CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Construction of dragline bucket

Dragline of bucket has been constructed in AutoCAD by using the dimensions and specification of bucket (as listed in section methodology). The bucket designed in AutoCAD is shown in Figure 5.1. The drawing module in AutoCAD has fairly simplified the preparation of dragline bucket for subsequent analysis. However, the drawing prepared in AutoCAD cannot be directly imported in ANSYS file. Therefore, the SOLIDWORKS has been used to convert AutoCAD drawing files in IGES files which can easily be read by ANSYS for analysis.

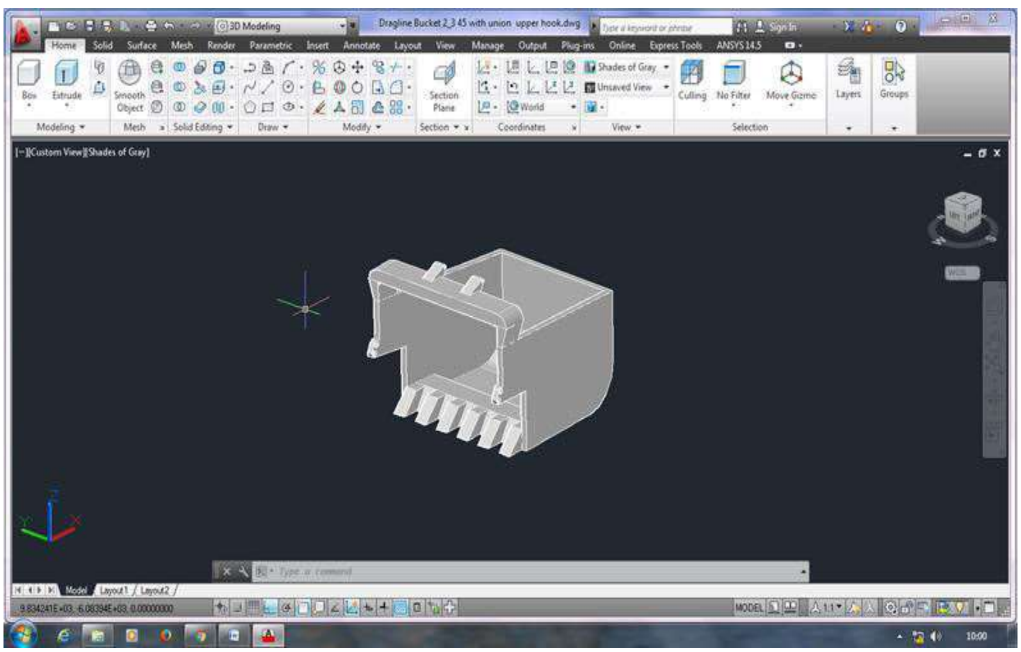
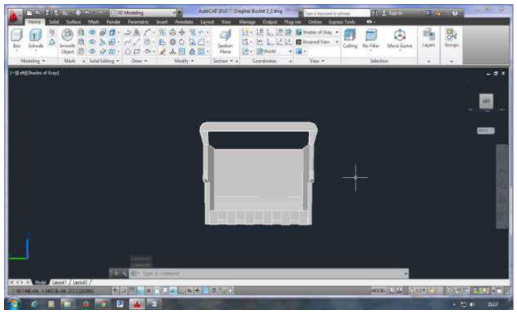
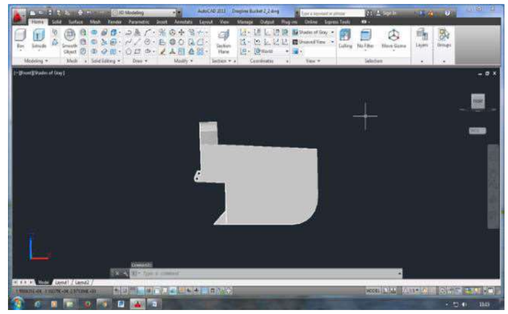
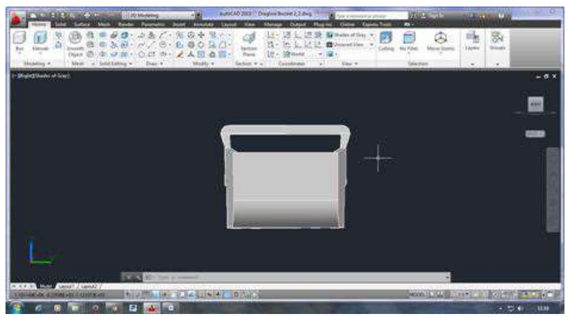


Figure 5. 1: 3D Solid bucket model

(a) (b)



(c)

Figure 5. 2: (a-c) Different views of a solid model of a bucket

The construction of dragline bucket has been able to provide a perfect visualization of the bucket in 3 dimensions. After constructing the dragline bucket on AutoCAD and converting the file in SOLIDWORKS, the finite element analysis has been used in the present work for analysis of stress and related parameters on the bucket under (i) static loading and (ii) dynamic loading conditions as explained already in the methodology chapter.

By using the finite element method, analysis has been done with the help of ANSYS and MATLAB. The outcome from the results has been expressed regarding equivalent stress, damage, deformation and fatigue life under different loading conditions of the dragline bucket.

Furthermore, rake angle studies and related optimization has also been done, as explained in the methodology section. The salient results are presented and discussed in this chapter.

5.2 Stress analysis on the dragline bucket

The stress analysis has been done under static and dynamic loading conditions as discussed one by one.

5.2.1 Stress analysis on the dragline bucket under static loading condition.

(i) Bucket in self- weight condition

Bucket in self-weight condition implies that the bucket is empty and only the dead load of the bucket is applied in the analysis. Based on this data, the static analysis obtains results on the Von Mises stresses, damage, fatigue life, factor of safety and fatigue sensitivity for the static bucket. An estimated dead load of the bucket is $7x10^5$N has been applied in the simulation.

1. Equivalent Stress (Von-Mises) of dragline bucket

Figure 5.3 shows the distribution of equivalent stress throughout the body of the bucket and its assembly.

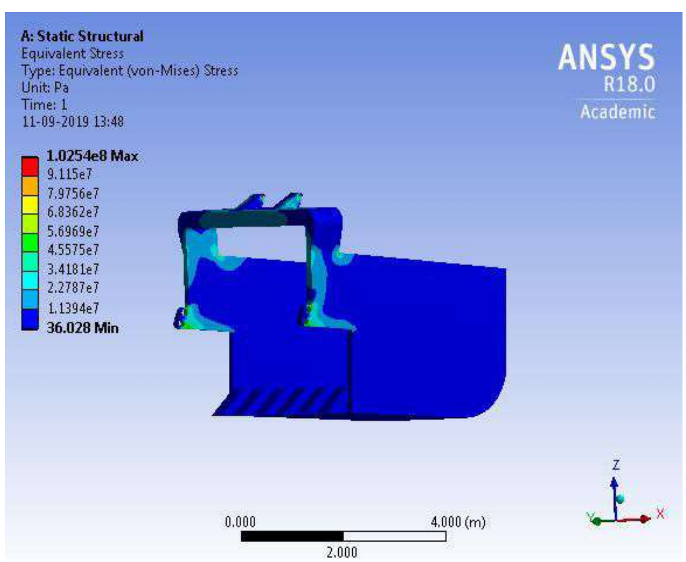


Figure 5. 3: Equivalent Stress (Von-Mises) of bucket under static loading condition

The analysis of equivalent stress (Von-Mises) reveals that the maximum equivalent stresses occurs in the hitch element and arc anchors of the bucket due to the self-weight of the bucket, as shown in the Figure 5.3. At these point the Von Mises stress reaches maximum value 102.5 MPa. Whereas other than these two places, the stresses are generally low in the whole body of the bucket such as $3.6x10^{-5}$ MPa. This implies that under static loading condition the bucket body is free from any stress capable of distorting it. Also, this analysis reveals that hitch element and arc anchors are the critical components in the bucket.

2. ***Damage of dragline bucket***

Figure 5.4 shows the distribution of damage throughout the body of the bucket and its assembly.

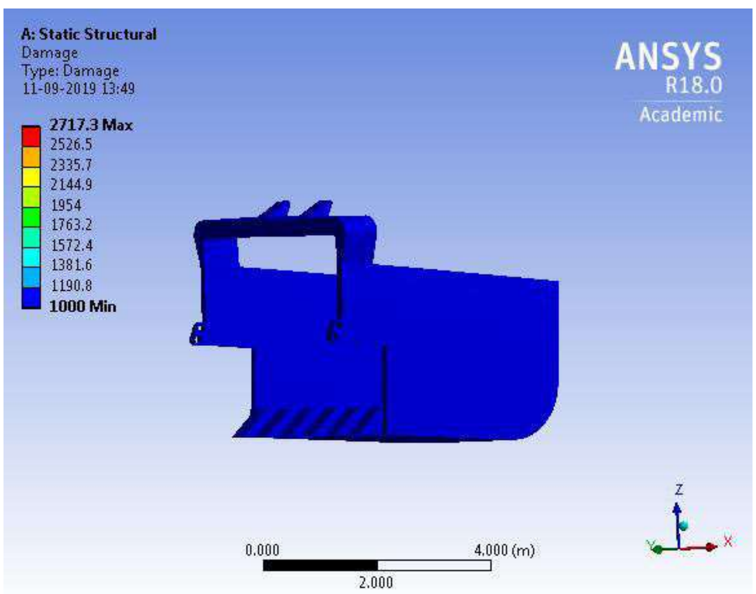


Figure 5. 4: Damage of bucket under static loading condition

Damage is represented as a contour plot of the fatigue damage for a given life of the component. Damage is defined as ratio of design life of component to the available life of component. In static loading condition under the self-weight of bucket the damage contour is shown in Figure 5.4. From the damage analysis it is clear that the value of damage varies from 1000 cycle - 2717.3 cycle. For fatigue damage, values more than 1 indicate failure before the design life is reached.

3. *Fatigue life of dragline bucket*

Figure 5.5 shows the fatigue life throughout the body of the bucket and its assembly.

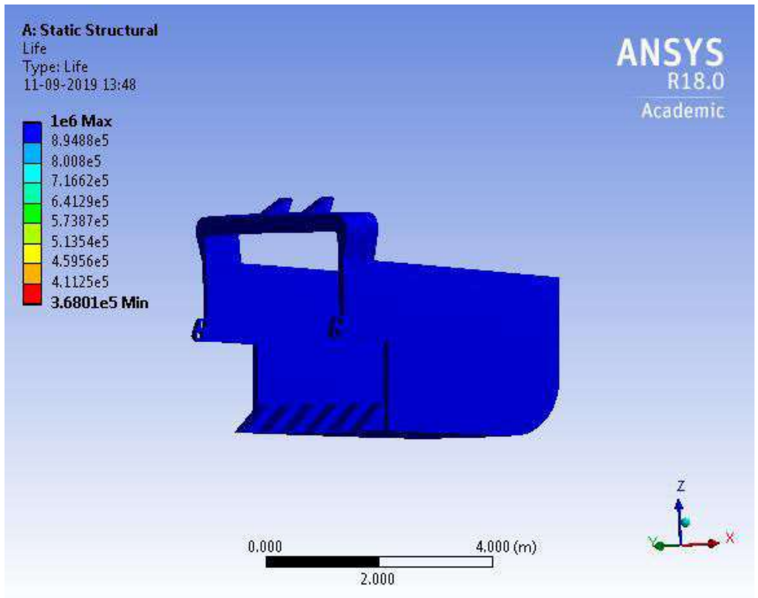


Figure 5. 5: Life of bucket under static loading condition

Fatigue failure is particularly insidious because it occurs without any obvious warning. Bucket fatigue life varies from 0.37xe^{6}- 1xe^{6} cycle as indicated in Figure 5.5. It is clearly observed that from Figure 5.5 that the stress magnitudes affect the fatigue life. The points subjected to high stress have low fatigue life and vice-versa. The remaining model has maximum value of fatigue life. Furthermore, the fatigue strength is seriously reduced by the introduction of stress elevators such as, a notch or hole. One of the best ways of minimizing fatigue failure is by the reduction of avoidable stress elevators through careful design and the prevention of accidental stress elevators by careful machining and fabrication.

