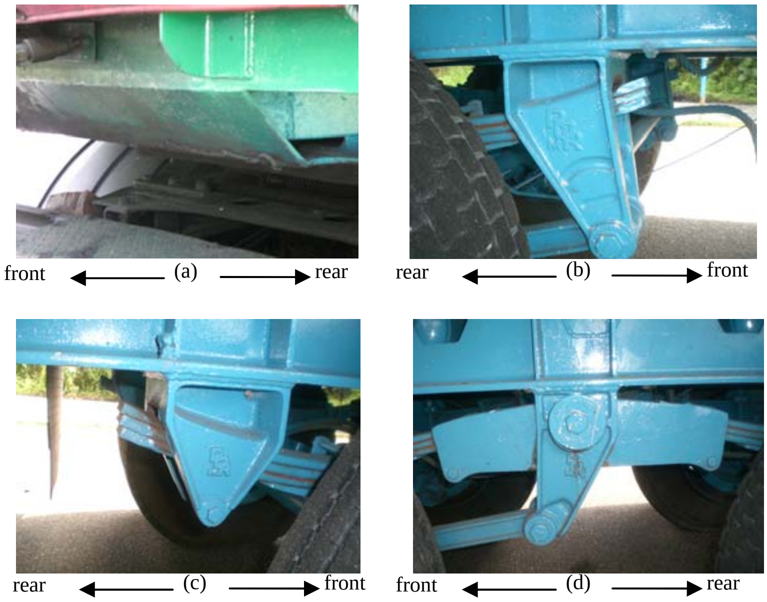

Figure 3 Boundary conditions representation in the object;
4(a). BC 1, 4(b). and 4(c). BC 2, 4(d). BC 3

### 2.2. Location of critical area

Based on the previous paper, the location of maximum Von Misses stress is at the opening of the chassis which is contacted with bolt as shown in Figure 4. The stress magnitude at the critical point is 386.9 MPa. This critical point is located at element 86104 and node 16045 (Kurdi et al., 2008).

