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# Structural Analysis on Several Modified Radiator Fin Designs using Computer Aided Engineering (CAE)

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**Abstract**: This study is about a structural design of a radiator for automobile with various type of fin designs. When the radiator is installed on an automobile, it is susceptible to various loads such as bumping, lifting and braking during operation. These loads tend to cause stress in the radiator's bolt area. The objective of this study is to run structural analysis on radiator with various designs of fin by using Computer-Aided Engineering (CAE) in CATIA V5R18 software and to compare it with the current design. Three different design modifications had been drawn. Design 1 is rectangular with an increased thickness of fin, Design 2 is specially designed in the form of a wave shape, and meanwhile Design 3 has additional louvered on the fin surface. The result shows that the Von Mises stress and principal stress of each analysis. In conclusion, Design 1 is the best since it has the lowest maximum Von Mises stress which is 4.06 MPa during lifting load and 4.58 MPa during bumping load but Design 2 has lowest maximum Von Mises stress during braking load which is 3.22 MPa. Furthermore, the maximum Von Mises stress of Design 1 is much lesser than the yield strength of aluminium material which is 241 MPa. Hence the material will not yield during operation when it is subjected to various loads.

**Keywords**: Radiator, Fins, Structural, Computational Aided Engineering, Finite Element Method

## 1. Introduction

Radiators are cooling devices that keep engines from overheating in automobiles. They are at the heart of every vehicle's cooling system. They are primarily responsible for keeping engines at the proper temperature so that they can work at their best (M.K. Singh, 2020). Radiators are generally fabricated from copper and brass or aluminum and comprising of numbers of pipes put in a series through which coolant circulates (R.J. Yadav, 2019). Radiators are commonly place at the frontal part of the engine in automobile, thus, they are subjected to various types of loads while the car moves.

Structural analysis is the process of predicting a structure's response to arbitrary external loads. The structural analysis of radiator is crucial as the radiator is subjected to various types of loads while operating such as lifting, braking, and bumping loads. During the preliminary structural design stage, a structure's possible external load is examined, and the size of the structure’s interconnected elements is determined based on the predicted loads. Failure of the structure of radiator will lead to failure of cooling system needed for the engine to cool off.

## 2. Methodology

The procedures of the study can be described by the flowchart in Figure 2.1. The design stage of the geometrical design is done by using a Computer-Aided Design software, CATIA V5R18. The process is then continued with meshing process and assigning the boundary condition for the radiator fin by using Finite Element Method (FEM).

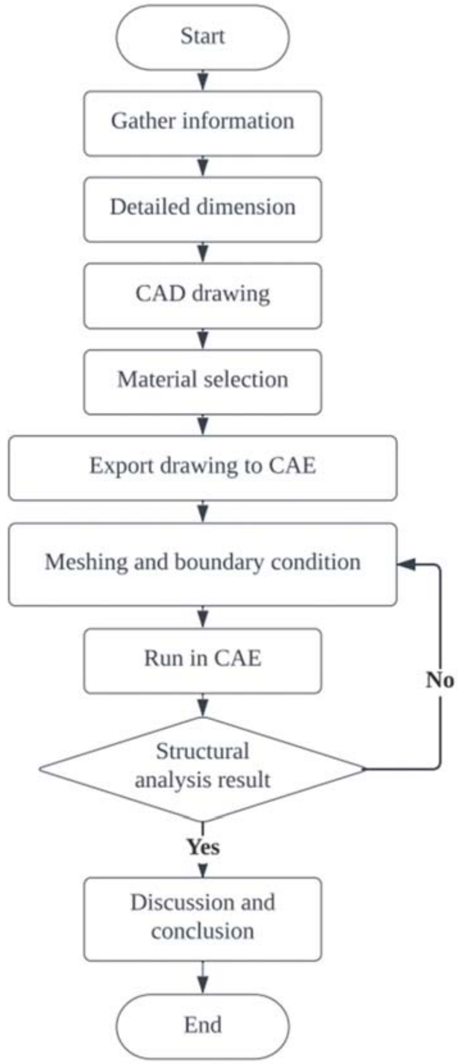


**Figure 2.1** Flowchart of the structural analysis by using computer aided engineering.

Finally, the simulations and analyzing processes are done by Computer Aided Engineering (CAE) software. The three designs of the radiator fins are shown in Figure 2.2 until 2.5 below (Muhammad Syazwan, 2020).