4. Factor of safety of dragline bucket

Figure 5.6 shows the factor of safety throughout the body of the bucket and its assembly.

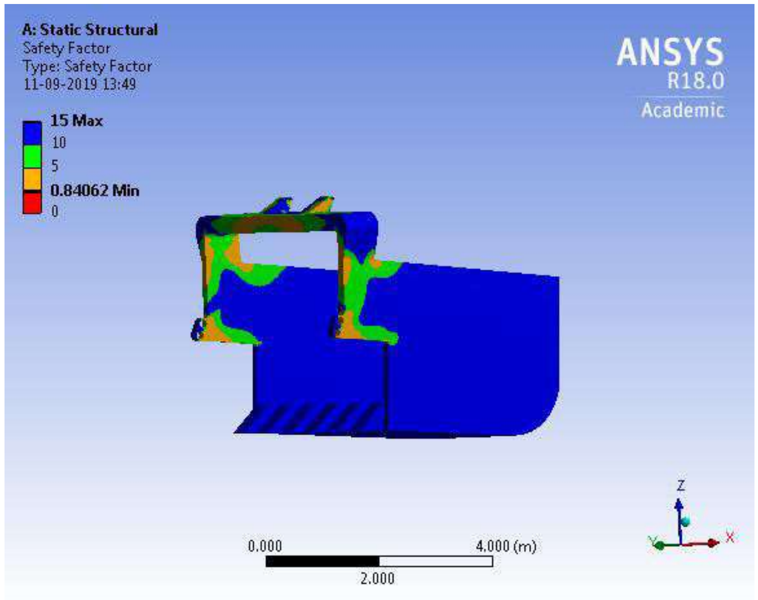


Figure 5. 6: Factor of safety of bucket under static loading condition

Factor of safety is a contour plot with respect to fatigue failure at a given design life. It has been observed from the analysis that the factor of safety is minimum near hitch element and arc anchors as also seen in Figure 5.6. The minimum value of factor of safety is 0.8406 near the hitch elements and arc anchors. The remaining of the bucket model have higher values. Being subjected to high stress values the factor of safety has been observed to be low in these components of the dragline bucket.

(ii) Bucket in loaded condition

The bucket in loaded condition means that dead load plus payload are used in the analysis, and the value of the load has been computed as 18.59800×10^5 N for broken sandstone material. This load has been applied on the bucket. By Applying the boundary and loading conditions, the results have been obtained for stress, damage, fatigue life, factor of safety and fatigue sensitivity as discussed in following sections.

1. *Equivalent stress (Von-Mises) of dragline bucket*

Figure 5.7 shows the distribution of equivalent stress throughout the body of the bucket and its assembly.

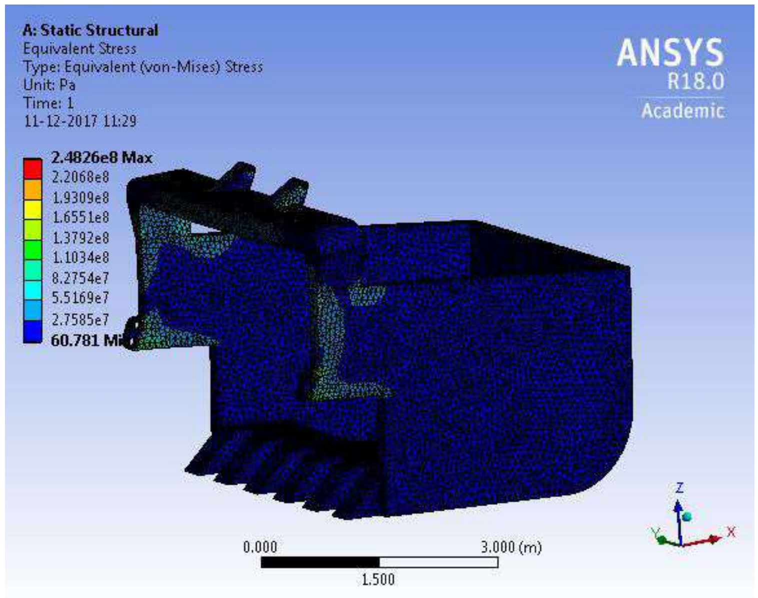


Figure 5. 7: Equivalent stress (Von-Mises) of bucket under static loading condition

In this analysis, it is found that due to self-weight plus payload application on the bucket, the equivalent stress varies between 60.781xe^{-6} MPa - 248.26 MPa at the hitch element and arc anchors of the bucket as clearly visible in Figure 5.7. At these points, the Von Mises stress reaches maximum value of 248.26 MPa. Other than these two places the stresses are generally low value such as 60.781xe^{-6} MPa in the whole body of the bucket. This implies that under static loading condition the bucket body is free from any stress capable of distorting it. Also, this analysis reveals that hitch element and arc anchors are the critical components in the bucket.

2. *Damage of dragline bucket*

Figure 5.8 shows the distribution of damage throughout the body of the bucket and its assembly.

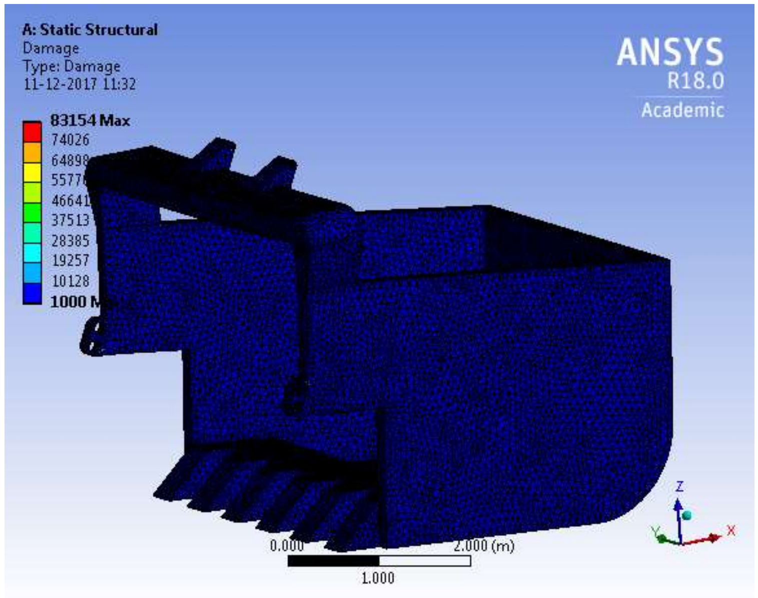


Figure 5. 8: Damage of bucket under static loading condition

Damage is represented as a contour plot of the fatigue damage for a given life of the component. Damage is defined as ratio of design life of component to the available life of component. In static loading condition under the self-weight plus payload of bucket, the damage contour is shown in Figure 5.8. From the damage analysis it is clear that damage varies from 1000 cycle - 83154 cycle. For fatigue damage, values more than 1 indicate failure before the design life is reached.

3. *Fatigue life of dragline bucket*

Figure 5.9 shows the fatigue life throughout the body of the bucket and its assembly.

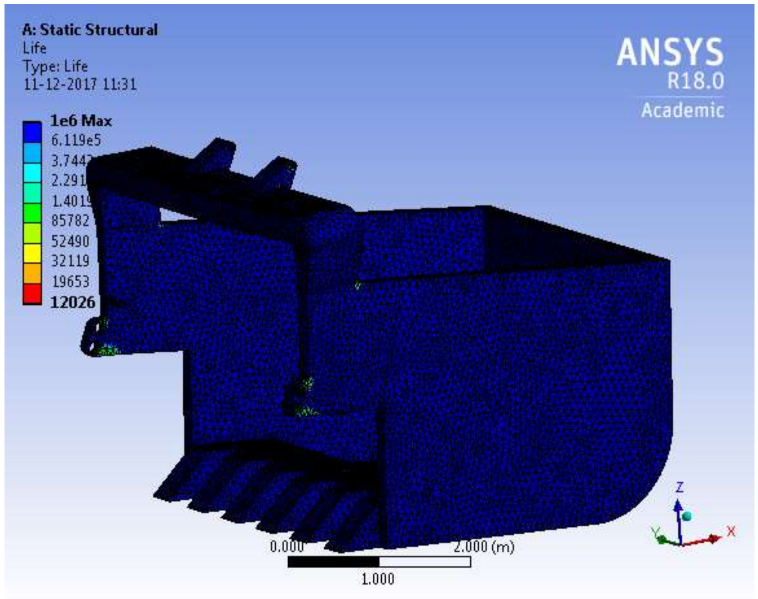


Figure 5. 9: Life of bucket under static loading condition

In the analysis, it is found that bucket fatigue life ranges from 12026 cycle - $1xe^6$ cycle in static loaded bucket condition. From the analysis, it is observed that the minimum life occurs near the hitch elements and arc anchors, which is clearly shown in Figure 5.9. At these points, the stresses reach maximum value. So, we can interpret again that the points where stresses are maximum, fatigue life is minimum. Practically all fatigue failures start at the surface. For many common types of loading, like bending and torsion, the maximum stress occurs at the surface and failure commencing from the surface. In axial loading conditions, the fatigue failure always begins at the surface. There is ample evidence that fatigue properties are very sensitive to surface condition.

4. *Factor of safety of dragline bucket*

Figure 5.10 shows the factor of safety throughout the body of the bucket and its assembly.

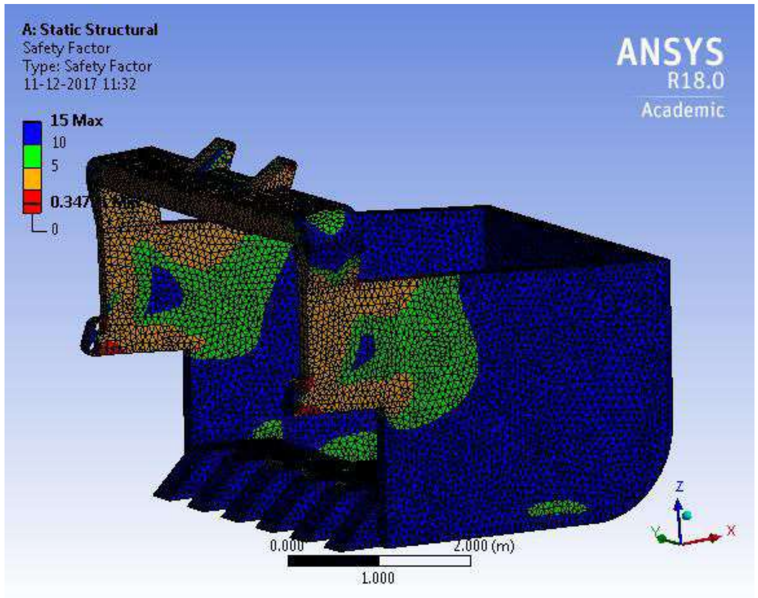


Figure 5. 10: Factor of safety of bucket under static loading condition

It has been observed from the analysis, that factor of safety is minimum near hitch element and arc anchors as observed in Figure 5.10. The factor of safety close to 1 indicates that the component is working very close to its elastic limit. Factor of safety less than 1 indicates that material exceeds elastic limit and if it is greater than 1, it indicates that it works without problem. In this case, also the analysis reveals that the minimum value of factor of safety is 0.347 near the hitch elements and arc anchors. The rest of the bucket model has higher values of factor of safety. Again, it is inferred that hitch element and arc of anchor are critical components in loaded bucket. Further, in comparison to empty bucket, the loaded bucket has lower factor of safety values at hitch elements and arc anchors.