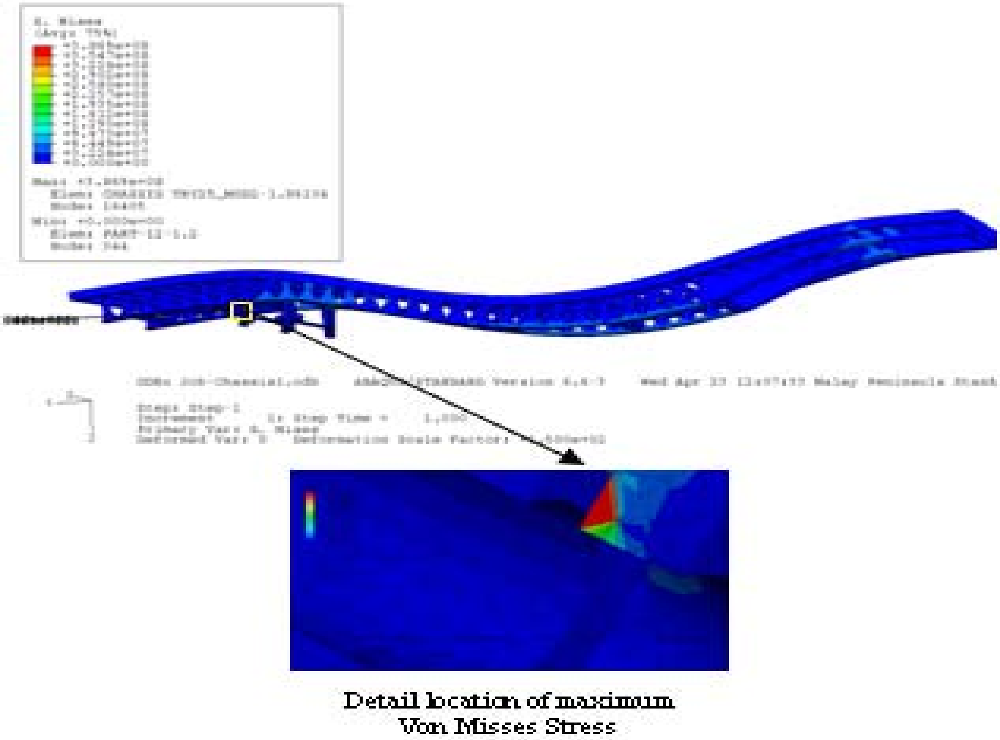

Figure 4 Von Misses stress distribution and critical point location

### *2.2.1. Sub-modeling technique application*

Sub-modeling is a finite element technique used to get more accurate results in a region of the model. It is used to study a local part of a model with a refined mesh based on interpolation of the solution from an initial (undeformed), relatively coarse, global model. Sub-modeling is also known as the cut-boundary displacement method or the specified boundary displacement method.

Some of the advantages of the sub-modeling techniques are; it can reduce or even eliminate, the need for complicated transition regions in solid finite element models; it enables to experimentation with different designs for the region of interest (different fillet radii, for example) and it helps in demonstrating the adequacy of mesh refinements. The sub-modeling is most useful when it is necessary to obtain an accurate and detailed solution in a local region; and when the detailed modeling of that local region has negligible effects on the overall solution (MSC.Fatigue Encyclopedia, 2003).

Based on the Von Misses highest stress area location obtained from previous paper (Kurdi et al., 2008), some part of chassis area is taken as a sub-structure component where the cyclic loading from the roughness of roads will be applied. The sub-structure component is shown in Figure 5.

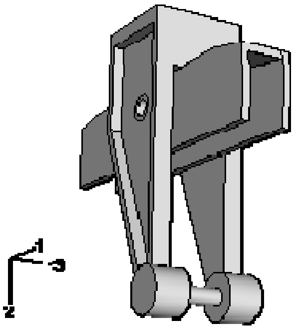

Figure 5 Sub structure Component of Truck Chassis

### 2.3. Cyclic loading

Figure 6 and Figure 7 show the accelerometer and Dewe-soft (commercial device) installations respectively. These devices are used to measure the acceleration point on the truck chassis. This data is obtained from direct measurement by some accelerometer placed on some point on the truck chassis while the truck is moving. The data from two accelerometers are shown in Figure 8 and Figure 9. This data is converted to the force that will be applied on the sub-structure component of truck chassis as cyclic loading.

