The A6061 alloy based composites are highly recommended over other conventional alloys in automobile and aerospace industries due to its strength with respect to low densities. The objective of this investigation is to determine the fatigue strength of A6061-T6 alloy and the parameters of exponential function which used for description of a fatigue curve. The fatigue curve described by exponential function is fit experimental points very closer. The method for determination of exponential function parameters from lowest and highest stress levels will guarantees the correspondence between extreme stresses.

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It is estimated that 50 to 90% of failures observed in propulsion systems, aerospace applications and energy generation plants are due to fatigue and its interaction with time and temperature[2]. Fatigue will not exhibit plastic deformation it causes brittle fracture in ductile material without notable ductility. Any structural members fatigue life depends on type of load, frequency of load, size of the member, manufacturing method, operating environment. Surface coating plays vital role in fatigue life in LCF&HCF. The life enhancement is reported approximately double time in both the cases[11]. Fatigue failure occurring at low number cycles and relatively high stress are called as low cycle fatigue. Laser hardening is a thermal treatment which would improve fatigue behavior without external quenching for transformation of Austenite to Martensite[10]. The laser polishing process create HAZ over a depth of 100-150µm in metallic surfaces the surface quality is improved and the effect of surface roughness is reduced economically[3].

The crack growth direction changes from initial notch orientation when load direction modified which promote mixed mode crack propagation and crack closure[4]. Crack propagation is a gradual process occurring at a defined load repetition. The defects and imperfections are caused due to manufacturing problem or localized damage by in service. The load ratio R has a key role in fatigue crack growth and its stable propagation[7].

Nonmetallic inclusion promotes Hydrogen assisted fatigue crack growth near the inclusion area. Inclusion size and maximum stress are the dominating factor for crack nucleation[5]. To obtain a reliable solution from EIFS and stochastic FCG requires large amount of test data. Both crack closer and crack growth rate are different when the stress ratio is varying, but fracture topographies of the specimens are same[15, 16]. In LCF non propagating cracks were observed the propagation depends on development of dislocation cells[6]. The short crack growth has combined to fractal geometry and the inapplicability of fracture mechanics parameters is due to unique characterize of crack and its dependency of size. From most of the crack growth theories it is evident that crack nucleation, propagation are depends on initial crack length[1].

**Exponential Function**

The fatigue curve of material is expressed in the form of exponential equation

\[ \sigma = \sigma_e \exp \left( \frac{A}{N + B} \right) \]  

Where

- \( \sigma \) = Maximum stress of a cycle (MPa)
- \( \sigma_e \) = Endurance limit (MPa)
- N = Number of cycles to failure under the stress \( \sigma \)
- A, B = Exponential function parameters

**Test procedure:** The standard specimens are machined according to ASTMstandards. The specimens are polished in order to reduce surface roughness and geometrical irregularities. The specimens are tested in INSTRON fatigue testing machine at the frequency of 15 Hz. The stress is varying tensile to compressive with maximum amplitude. The specimens are subjected to stress above the endurance limit like 320MPa, 290MPa, 240MPa, 200MPa and 170MPa. The stress ratio is maintained as -1 in order to obtain complete stress reversal.

**TABLE 1:** fatigue test results of A6061-T6 alloy specimens

<table>
<thead>
<tr>
<th>Stress level</th>
<th>Number</th>
<th>Stress (MPa)</th>
<th>Life N (cycles)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>320</td>
<td>1930</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>290</td>
<td>19640</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>240</td>
<td>58450</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>200</td>
<td>309700</td>
</tr>
<tr>
<td>5</td>
<td>150</td>
<td>170</td>
<td>1139500</td>
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The above table data will help to find fatigue limit and exponential function parameters.

**Three stress level analysis.**

To find the parameters A, B take 3 stress levels \( \sigma_1, \sigma_2, \sigma_3 \) and the corresponding number of cycles to failure \( N_1, N_2, N_3 \). There are more combination of three stresses were possible, for five stress 120 combinations there are 10 possible combinations.

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combination of stresses exist but 10 combination only satisfy the conditions \( \sigma_1 \geq \sigma \geq \sigma_2 \) [13]. The parameter \( B \) in the equation can be found from the relation

\[
B = \frac{(N_3 - N_1)(N_3 \ln \sigma_3 - N_1 \ln \sigma_1) - (N_4 - N_1)(N_3 \ln \sigma_3 - N_4 \ln \sigma_2)}{(N_4 - N_1)(\ln \sigma_1 - \ln \sigma_3) - (N_4 - N_3)(\ln \sigma_1 - \ln \sigma_3)}
\]

(2)

From the value of \( B, A \) can be found from the following relation

\[
A = \frac{(N_1 + B)(N_2 + B)(\ln \sigma_1 - \ln \sigma_2)}{(N_2 - N_1)}
\]

(3)

The calculated fatigue limit \( \sigma_{EC} \) calculated from the following expression

\[
\ln \sigma_{EC} = \ln \sigma_1 - \left( \frac{A}{N_1 + B} \right) = \ln \sigma_2 - \left( \frac{A}{N_2 + B} \right)
\]

(4)

The parameters of equation (1) for 10 combination of stress levels which satisfy the condition \( \sigma_1 \geq \sigma \geq \sigma_2 \) are calculated by equation 2&3. The parameters of exponential function, calculated endurance limit and error percentage corresponding to the combination of stress levels are tabulated in table -2.