5. *Fatigue sensitivity of dragline bucket*

Figure 5.11 shows the fatigue sensitivity throughout the body of the bucket and its assembly.

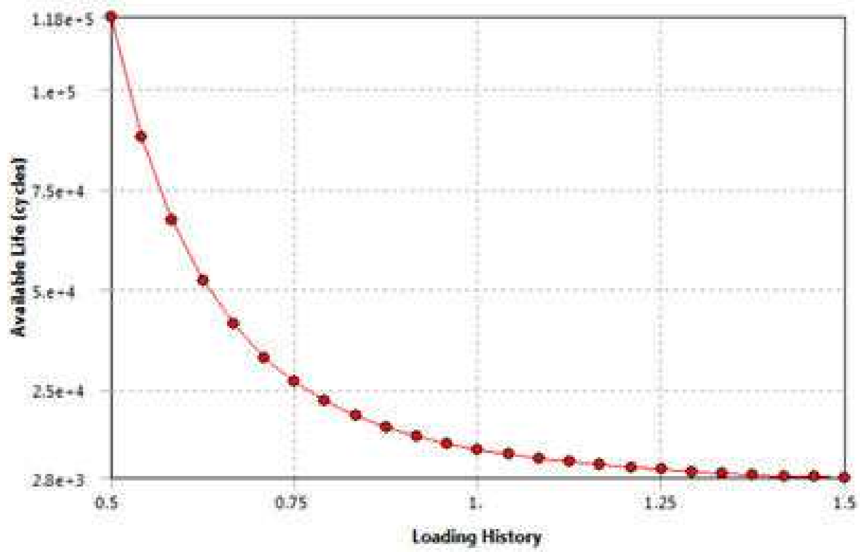


Figure 5. 11: Fatigue sensitivity of bucket under static loading condition

Fatigue sensitivity shows that how the fatigue results change as a function of loading at the critical location on the model. Fatigue sensitivity obtained from the analysis of bucket is shown in Figure 5.11.

(iii) Bucket in maximum loaded condition

With further increase in the load up to 20x10^5 KN, the stress value increases beyond the elastic limit of the material. The material shifts into the plastic zone. All the results are given below.

Solid body deforms under external loading. It is further found that up to certain limiting loads, a solid will recover its original dimensions when load is removed. The recovery of the original dimensions of a deformed body when load is removed is called elastic behaviour. The limiting load beyond which the material no longer behaves elastically is the elastic limit. If the elastic limit is exceeded, the solid body will experience a permanent deformation when the load is removed. A body which is permanently deformed is said to have undergone plastic deformation.

1. Equivalent stress (Von-Mises) of dragline bucket

Figure 5.12 shows the distribution of equivalent stress throughout the body of the bucket and its assembly.

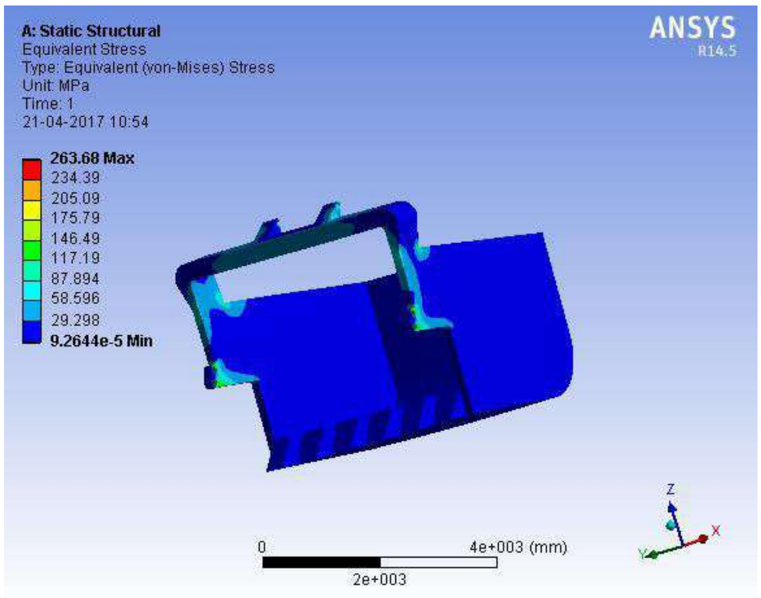


Figure 5. 12: Equivalent stress (Von-Mises) of bucket under maximum static loading condition

It has been found by applying self-weight plus payload on the bucket the equivalent stress varies from 9.2xe^{-5} MPa - 263.68 MPa near the hitch elements and arc anchors of the bucket as shown in Figure 5.12. At these points, the Von Mises stress reaches maximum value of 263.68 MPa. Under the static loading condition, stresses are cross the elastic limit of material. Yielding produces permanent changes of shape, which may prevent the part from functioning properly any longer. Other than these two places the stresses are generally low value such as 9.2xe^{-5} MPa in the whole body of the bucket. This implies that under static loading condition the bucket body is free from any stress capable of distorting it. Also, this analysis reveals that hitch element and arc anchors are the critical components in the bucket.

2. *Damage of dragline bucket*

Figure 5.13 shows the distribution of damage throughout the body of the bucket and its assembly.

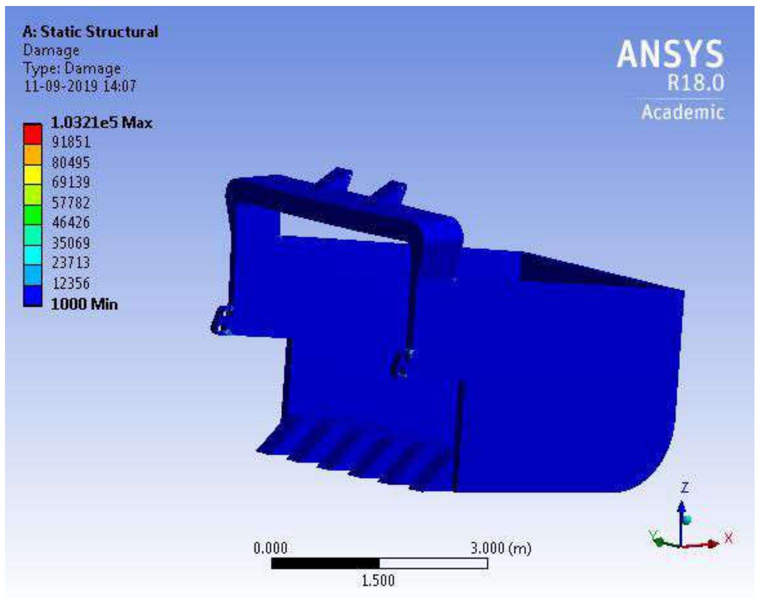


Figure 5. 13 Damage of bucket under maximum static loading condition

Damage is represented as a contour plot of the fatigue damage for a given life of the component. Damage is defined as ratio of design life of component to the available life of component. In static loading condition under the self-weight plus payload of bucket, the damage contour is shown in Figure 5.13. From the damage analysis it is clear that damage varies from 1000 cycle – 1.0321×10^5 cycle. For fatigue damage, values more than 1 indicate failure before the design life is reached.

3. Fatigue life of dragline bucket

Figure 5.14 shows the fatigue life throughout the body of the bucket and its assembly.

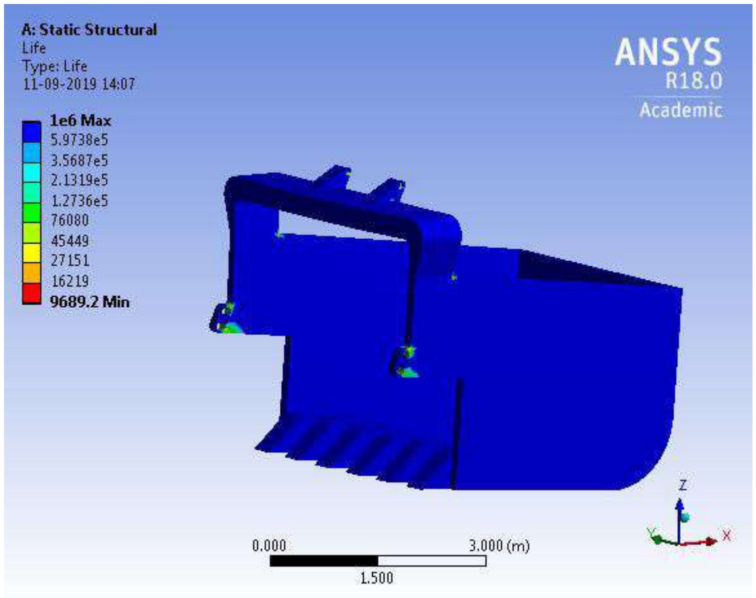


Figure 5. 14 Life of bucket under maximum static loading condition

Fatigue failure is particularly insidious because it occurs without any obvious warning. Bucket fatigue life varies from 9689.2 cycle - $1xe^6$ cycle as indicate in Figure 5.14. It is clearly observed that from Figure 5.14 that the stress magnitudes affect the fatigue life. The points subjected to high stress have low fatigue life and vice-versa. The remaining model has maximum value of fatigue life. Furthermore, the fatigue strength is seriously reduced by the introduction of stress elevators such as, a notch or hole. One of the best ways of minimizing fatigue failure is by the reduction of avoidable stress elevators through careful design and the prevention of accidental stress elevators by careful machining and fabrication.

4. Factor of safety of dragline bucket

Figure 5.15 shows the factor of safety throughout the body of the bucket and its assembly.

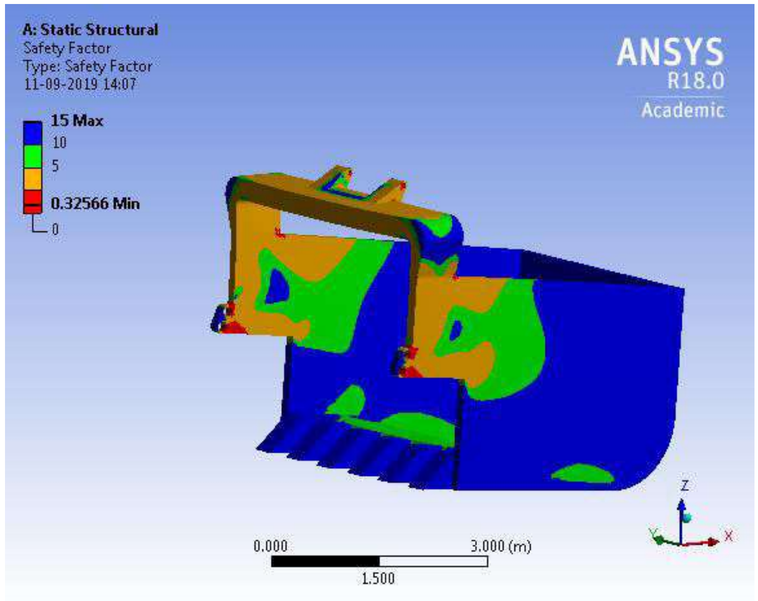


Figure 5. 15: Factor of safety of bucket under maximum static loading condition

In this analysis, it is found that the minimum value of factor of safety is 0.3256 near the hitch elements and arc anchors are shown in Figure 5.15. The points of maximum stress coincide with the lowest factor of safety with a value of 0.3256. The remaining of the bucket model have higher values of factor of safety. Again, it is inferred that hitch element and arc of anchor are critical components in loaded bucket. Further, in comparison to empty bucket, the loaded bucket has lower factor of safety values at hitch elements and arc anchors.

5. Stress-strain diagram of dragline bucket

Figure 5.16 shows the stress-strain diagram of the bucket when stress crosses the elastic limit of material.