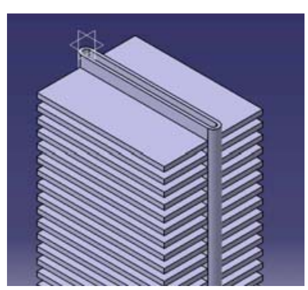

**Figure 2.2** Isometric view of the current design of radiator fin

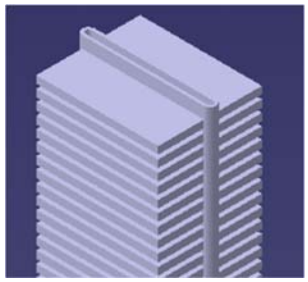

**Figure 2.3** Isometric view of Design 1 with rectangular shape of fin with increased thickness.

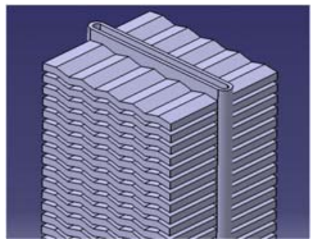

**Figure 2.4** Isometric view of Design 2 with wavy type of fins.

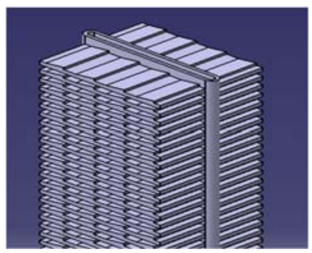

**Figure** Error! No text of specified style in document.**.5** Isometric view of Design 3 with additional louvered fin on the surface.

There are three types of loads applied on the radiator structure to analyse the strength of each design. The loads are lifting, braking, and bumping as the radiator is subjected to these types of loads while the automobile is moving (M. Taipalle et al., 2017 and G. Vikrant et al., 2013).

The radiator is expected to have a lifting load in vertical direction. This is the load that supports the radiator as the radiator is mounted on the front part of the car together with other parts in the engine hood.

$$P_v = m_v + (G_c + G_{nr}) \quad kg \tag{1}$$

Where;

$P_v$ = the vertical force (kg)

$m_v$ = 2.5 for private cars, 2.5 for busses, 3.0 for lorries

$G_c$= total weight of the car (kg)

$G_{nr}$ = weight of unsprung mass (kg)

The braking load in longitudinal direction is bound to happen on the longest part of the radiator which is the length. Although the size is compact, the weight of the radiator body itself will somehow contribute to the load in the longitudinal direction.

$$P_x = \pm\, m_x + (G_c + G_{nr}) \quad kg \tag{2}$$

Where;

$P_x$ = the longitudinal force (kg)

$m$ = 0.7 to 1.0

$G_c$ = total weight of the car (kg)

$G_{nr}$ = weight of unsprung mass (kg)

The bumping load happened due to the moving vehicle hits bumpy road. The bumping load exerted on the radiator depends on the speed of the vehicle as well as the weight and gravitational forces. The bumping load occurs in vertical direction from where the radiator is mounted.

$$h_1 = f_{og} + f_{r1}\left(\frac{r_1}{z_1}\right) + f_{og}\left(\frac{r_1}{r_2}\right) + f_{r2}\left(\frac{r_1}{z_2}\right) \quad mm \tag{3}$$

Where;

$h_1$ = Bump height

$f_{og}$ = deflection of the tyres (mm)

$f_r$ = deflection of the springs (mm)

r = the track width (mm)

z = the width between suspension attachments (mm)

The radiator is generally exposed to three types of loads. The loads are the lifting load in vertical direction, the braking load in the longitudinal direction and the bumping load in vertical direction. The radiator also been fixed and not moving by bolt in each corner of radiator. Figure 2.6 until 2.8 show the boundary conditions set on the radiator for the three types of loads applied on the structure. From the simulation, critical points are expected to be obtained and the results will be analyzed.

