Engine Air Filter Pre-Cleaner

Background
An engine air filter pre-cleaner provides the first line of defense against debris in the air. Pre-cleaners are particularly useful in landfill applications and other high-debris environments. The 836K compactor spends a lot of time at low idle. Low idle poses the most issues for the current non-powered pre-cleaner effectiveness because it requires high airflow to spin the impeller to dispel debris. There are current powered pre-cleaner options, however they do not meet the C18 requirement with just one pre-cleaner.

Purpose
To design a pre-cleaner that will operate independent of engine speed and provide 250 hour filter life for the 836K landfill compactor. The final solution shall contain a 3D model with accompanying airflow simulations and finite element analysis.

Design Criteria
- No added engine restriction – all designs based on Caterpillar C18 engine
- Must be no taller than existing pre-cleaner
- Operate at all engine speeds (low idle)
- Meet engine mass airflow (MAF) requirements for max intake and low idle: 2846kg/hr and 380kg/hr, respectively
- Use existing machine space for pre-cleaner

Alternative Solutions
1. Add motor to existing geometry
2. Add a fan to existing geometry to provide swirl around cap
3. Add foam to intake to trap dust particles
4. “Riffle” the cap to provide swirl and dispel dust from the sides
5. Fan powered cyclone with cone dispersion geometry and secondary pre-cleaner

Impact, Sustainability, & Conclusion
This pre-cleaner design will beneficially reduce the economic input needed by the customer and allow Caterpillar to be in complete control of their own design. There will be greater customer satisfaction due to the reduced costs on purchasing filters and the reduced time changing filters. The average time between filter changes at 250 hours from the current time of 25 hours would result in about $30,000 in savings and 41 hours of additional work time.

Potential Issues
- Fan failure and replacement
- Added complexity of electrical component

Analysis Inputs
- 3 Times Gravity applied to the fore direction of the machine
- 4 Times Gravity applied downwards on the machine
- 1500 RPM fan speed
- 0.106 Kg's engine intake

Final Solution and Quantitative Analysis
The final solution was produced in Creo and 3D Printed on the Makerbot Printers available to the team. Finite element analysis (FEA) was used to locate stress concentrations in the geometry. The upper limit on the FEA graphs is the material yield stress. The model does not detect any failure due to stress. Autodesk Computational Fluid Dynamics (CFD) and Ansys Fluent were used to simulate airflow through the pre-cleaner. The CFD software showed the velocities in the pre-cleaner. High air velocities were located at areas where dust will be dispelled and the engine will pull in air.

Economic Analysis

Filter Costs

<table>
<thead>
<tr>
<th>Filter Costs</th>
<th>Change after 2 hrs</th>
<th>Change after 25 hrs</th>
<th>Change at 50 hrs</th>
<th>Change at 250 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per 250 hrs</td>
<td>$4,159.69</td>
<td>$771.70</td>
<td>$133.11</td>
<td>$665.55</td>
</tr>
<tr>
<td>Filters Needed per Year</td>
<td>779</td>
<td>247</td>
<td>124</td>
<td>21</td>
</tr>
<tr>
<td>Yearly Cost</td>
<td>$102,779.94</td>
<td>$32,889.58</td>
<td>$16,444.79</td>
<td>$3,288.96</td>
</tr>
<tr>
<td>Yearly Savings</td>
<td>$99,490.98</td>
<td>$29,600.62</td>
<td>$13,155.83</td>
<td>$2,960.70</td>
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<tr>
<td>Assumed Time to Change each Filter (hr)</td>
<td>0.03</td>
<td>0.17</td>
<td>0.83</td>
<td>0.17</td>
</tr>
<tr>
<td>Total Yearly Filter Change Time (hr)</td>
<td>31.25</td>
<td>5.21</td>
<td>1.67</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Recommendations
The design should be compared to industry standards and further analysis should be conducted as per standard. The design should be injected molded at full scale and tested on a machine and in lab to collect data.