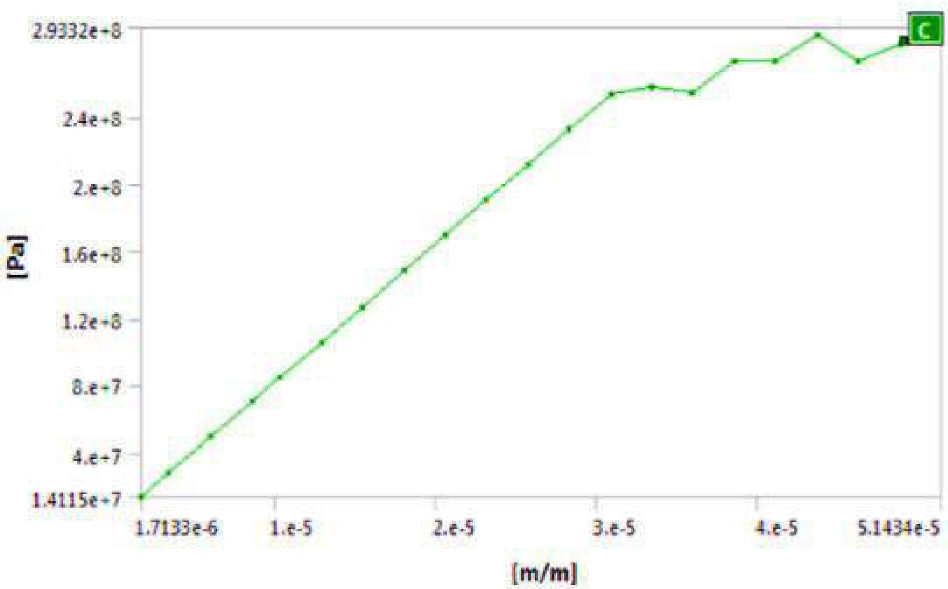


Figure 5. 16: Stress-strain diagram of bucket under maximum static loading condition

When the material is selected as a non-linear and load is increased beyond the prescribed limit, then the stress value crosses the yield strength of the material as shown in the stress-strain diagram. In Figure 5.16 Point C indicates that maximum value of stress 263.68 MPa occurs in the bucket when applied the maximum loading condition. The material behaviour is linear in the elastic range up to 250 MPa (yield strength of the material) and above 250 MPa material behaviour is non-linear as depicted in Figure 5.16.

5.3 Stress analysis of hitch elements and arc anchors in static loading condition

In the bucket assembly, there are many parts to be attached. However, the stress analysis has clearly revealed that hitch element and arc anchors are the critical elements in dragline bucket in different loading conditions. Therefore, a detailed investigation of these critical components was carried out, and results are described in following section.

5.3.1 Analysis of hitch elements under bucket loaded condition

In this analysis load of 18.5 x 10^5 KN was applied on the base of bucket, and the following results were obtained.

1. ***Equivalent stress(Von-Mises) on hitch elements***

Figure 5.17 shows the distribution of equivalent stress throughout the hitch elements of the bucket.

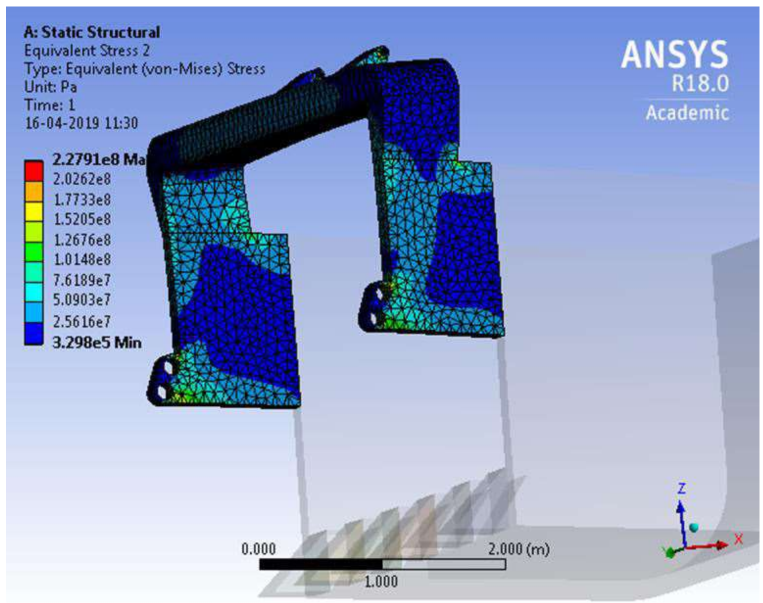


Figure 5. 17: Equivalent stress(Von-Mises) on hitch elements under static loading condition

In this study, it is found that the variations of stresses near the hitch elements are 0.3298 MPa to 227.91 MPa as clearly visible in Figure 5.17. At the hitch elements, the Von Mises stress reaches maximum value 227.91 MPa. Beyond these points, stresses are generally low value such as 0.3298 MPa. The stress value 227.91 is not enough to distortion to hitch elements of bucket because the elastic limit of yielding of the bucket material is 250 MPa. Also, this analysis reveals that hitch elements are the critical components in bucket.

2. Damage of hitch elements

Figure 5.18 shows the damage throughout the hitch elements of the bucket.

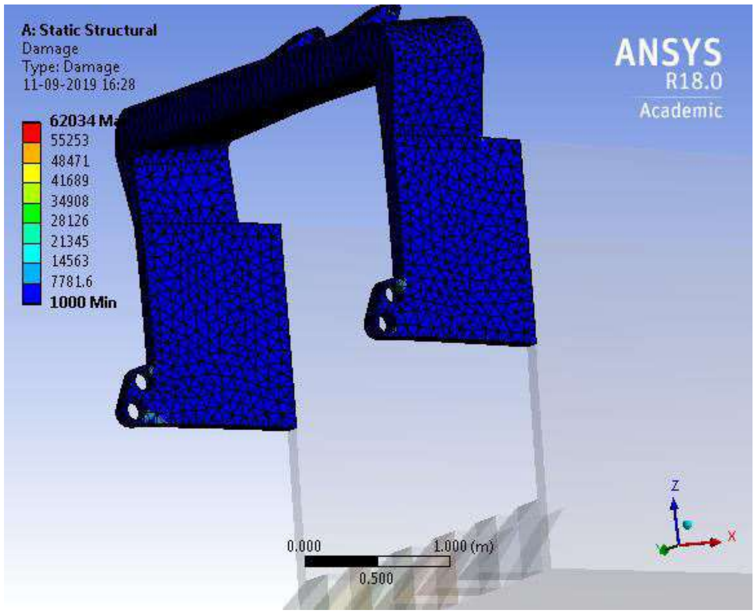


Figure 5. 18: Damage of hitch elements under static loading condition

Damage is represented as a contour plot of the fatigue damage for a given life of the component. In static loading condition under the self-weight plus payload of bucket, the damage contour is shown in Figure 5.18. From the damage analysis it is clear that damage varies from 1000 cycle – 62034 cycle. For fatigue damage, values more than 1 indicate failure before the design life is reached.

3. Fatigue life of hitch elements

Figure 5.19 shows the fatigue life throughout the hitch elements of the bucket.

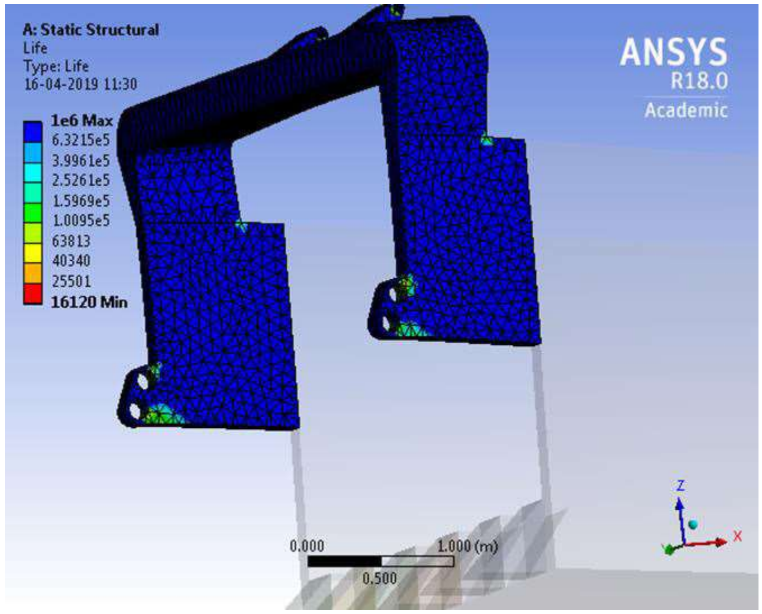


Figure 5. 19: Life of hitch elements under static loading condition

Hitch elements fatigue life varies from 16120 cycle - 1xe^{6} cycle as indicate in Figure 5.19. It is clearly observed that from Figure 5.19 that the stress magnitudes affect the fatigue life. The points subjected to high stress have low fatigue life and vice-versa. Furthermore, the fatigue strength is seriously reduced by the introduction of stress elevators such as, a notch or hole. One of the best ways of minimizing fatigue failure is by the reduction of avoidable stress elevators through careful design and the prevention of accidental stress elevators by careful machining and fabrication.

4. Factor of safety of hitch elements

Figure 5.20 shows the factor of safety throughout the hitch elements of the bucket.

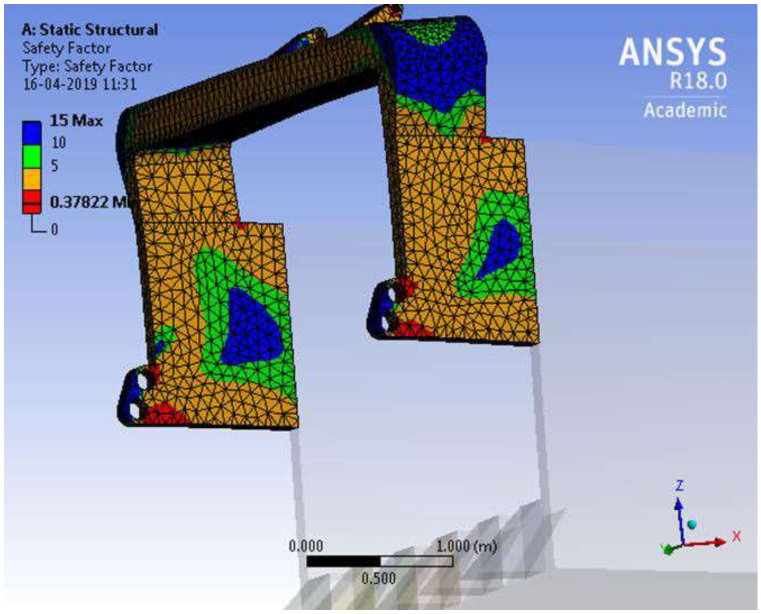


Figure 5. 20: Factor of safety of hitch elements under static loading condition

In this analysis, it is found that the minimum value of factor of safety is 0.3782 near the hitch elements and arc anchors are shown in Figure 5.20. The points of maximum stress coincide with the lowest factor of safety with a value of 0.3782. The rest of the bucket model has higher values of factor of safety. Again, it is inferred that hitch elements are critical components in loaded bucket. From the analysis it has been found that lower factor of safety values obtained under these conditions at hitch elements.

5. *Fatigue sensitivity of hitch elements*

Figure 5.21 shows the fatigue sensitivity of the hitch elements of the bucket.