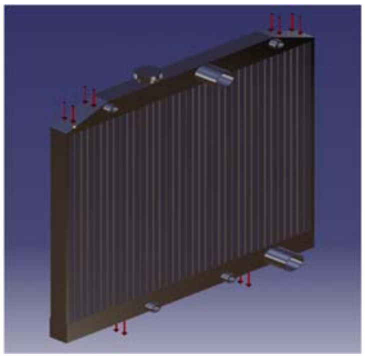

**Figure 2.6** The lifting load in vertical direction.

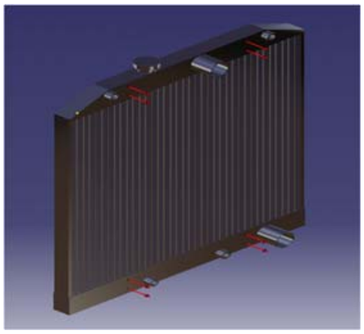

**Figure 2.7** The braking load in longitudinal direction.

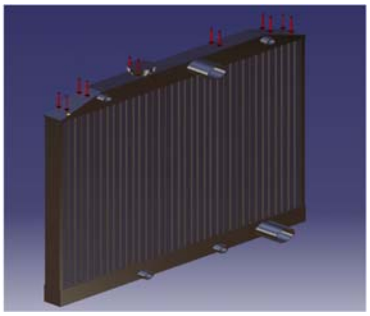

**Figure 2.8** The bumping load in vertical direction.

## 3. Result and Discussion

The results from the simulation are tabulated in Table 3.1 until 3.3 below. Comparison of stress between the three designs with the current design can be seen in Figure 3.1 until 3.3.

**Table** Error! No text of specified style in document.**.1** Result for each design with lifting load

| Stress / Radiator | Max Von Mises (MPa) | Max Principal Stress (MPa) | Min Principal Stress (MPa) |
|---|---|---|---|
| **Current Design** | 4.31 | 3.32 | $1.2x\ 10^{-3}$ |
| **Design 1** | 4.06 | 3.06 | $1.27 \times 10^{-3}$ |
| **Design 2** | 4.22 | 3.04 | $555 \times 10^{-6}$ |
| **Design 3** | 4.31 | 3.06 | $784 \times 10^{-6}$ |

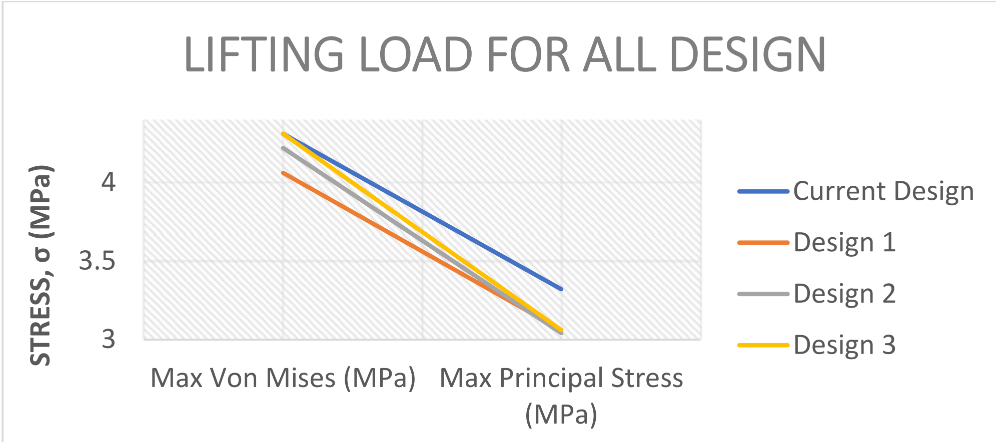


**Figure** Error! No text of specified style in document.. **1** Lifting load for all designs

Figure 3.1 showed the comparison of maximum Von Mises stress and maximum principal stress between the current design of radiator fin with three new designs during lifting load. From the lifting load results, all three designs have lesser Von Mises stress as compared to the current design. Design 1 has the lowest Von Mises stress compared to other designs.

**Table** Error! No text of specified style in document.**.2** Result for each design with braking load

| Stress / Radiator | Max Von Mises (MPa) | Max Principal Stress (MPa) | Min Principal Stress (MPa) |
|---|---|---|---|
| **Current Design** | 3.33 | 2.9 | $1.6 \times 10^{-3}$ |
| **Design 1** | 4.36 | 3.92 | $2.58 \times 10^{-3}$ |
| **Design 2** | 3.22 | 2.86 | $1.18 \times 10^{-3}$ |
| **Design 3** | 3.99 | 3.14 | $1.87 \times 10^{-3}$ |