Figure 6 Accelerometer installation on the truck chassis

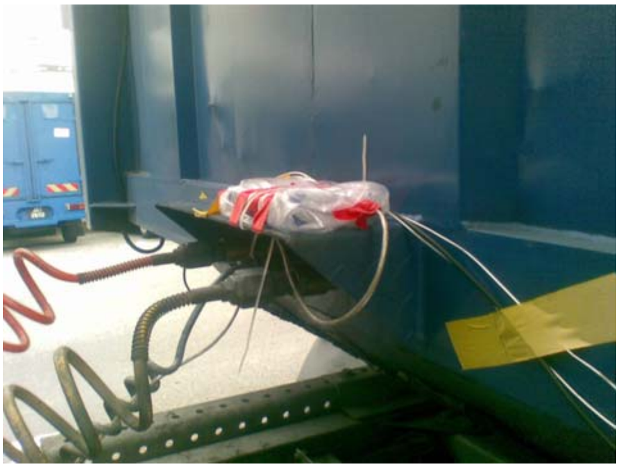

Figure 7 Dewe-soft device installation on the truck chassis

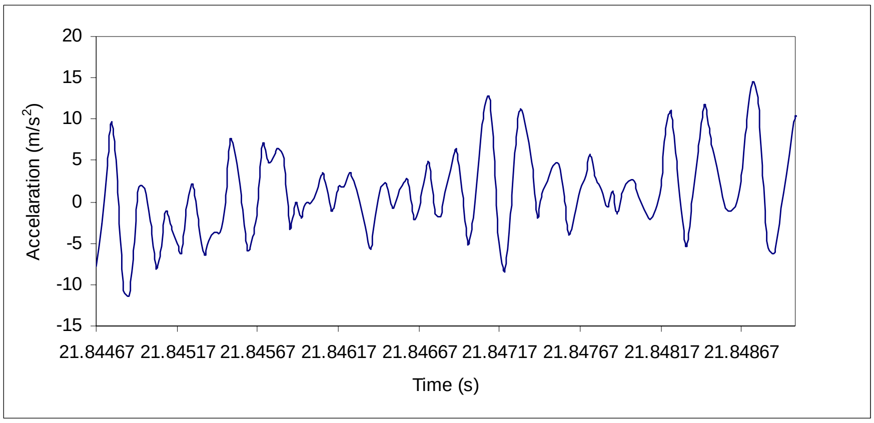

Figure 8 Acceleration of moving truck at accelerometer 1

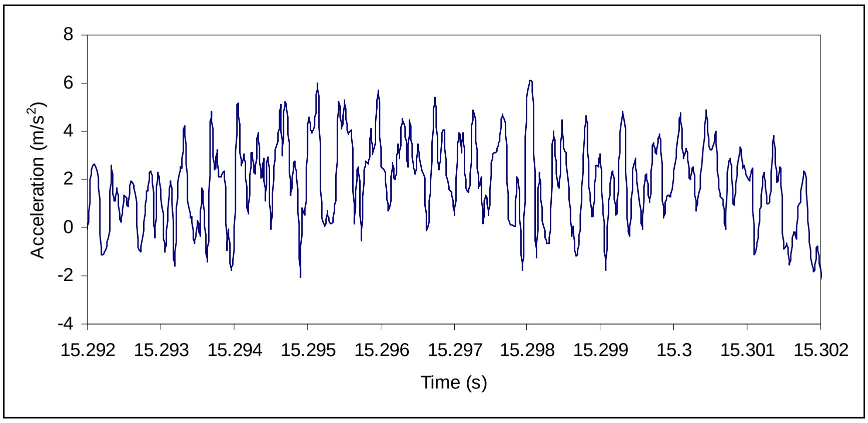

Figure 9 Acceleration of moving truck at accelerometer 2

## 3. RESULTS AND DISCUSSION

Figure 10 shows the Von Misses stress distribution of sub-structure components subjected by static loading whereas Figure 11 shows the Von Misses stress distribution of the same model is subjected to cyclic loading obtained by direct measurement from moving truck. The location of highest stress area for both models is the same, namely at node 15951 whereas the magnitude of highest stress is little different, the stress of model subjected by cyclic loading is higher than the result of the model subjected to static loading. The differences of highest stress magnitude of both models is not significant, just 0.6%. It shows that the dominant loading on the truck chassis comes from cargo and its contents as static loading; the road roughness does not give a significant effect to the stress of component.