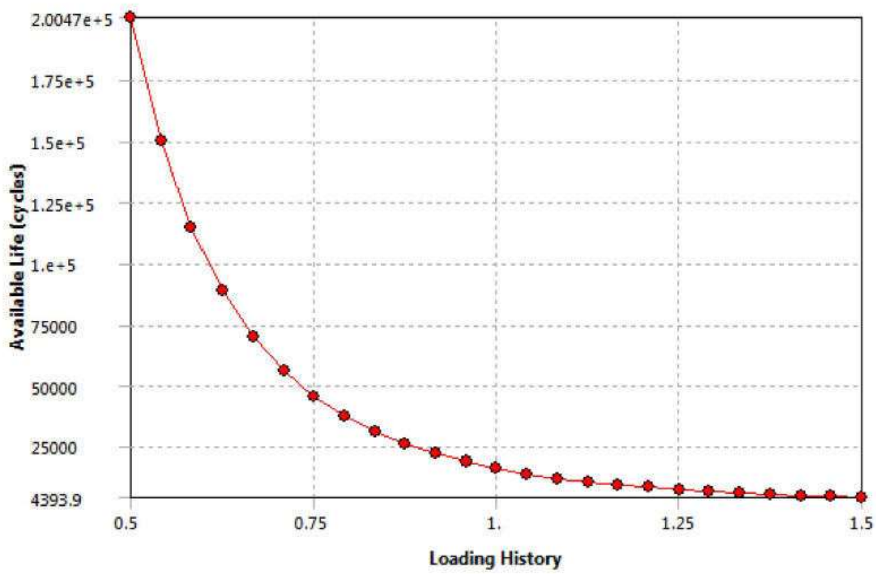


Figure 5. 21: Fatigue sensitivity of hitch elements under static loading condition

Fatigue sensitivity obtained from the analysis of hitch elements shown in Figure 5.21. The fatigue sensitivity graph shows that if loading condition lower the 50% of its value, life of the hitch element will increase and if its value increases by 150% then decrease the life of hitch elements.

5.3.2 Analysis of arc anchors under bucket loaded condition

In this analysis applied the load 18.5 x 10^5 KN on the base of the bucket and the following results have been found. Based on the data, the static analysis will obtain results on the Von Mises stresses, fatigue life, factor of safety and fatigue sensitivity of the bucket model.

1. Equivalent stress(Von-Mises) on arc anchors

Figure 5.22 shows the distribution of equivalent stress throughout the arc anchors of the bucket.

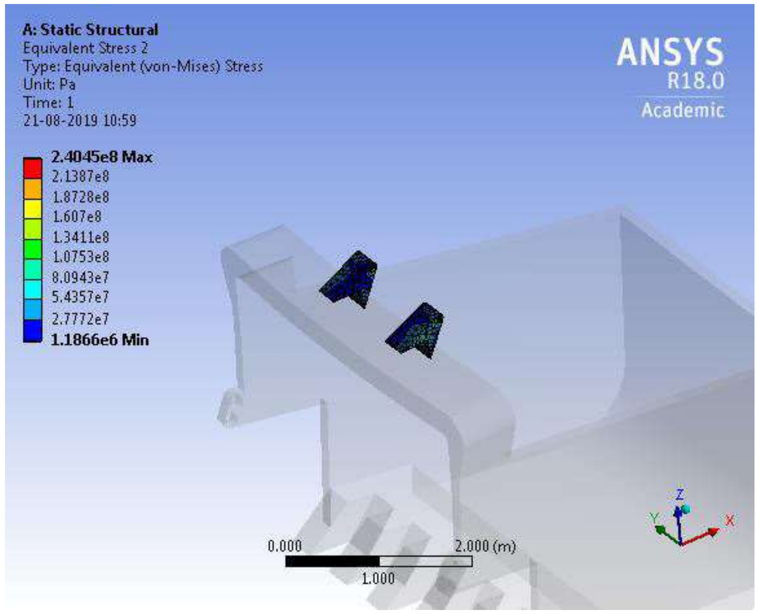


Figure 5. 22: Equivalent stress(Von-Mises) on arc anchors under static loading condition

In static loading condition, the maximum stresses are located at the arc of anchors. At these points, the Von Mises stresses reach maximum value 240 MPa. Outsides of these points stresses are generally low in value. The lower value of stress in arc anchors are 1.18 MPa. The variations of stresses near the arc anchors are shown in Figure 5.22. This stresses value is not sufficient to distort the arc elements of bucket because the elastic limit of yielding of the bucket material is 250 MPa.

2. Damage of arc anchors

Figure 5.23 shows the damage throughout the arc anchors of the bucket.

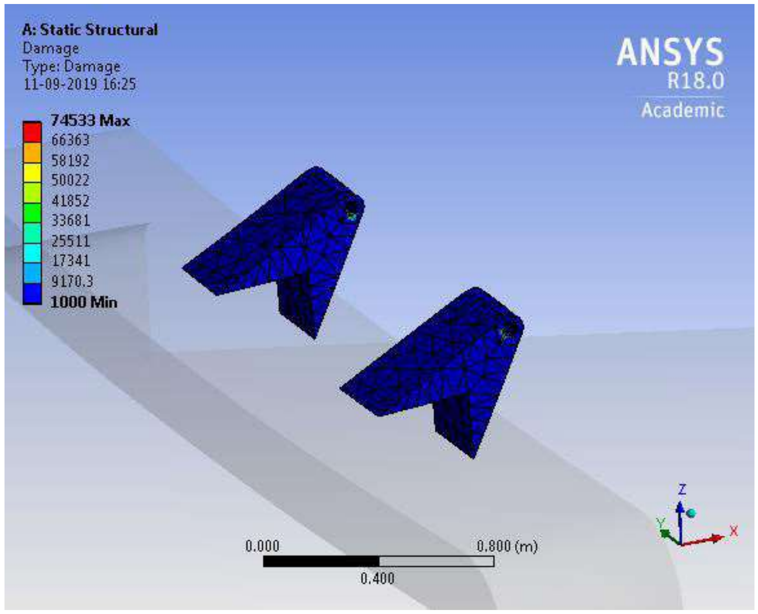


Figure 5. 23: Damage of hitch elements under static loading condition

In static loading condition under the self-weight plus payload of bucket, the damage contour is shown in Figure 5.23. From the damage analysis it is clear that damage varies from 1000 cycle – 74533 cycle. For fatigue damage, values more than 1 indicate failure before the design life is reached.

3. Fatigue life of arc anchors

Figure 5.24 shows the fatigue life throughout the arc anchors of the bucket.

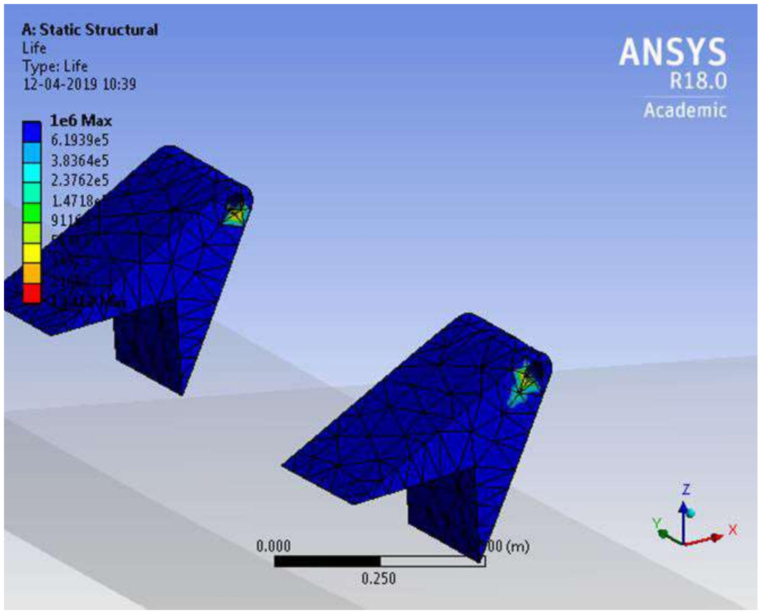


Figure 5. 24: Life of arc anchors under static loading condition

Arc anchors fatigue life varies from 13412 cycle - $1xe^{6}$ cycle as indicate in Figure 5.24. It is clearly observed that from Figure 5.24 that the stress magnitudes affect the fatigue life. The points subjected to high stress have low fatigue life and vice-versa. Furthermore, the fatigue strength is seriously reduced by the introduction of stress elevators such as, a notch or hole. One of the best ways of minimizing fatigue failure is by the reduction of avoidable stress elevators through careful design and the prevention of accidental stress elevators by careful machining and fabrication.

4. Factor of safety of arc anchors

Figure 5.25 shows the factor of safety throughout the arc anchor of the bucket.

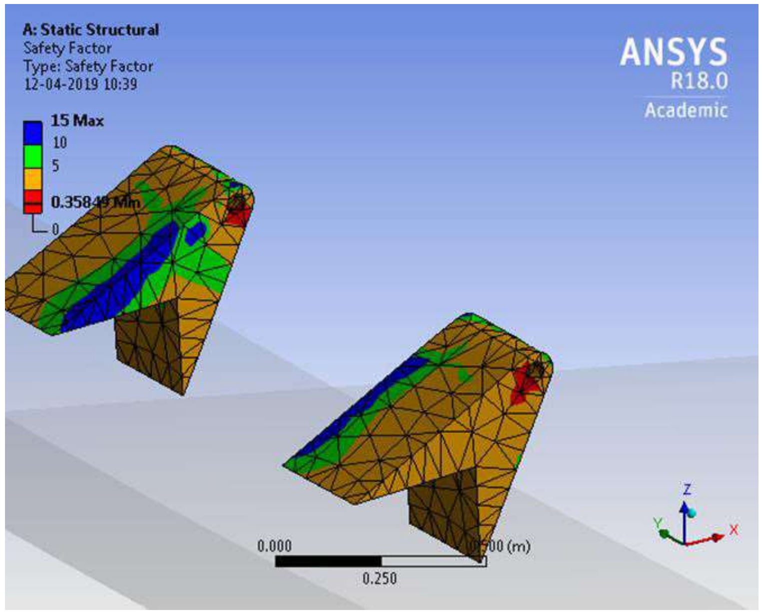


Figure 5. 25: Factor of safety of arc anchors under static loading condition

In this analysis, it is found that the minimum value of factor of safety is 0.3584 near the hitch elements and arc anchors are shown in Figure 5.25. The points of maximum stress coincide with the lowest factor of safety with a value of 0.3584. The rest of the bucket model has higher values of factor of safety. Again, it is inferred that hitch elements are critical components in loaded bucket. From the analysis it has been found that lower factor of safety values obtained under these conditions at hitch elements.

5. Fatigue sensitivity of arc anchors

Figure 5.26 shows the fatigue sensitivity of the arc anchors of the bucket.

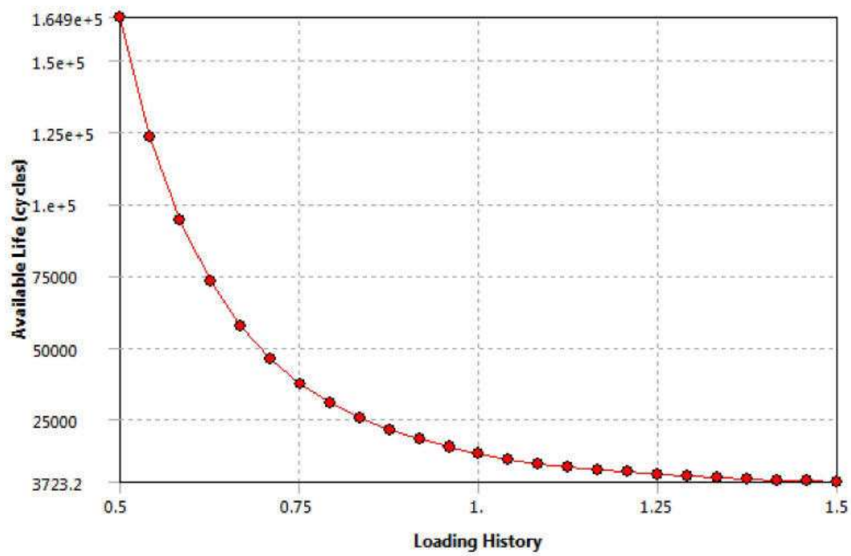


Figure 5. 26: Fatigue sensitivity of arc anchors under static loading condition

Fatigue sensitivity obtained from the analysis of arc elements is shown in Figure 5.26. The fatigue sensitivity graph shows that if loading condition lower the 50% of its value, life of the arc element will increase and if its value increases by 150% then decrease the life of arc elements.