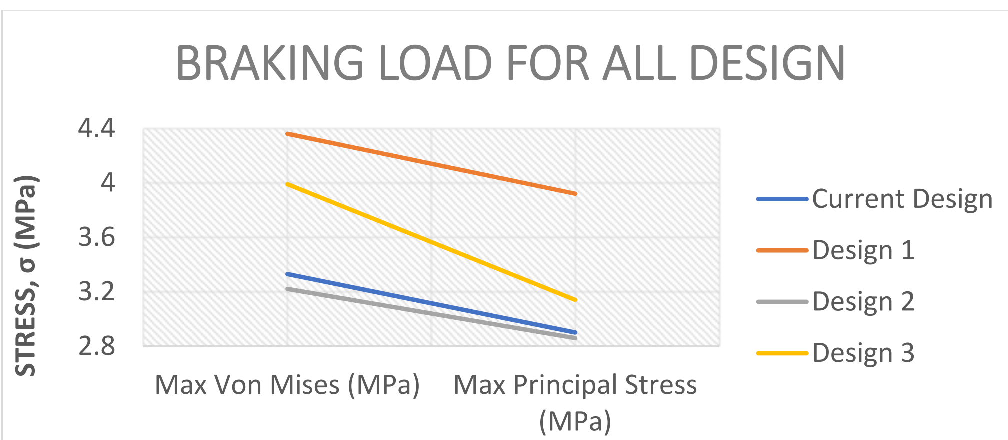


**Figure** Error! No text of specified style in document.**.1** Braking load for all designs

Figure 3.2 showed the comparison of maximum Von Mises stress and maximum principal stress between the current design of radiator fin with three new designs during braking load. From the braking load results, Design 2 has lesser Von Mises stress and Design 1 and Design 3 have higher Von Mises stress as compared to the current design.

**Table** Error! No text of specified style in document.**.3** Result for each design with bumping load

| Stress / Radiator | Max Von Mises (MPa) | Max Principal Stress (MPa) | Min Principal Stress (MPa) |
|---|---|---|---|
| **Current Design** | 4.97 | 3.84 | $3.28 \times 10^{-3}$ |
| **Design 1** | 4.58 | 3.47 | $2.35 \times 10^{-3}$ |
| **Design 2** | 4.61 | 3.35 | $1.46 \times 10^{-3}$ |
| **Design 3** | 4.95 | 3.61 | $1.77 \times 10^{-6}$ |

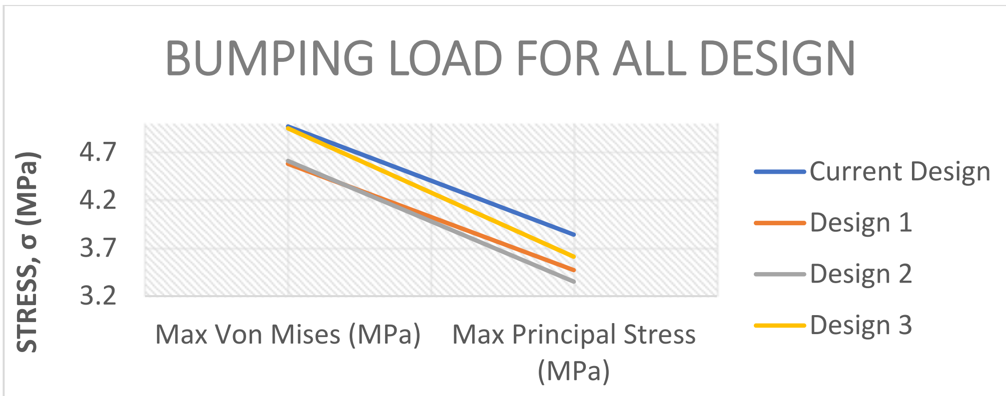


**Figure** Error! No text of specified style in document.**.2** Bumping load for all designs

Figure 3.3 showed the comparison of maximum Von Mises stress and maximum principal stress between the current design of radiator fin with three new designs during bumping load. From the bumping load results, all three designs have lesser Von Mises stress as compared to the current design and Design 1 has the lowest Von Mises stress as compared to other designs.

## 4. Conclusion

From the results obtained, Design 1 can be concluded to be the best as it has the lowest maximum Von Mises stress which is 4.06 MPa during lifting load and 4.58 MPa during bumping load. This is because the design of fin for Design 1 is it has increased thickness of fin as compared to other designs. The maximum Von Mises of Design 1 is much lesser than the yield strength of aluminium material which is 241 MPa. Hence the material will not yield during operation when it is subjected to various loads.

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