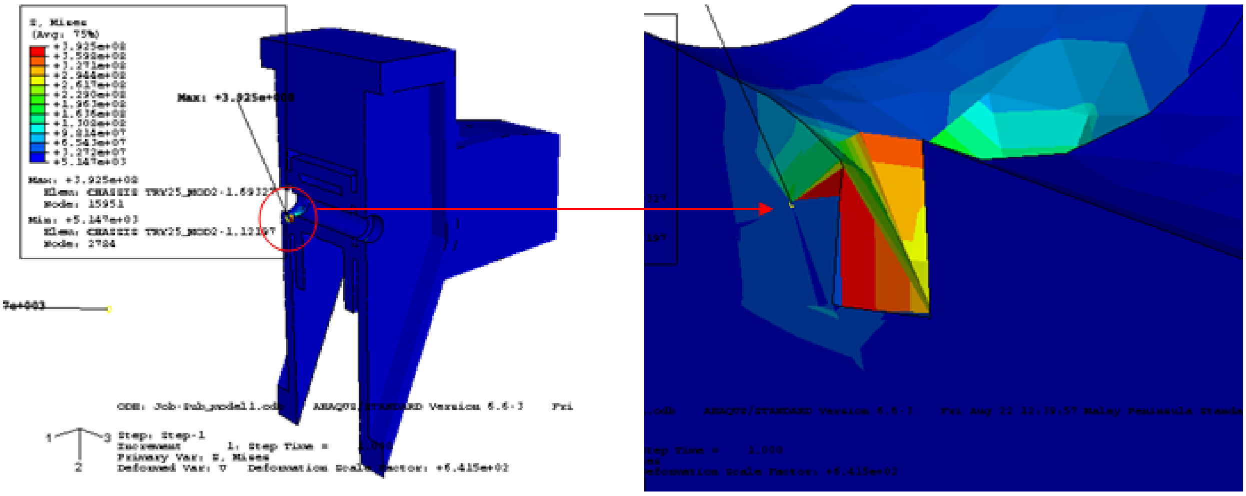

Figure 10 Von Misses result of sub-modeling technique without cyclic loading

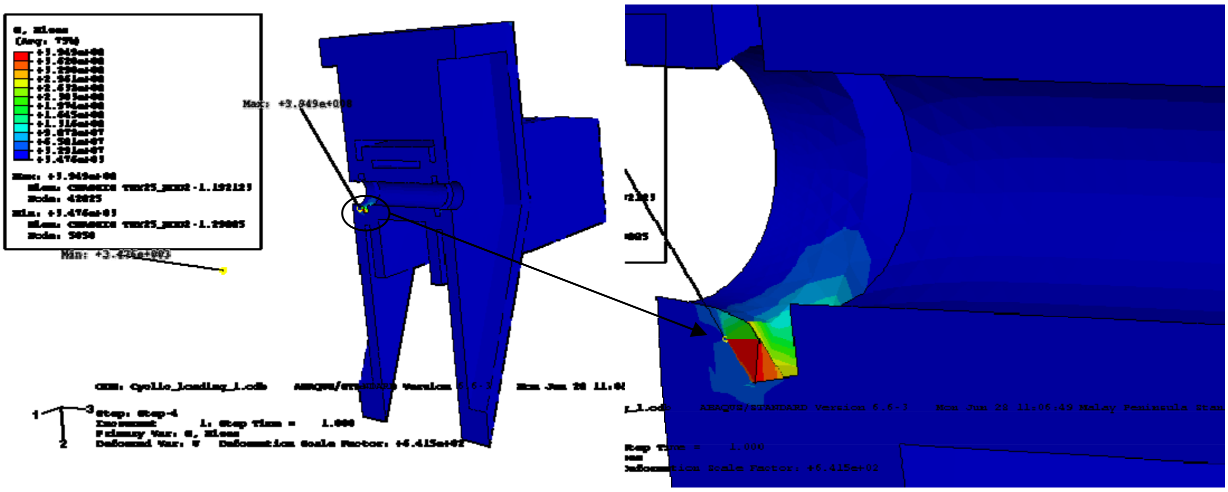

Figure 11 Von Misses result of sub-modeling technique with cyclic loading

## 4. CONCLUSION

The finite element simulation of cyclic loading from the road roughness has been done successfully on the sub-structure truck chassis component. The result shows no significant effect of cyclic loading to the stress of the model, so it can be concluded that the static load is a dominant factor that causes a high stress in the truck chassis. The result need to be validated by experiment and it is necessary to do further research to look for other effects of cyclic loading to the failure of chassis such as the effect of cyclic loading on the fatigue life of a component. The stress distribution of chassis can be used as preliminary data for fatigue life prediction of truck chassis.

## 5. ACKNOWLEDGEMENT

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