5.4 Stress analysis of bucket under dynamic condition

In the research work, the dynamic loading condition has been considered when the bucket moves in a forward direction to fill the broken rock material at a constant velocity. Based on the data, the dynamic analysis occurs to obtain the results on the Von Mises stress, factor of safety and deformation on the bucket and its assembly.

5.4.1 Bucket under dynamic condition

Simulation in this investigation uses external pressure and velocity of bucket. The velocity applied at the drag hitch element of bucket is 0.5 m/s(assume), and the external pressure applied on the digging teeth of bucket is 0.78 MPa (the method of computation is given in chapter 4).

1. Equivalent stress (Von-Misses) of the bucket

Figure 5.27 shows the distribution of equivalent stress throughout the body of the bucket and its assembly.

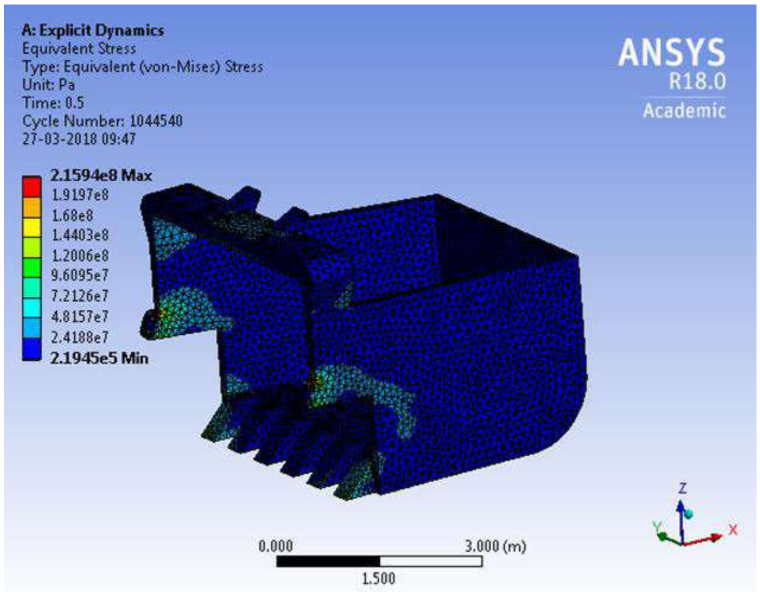


Figure 5. 27: Equivalent stress (Von-Misses) of bucket under dynamic condition

For analysis, the developed 3D model simulates the cutting action operation of the dragline bucket. Stress accumulates in the teeth and hitch elements of the bucket. Failure of the configuration initiates in the teeth and hitch elements of the bucket. It was found that the Von-Mises stress varied from 0.219 MPa to 216 MPa. Simulation results show the maximum stress that zones that are prone to failure. Von-Mises stress distribution for dynamic conditions bucket is shown in Figure 5.27.

2. *Factor of safety of bucket*

Figure 5.28 shows the distribution of factor of safety throughout the body of the bucket and its assembly.

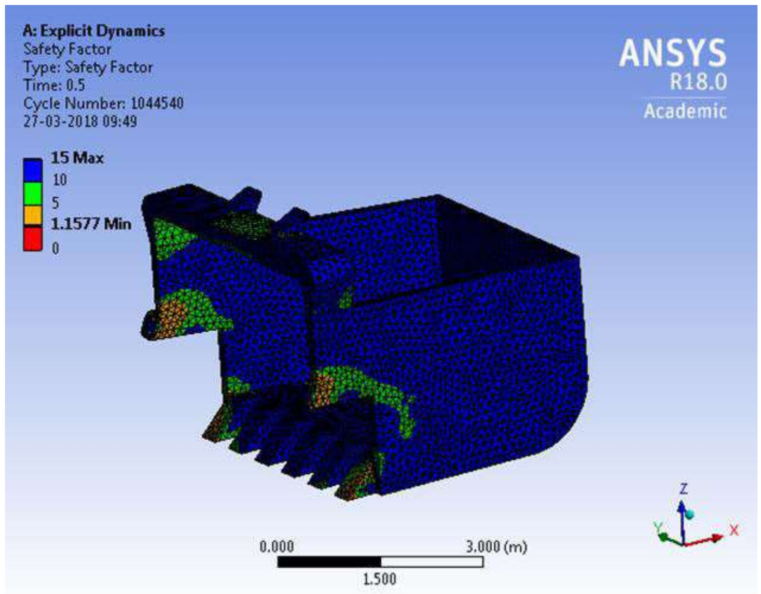


Figure 5. 28: Factor of safety of bucket under dynamic condition

To increase the service life of the bucket and its assembly, a recommendation would be useful in terms of using a higher grade or alloyed steel in sensitive parts of the bucket. From the analysis, it has been observed that the safety of factor is minimum near the hitch element and teeth tip as evident in Figure 5.28. The minimum value of factor of safety is 1.157, as shown in figure 5.28. If failure would result in loss of life, the factor of safety should be increased. The factor of safety will also depend on the expected type of loading.

3. Deformation of bucket

Figure 5.29 shows the deformation the body of the bucket and its assembly.

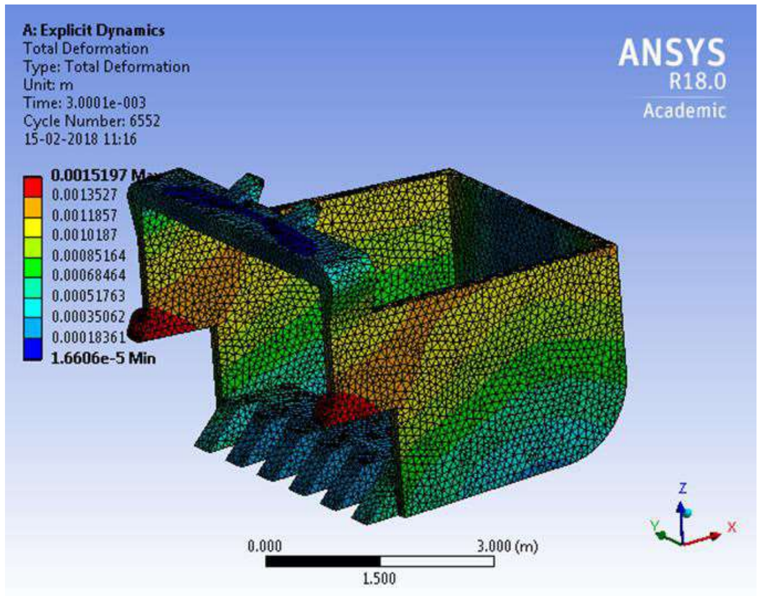


Figure 5. 29: Deformation of bucket teeth and hitch elements under dynamic condition

In the dynamic analysis, it is found that the deformation of bucket is varying between 0.016 mm to 1.5 mm which is shown in Figure 5.29. In this analysis the maximum deformation of the hitch elements is 1.5 mm, and the deformation of teeth of the bucket is 0.85 mm shown in Figure 5.29.

5.5 Stress analysis of bucket teeth in static condition

Based on the data, the static analysis will obtain results on the Von Mises stresses, total deformation, directional deformation and factor of safety of the bucket model.

5.5.1 Bucket teeth under static condition

In this analysis, the bucket base is fixed, and load is applied on the bucket teeth.

1. Equivalent stress (Von-Misses) on bucket teeth

Figure 5.30 shows the distribution of equivalent stress throughout the bucket teeth.

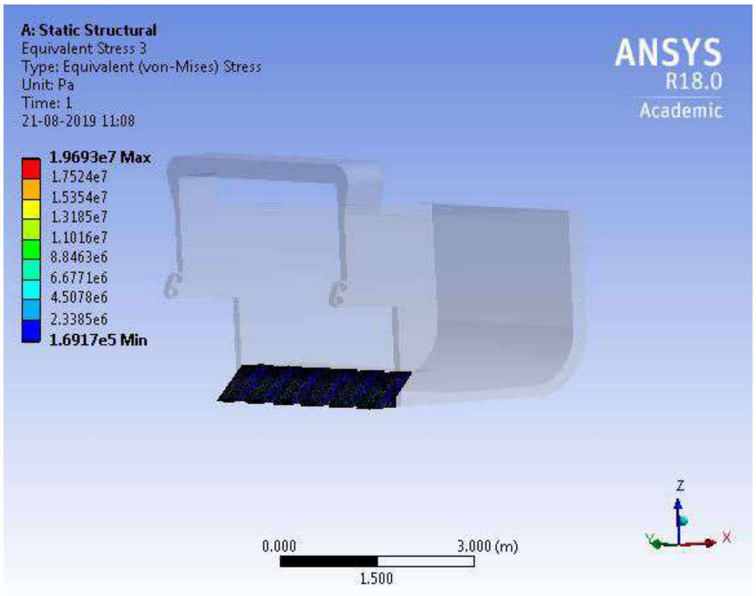


Figure 5. 30: Equivalent stress (Von-Misses) of bucket teeth under static loading condition

In this analysis, by applying the boundary and loading conditions, we have found that the equivalent stresses range is 5.7x10^{-5} MPa to 19.69 MPa near the bucket teeth shown in Figure 5.30. The maximum stresses are located at the tip of bucket teeth. At the tip of the teeth the Von Mises stress reaches maximum value as 19.69 MPa. Other than tip of the teeth stresses are generally low value as 5.7x10^{-5} MPa as shown in Figure 5.30.

2. Total deformation of bucket teeth

Figure 5.31 shows the total deformation of the bucket teeth in static loading condition.

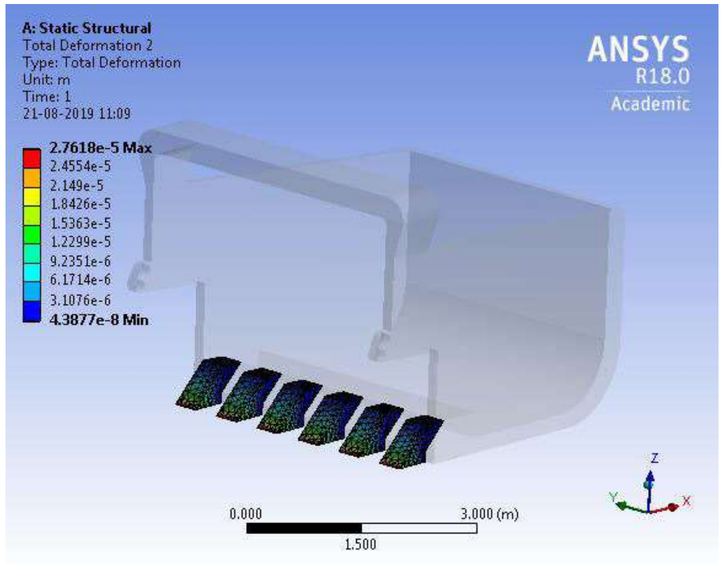


Figure 5. 31: Total deformation of bucket teeth under static loading condition

Total deformation of bucket teeth is 0.0004 mm to 0.027 mm, as shown in Figure 5.31. Total deformation indicates that bucket teeth are deformed in all direction (x, y and z-direction).

3. *Directional deformation (x-direction) of bucket teeth*

Figure 5.32 shows the directional deformation of the bucket teeth in static loading condition.