### Table 2: Parameters of exponential function for fatigue curve of Al6061-T6 alloy

<table>
<thead>
<tr>
<th>Number of the combination of stresses ( j )</th>
<th>Stress level number ( i )</th>
<th>( B )</th>
<th>( A )</th>
<th>( \sigma_{endurance} (\sigma_{EC}) ), MPa</th>
<th>( \Delta ) endurance, MPa</th>
<th>ERROR %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,2,3</td>
<td>401976.42</td>
<td>946567.6</td>
<td>30.71</td>
<td>109.28</td>
<td>78.05</td>
</tr>
<tr>
<td>2</td>
<td>1,2,4</td>
<td>90239.21</td>
<td>56293.05</td>
<td>173.74</td>
<td>33.74</td>
<td>24.1</td>
</tr>
<tr>
<td>3</td>
<td>1,2,5</td>
<td>104834.90</td>
<td>73869.25</td>
<td>160.20</td>
<td>20.20</td>
<td>14.42</td>
</tr>
<tr>
<td>4</td>
<td>1,3,4</td>
<td>49243.81</td>
<td>28051.05</td>
<td>184.96</td>
<td>44.96</td>
<td>32.11</td>
</tr>
<tr>
<td>5</td>
<td>1,3,5</td>
<td>74128.46</td>
<td>51325.77</td>
<td>162.92</td>
<td>44.96</td>
<td>14.40</td>
</tr>
<tr>
<td>6</td>
<td>1,4,5</td>
<td>165426.08</td>
<td>121429.8</td>
<td>154.89</td>
<td>14.89</td>
<td>10.63</td>
</tr>
<tr>
<td>7</td>
<td>2,3,4</td>
<td>31073.54</td>
<td>22137.83</td>
<td>187.42</td>
<td>47.42</td>
<td>33.87</td>
</tr>
<tr>
<td>8</td>
<td>2,3,5</td>
<td>58747.17</td>
<td>44795.67</td>
<td>163.76</td>
<td>23.76</td>
<td>16.97</td>
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<tr>
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<td>2,4,5</td>
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</tr>
<tr>
<td>10</td>
<td>3,4,5</td>
<td>341182.14</td>
<td>188753.40</td>
<td>149.65</td>
<td>9.65</td>
<td>6.89</td>
</tr>
</tbody>
</table>

**Dynamic changes in exponential function parameters**

To investigate the variation in parameters of exponential function and endurance limit the stress level \( \sigma_1 \& \sigma_2 \) and the corresponding number of cycles to failure \( N_1 \& N_2 \) are taken in such away that \( \sigma_1 \) is maximum stress and \( \sigma_2 \) is minimum stress for a given pair of stresses. It is possible to set the parameter \( B \) with the accuracy of \( 10^3 \). The Factor ‘\( A \)’ determined from equation 3.

### Table 3: Dynamics of changes in the parameters of the exponential equation

<table>
<thead>
<tr>
<th>( B )</th>
<th>( A )</th>
<th>( \sigma_{endurance} ), MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>340,000</td>
<td>281287.3</td>
<td>140.56</td>
</tr>
<tr>
<td>341,000</td>
<td>282300.6</td>
<td>140.49</td>
</tr>
<tr>
<td>342,000</td>
<td>283315.0</td>
<td>140.41</td>
</tr>
<tr>
<td>343,000</td>
<td>284330.6</td>
<td>140.33</td>
</tr>
<tr>
<td>344,000</td>
<td>285347.0</td>
<td>140.25</td>
</tr>
</tbody>
</table>

Form the table-3 it is observed that when the value of \( B \) changes proportionally \( A \) also changes. When \( B \) and \( A \) increases the calculated endurance limit decreases. The optimal value of parameters \( A, B \) of the exponential function equation is accepted when the actual fatigue limit deviation doesn’t exceed 1%. It is evident from the above table and the recommended value of \( B \) for Al6061-T6 alloy is 3,40,000 which has close association with experimental value.

**Two stress level analysis**
From the table it is observed that when value of B increases A also increases. In any pair of stresses one of the stress is maintained as constant and the other is decreased the value of B &A increased.

CONCLUSIONS
1. The exponential function describes the fatigue curve with minimum deviation of experimental results.
2. The percentage of error is minimum when the combination of stresses consists lower stresses and it is maximum when combination of stresses consists of higher stresses.
3. The exponential function parameters variation is proportional one and ratio of A/B is maintained as constant one near the endurance limit.

REFERENCES