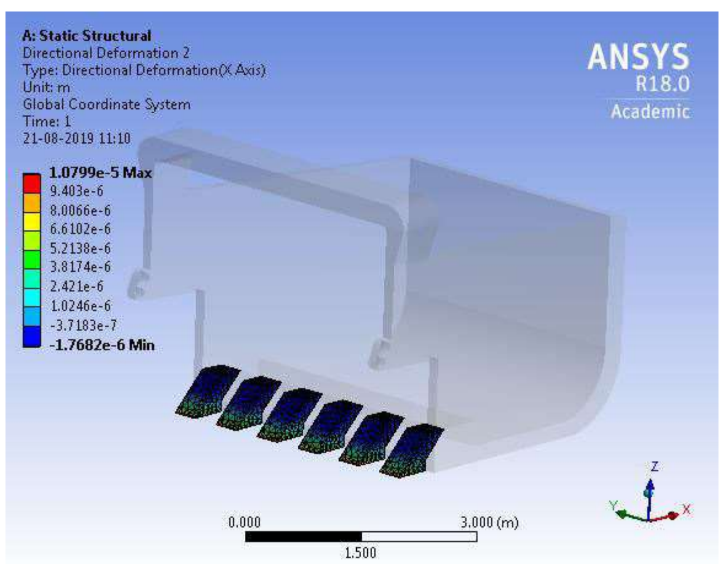


Figure 5. 32: Directional deformation (x-direction) of bucket teeth under static loading condition

In static loading condition, it has been found that the directional deformation of teeth in the x-direction is 0.0017 mm to 0.0107 mm as shown in Figure 5.32. Deformation of teeth plays an important role in the accurate working of the bucket. Thus, excessively deformed teeth can create problem for the correct performance of its function.

4. Factor of safety of bucket teeth

Figure 5.33 shows the distribution of factor of safety throughout the bucket teeth.

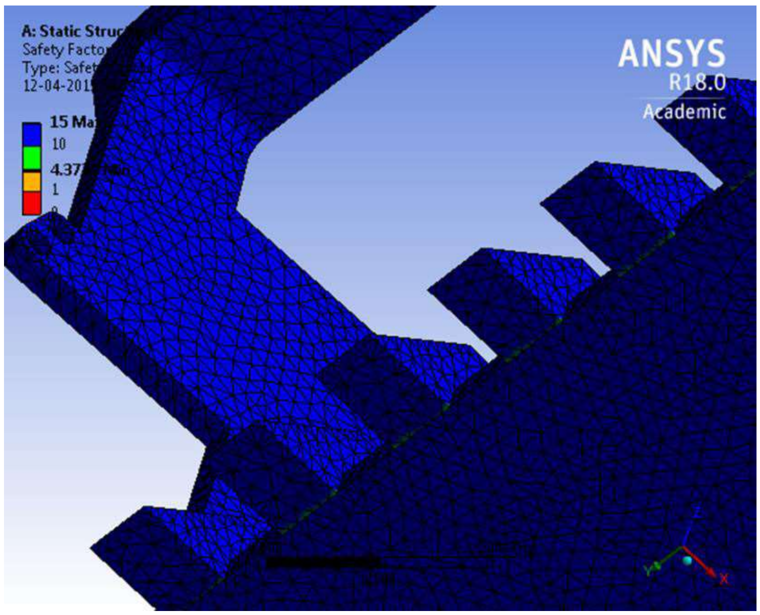


Figure 5. 33: Factor of safety of bucket teeth under static loading condition

The further analysis it has been found that the factor of safety is 1.0 near the bucket teeth, as illustrated in Figure 5.33. The remaining of the model have higher factor of safety values. It indicates that the model is working very close to its elastic limit. If factor of safety is greater than 1,it indicates trouble-free condition.

5.6 Comparison of the results between static and dynamic loading condition.

Table 5. 1: Comparison of bucket results

S.No.	Loads (N)	Stress MPa		Damage (cycle)		Life (cycle)		Factor of safety
		Min.	Max.	Min.	Max.	Min.	Max.	Min. value
Bucket under static loading condition	$7x10^5$	$3.6x10^{-5}$	102.5	1000	2717.3	$0.368x10^6$	$1xe^6$	0.840
	$18.5x10^5$	$60x10^{-6}$	248.26	1000	83154	12026	$1xe^6$	0.347
	Pressure on teeth (MPa)	Stress MPa		Total deformation (mm)				Factor of safety
		Min.	Max.	Min		Max.		Min. value
Bucket under dynamic condition	0.78	0.219	215.94	0.016		1.5		1.157

In static loading condition, it has been found that the stresses concentration occurs near the hitch elements and arc anchors. When increased the load on the bucket it is found the stress value increases near the hitch element and arc anchors. From the analysis, it is found that when load is increased damage cycle increases and decreases the fatigue life of bucket. Also, it decreases the factor of safety.

In the dynamic loading conditions, it has been found that the maximum stress concentration occurs near the hitch element, arc anchors and tip of the bucket teeth. From the analysis, it has been found that factor of safety value is more than 1, it indicates that it works properly without any problem. From both analysis it has been found that the critical component of bucket is hitch elements, arc anchors and teeth. To use higher grade or alloyed steel in critical parts manufacturing to increase the service life of the bucket and its assembly.

5.7 Optimisation of rake angle of the bucket

Rake angle plays a critical role in designing of teeth. For the optimum value of rake angle, the material cutting, filling and flowing out will be very smooth, at the same time specific pressure acting on the teeth will have a lesser value, which ought to enhance the teeth life. In this analysis, to optimise the rake angle of bucket taken as two types of broken rock material frequently encountered in mines have been considered, namely sandstone and shale.

5.7.1 Optimisation of rake angle of the bucket for sandstone material

1. If the Rake Angle varies between 15^0 to 90^0

In this case, the rake angle of bucket teeth was varied from 15^0 to 90^0 to evaluate its influence on resistive force.

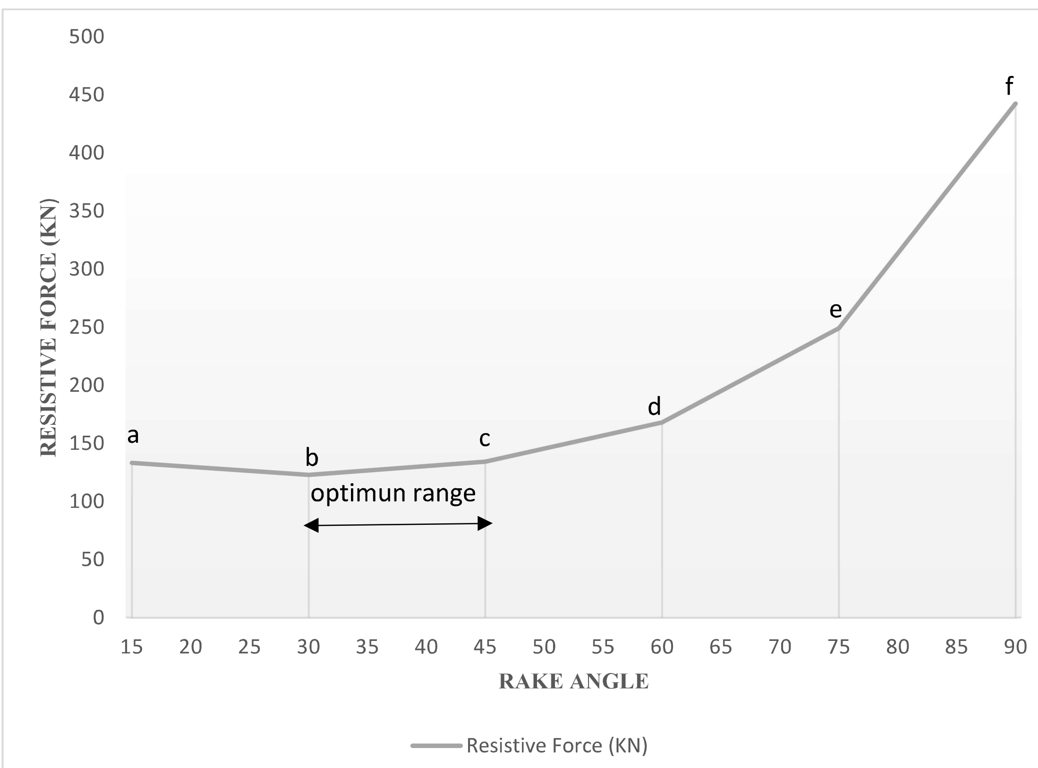


Figure 5. 34: Effect of rake angle on resistive force

For this analysis, as is evident from Figure 5.34, the optimum range of the rake angle has been found as 30^0 to 45^0. It is observed when the rake angle of bucket increases from (30^0-60^0), resistive force gradually increases. On further increasing the rake angle from (60^0-75^0), resistive force starts increasing. When the rake angle increases from (75^0-90^0), the resistive force increases sharply. So, we can say that for the smooth working of the dragline bucket, the rake angle should lie between 30^0-45^0.

2. Effect of change in bucket width

For this analysis, the maximum value of the dragline bucket width has been taken as 4 m, and the maximum value of teeth depth has been taken as 0.50 m.

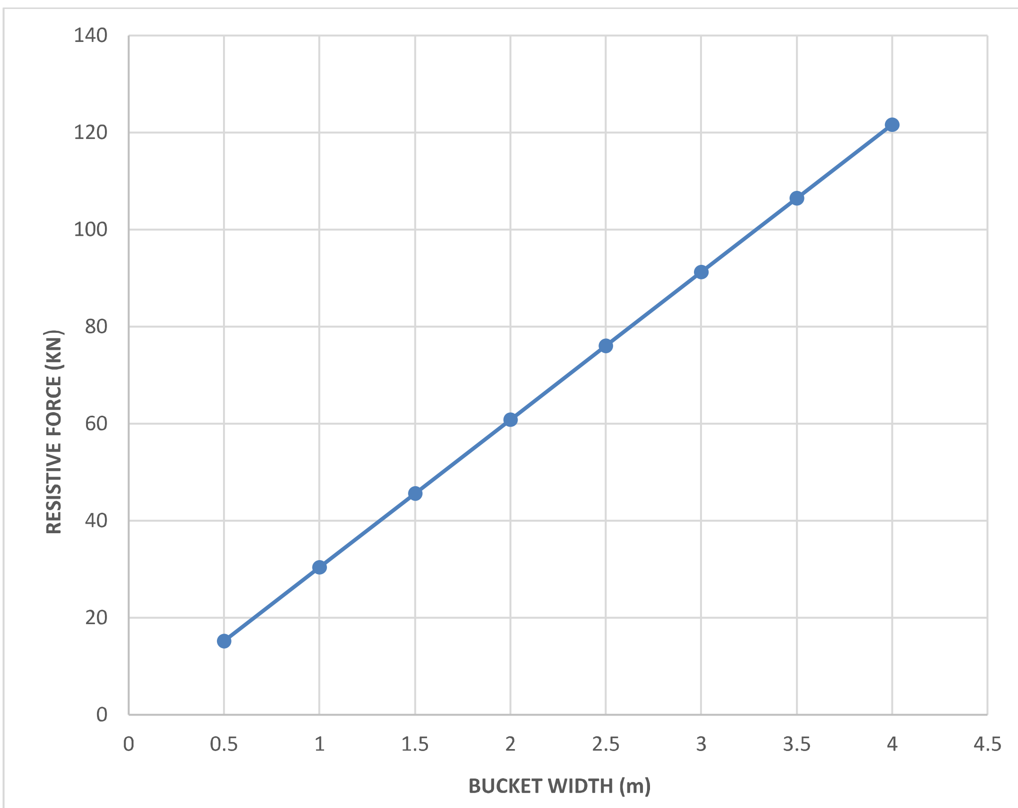


Figure 5. 35: Graph between bucket width and resistive force

It is clearly evident from Figure 5.35 that with increase in bucket width, the resistive force on the bucket also increases. However, when we compare the magnitude of resistive force for sandstone and shale, it is observed that magnitudes are lower for sandstone in comparison to shale rock. Higher resistive force implies greater difficulty in digging and higher abrasion. However, many other design and operational parameters need to be considered in deciding the width of bucket.

3. Teeth depth versus resistive force

In this case, the relationship among the variations of rake angle, tool depth and resistive force has been studied. For a value of rake angle (15^0), bucket teeth depth was changed from 0.1m to 0.5m to evaluate its affect on the resistive force. Further the process was done by changing the rake angle values changes from 15^0 to 30^0 upto 90^0 for the teeth depths ranging from 0.1m – 0.5m. The influence of these changes on the resistive forces was evaluated and presented in Figure 5.36.

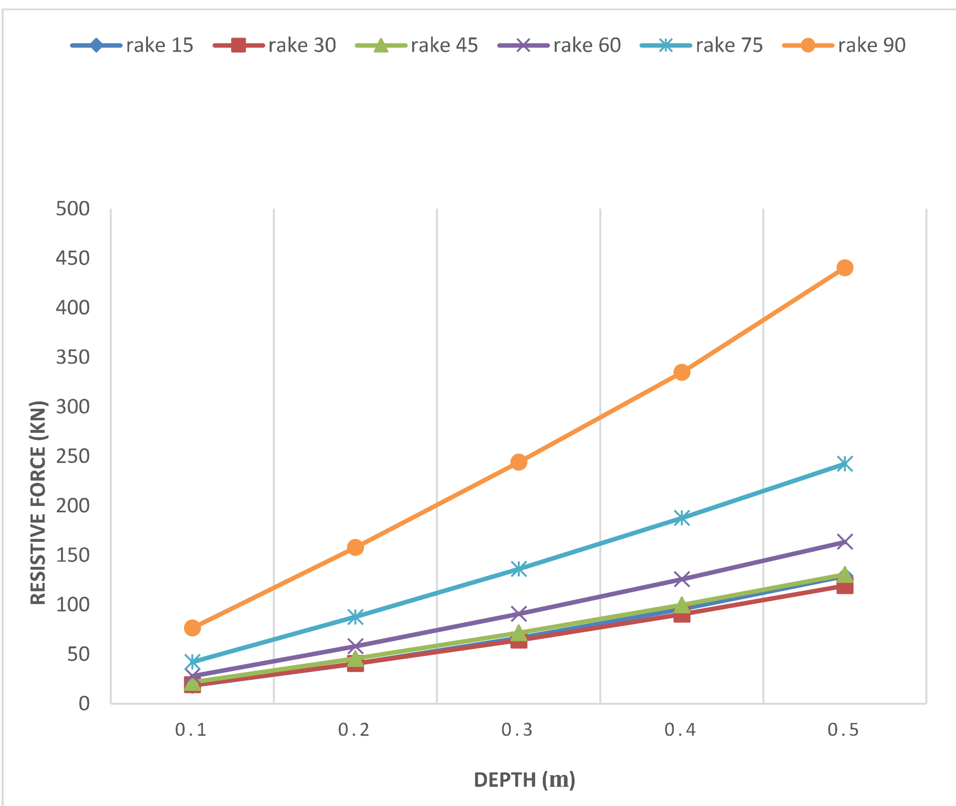


Figure 5. 36: Effect of teeth depth on resistive force

In Figure 5.36, it is clear that when teeth depth increases, the resistive force also increases for a given rake angle value. However, for optimum rake angle, the increase in resistive force is slow, but beyond the optimum rake angle there is sharp increase in the resistive forces on the teeth.

5.7.2 Optimization of rake angle of the bucket for shale rock material

1. If the Rake Angle varies between 15^0 to 90^0

Similarly, in this case, the rake angle of bucket teeth was varied from 15^0 to 90^0 to its evaluate influence on resistive force.

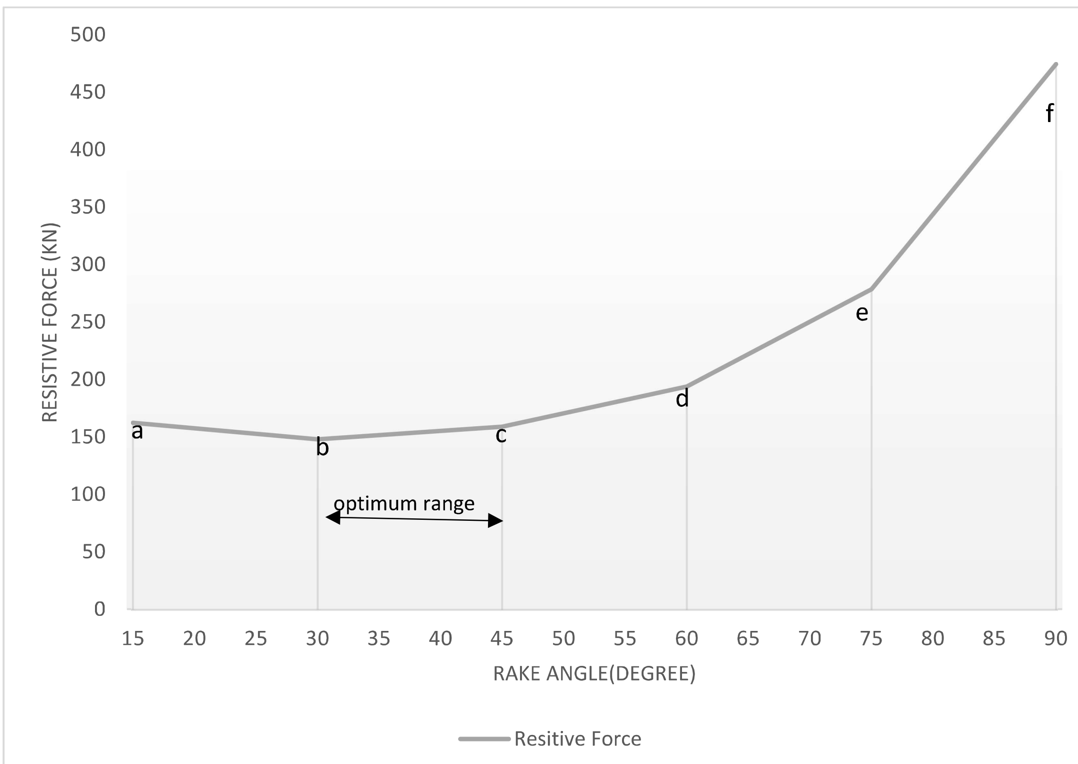


Figure 5. 37: Effect of rake angle on resistive force

Similar studies were conducted for shale formation. For this analysis, as is evident from Figure 5.37, the optimum range of the rake angle has been found as 30^0 to 45^0. It is observed when the rake angle of bucket increases from (30^0-60^0), resistive force gradually increases. On further increasing the rake angle from (60^0-75^0), resistive force suddenly increases. When the rake angle increases from (75^0-90^0), resistive force increased sharply. So, we can say that for the smooth working of the dragline bucket, the rake angle should lie between 30^0-45^0**.**

2. Teeth depth versus resistive force

Similarly, in this case, the relationship among the variations of rake angle, tool depth and resistive force has been studied. For a value of rake angle (15^0), bucket teeth depth was changed from 0.1m to 0.5m to evaluate its affect on the resistive force. Further the process was done by changing the rake angle values changes from 15^0 to 30^0 upto 90^0 for the teeth depths ranging from 0.1m – 0.5m. The influence of these changes on the resistive forces was evaluated and presented in Figure 5.38.

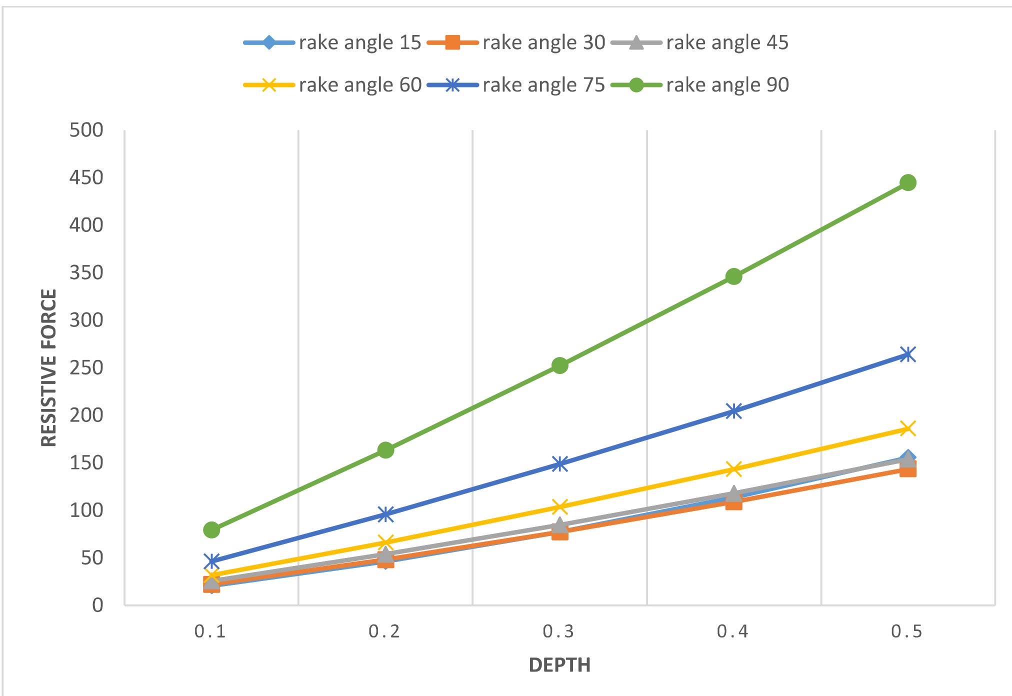


Figure 5. 38: Effect of teeth depth on resistive force

In Figure 5.38, the results are plotted between resistive forces and teeth depth. It is clear that as the teeth depth increases for a particular value of rake angle, then resistive forces also increase. However, for optimum rake angle, the increase in resistive force is slow, but beyond the optimum rake angle there is sharp increase in the resistive forces on the teeth.

Graphs are plotted between the different parameters to know the effect on the resistive force for different values of selected parameters. From the graphs, the resistive force has been observed to be increasing with increase in rake angle, bucket width and teeth depth, so it is necessary to select the optimum value of rake angle. From the analysis, the optimum range of the rake angle has been found be ranging from 30^0 - 45^0 both for sandstone and shale rock.

5.8 Validation

The dragline worked almost 20–21 h per day. Some small maintenance was required during shift changeovers. Also, routine maintenance was done in the morning. While validating the results of the simulation study, it was found, from the official maintenance logs of past year that the shortest working life was that of the bucket teeth. It varied from 200 to 300 h in the given sandstone formation.

The entire bucket is replaced after approximately 1000-1200 hours of its operation in the field. The stress generated shaped deformation, and damage to the hitch element was observed in the study mine, as shown in Figure 5.39 a and b. Similarly, the damaged teeth of the dragline bucket are shown in Figure 5.39 c and d. Also, the damaged arc anchors of the dragline are shown in Figure 5.39 e and f.

(a)

(b)

(c)

(d)

(e)

(f)

Figure 5. 39(a-f) Deformation and damage of hitch element, bucket teeth and arc anchors

It was found from the simulation results that stress is accumulated in the hitch element and bucket teeth. Figure 5.39 a–f shows the deformation of teeth, damage of hitch elements and damage of arc anchors from different dragline buckets in the mine. Figure 5.39 d shows that a small part of the teeth tip was broken, and Figure 5.39 c shows that the teeth were worn out and deformed under dynamic conditions. The maintenance logs of the study mine also reported maximum failure at the tip of teeth and the hitch element of the bucket.