LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Figure Captions</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 2.1</td>
<td>Layer-by-layer fabrications</td>
<td>14</td>
</tr>
<tr>
<td>Figure 2.2</td>
<td>AM growth trend</td>
<td>16</td>
</tr>
<tr>
<td>Figure 2.3</td>
<td>Approximate AM percentage uses in the Asia/Pacific region by the end of year 2016</td>
<td>17</td>
</tr>
<tr>
<td>Figure 2.4</td>
<td>Use of AM for direct part production worldwide</td>
<td>18</td>
</tr>
<tr>
<td>Figure 2.5</td>
<td>Percentage of response for different AM processes</td>
<td>18</td>
</tr>
<tr>
<td>Figure 2.6</td>
<td>AM market status</td>
<td>19</td>
</tr>
<tr>
<td>Figure 2.7</td>
<td>Laminated object manufacturing process</td>
<td>21</td>
</tr>
<tr>
<td>Figure 2.8</td>
<td>Stereolithography process</td>
<td>22</td>
</tr>
<tr>
<td>Figure 2.9</td>
<td>Fused deposition modelling process</td>
<td>23</td>
</tr>
<tr>
<td>Figure 2.10</td>
<td>Three-dimensional printing process</td>
<td>24</td>
</tr>
<tr>
<td>Figure 2.11</td>
<td>Selective Laser Sintering process</td>
<td>28</td>
</tr>
<tr>
<td>Figure 2.12</td>
<td>SLS process parameter</td>
<td>35</td>
</tr>
<tr>
<td>Figure 2.13</td>
<td>Changes in laser-spot diameter</td>
<td>37</td>
</tr>
<tr>
<td>Figure 2.14</td>
<td>Scan-spacing</td>
<td>38</td>
</tr>
<tr>
<td>Figure 2.15</td>
<td>Scanning strategy</td>
<td>39</td>
</tr>
<tr>
<td>Figure 2.16</td>
<td>Stair-step</td>
<td>41</td>
</tr>
<tr>
<td>Figure 2.17</td>
<td>Feed-Heater Set Point</td>
<td>44</td>
</tr>
<tr>
<td>Figure 2.18</td>
<td>Part-Heater Set Point</td>
<td>44</td>
</tr>
<tr>
<td>Figure 2.19</td>
<td>Schematic view of powder fluff</td>
<td>50</td>
</tr>
<tr>
<td>Figure 2.20</td>
<td>Cracking appears in part-Bed and feed-cartridge</td>
<td>51</td>
</tr>
</tbody>
</table>
Figure 2.21 Schematic view of clumping 52
Figure 2.22 Crystals and condensation on the lens of the IR and laser window 53
Figure 2.23 Schematic View of Bonus Z 54
Figure 2.24 Schematic view of curling “In-Build” 55
Figure 2.25 Schematic view of curling “Post-Build” 56
Figure 2.26 Schematic view of “Growth” 57
Figure 2.27 Schematic view of a “Missed-Scan” 58
Figure 2.28 Schematic view of “Weak Parts/Porosity” 59
Figure 2.29 Depiction of value engineering job plan phase 75
Figure 3.1 Particle size distribution graph of Aluminum Oxide ball milled for 50hours 80
Figure 3.2 Particle size distribution graph of MgO ball milled for first 50 hours 81
Figure 3.3 Particle size distribution graph of MgO ball milled for second 50 hours 81
Figure 3.4 Particle size analyzer 83
Figure 3.5 Composite materials heated at temperatures of 100°C and 180°C for the periods of 25 hours, 50 hours, 75 hours and 100 hours 83
Figure 3.6 EDM wire cut machine (FANUC ROBOCUT, α-1ì B) 84
Figure 3.7 Casting process arrangement 84
Figure 3.8 SLS system (EOS INT P395) 85
Figure 3.9 EOS SLS system integrated process chain management 86
Figure 3.10 Experimental procedure flow chart 87
Figure 3.11 X-ray diffraction (XRD) analysis 91
Figure 3.12 Hitachi-3400N scanning electron microscope (SEM) 92
Figure 3.13 Schematic principle of DSC measurement 93
Figure 3.14  DSC Analysis apparatus (SDT Q 600)  93
Figure 3.15  Melt flow rate indexer (MFI) equipment  95
Figure 3.16  Melt flow index tester  96
Figure 3.17  Universal testing machine (Tinius Olsen H25KS and Instron 3345)  97
Figure 3.18  Impact strength tester  97
Figure 3.19  Flammability tester (Vertical and Inclined at 45°)  98
Figure 3.20  Characteristics that determine the application of thermoplastic polymers  99
Figure 3.21  Crystallisation temperature ($T_c$) with crystal growth rate $v$ for different molar mass in g mol$^{-1}$  103
Figure 3.22  Relationship between molecular weight, Mw and viscosity, $\eta_0$  104
Figure 3.23  Relative viscosity with volume fraction filler  105
Figure 3.24  SEM micrographs of SMMT clay 5 wt% and PA2200  108
Figure 3.25  SEM micrographs of SMMT clay 10 wt% and PA2200  109
Figure 3.26  Particle size measured through SEM micrographs of SMMT clay 5 wt% and PA2200 composite  109
Figure 3.27  SEM micrographs of Aluminium Oxide 10 wt% and PA2200  110
Figure 3.28  SEM micrographs of Aluminium Oxide 15 wt% and PA2200  110
Figure 3.29  Particle size measured through SEM micrographs of Aluminium Oxide 10 wt% and PA2200 composite.  111
Figure 3.30  Particle size measured through SEM micrographs of Aluminium Oxide 15 wt% and PA2200 composite.  111
Figure 3.31  SEM micrographs of Magnesium Oxide 10 wt% and PA2200  112
Figure 3.32  SEM micrographs of Magnesium Oxide 15 wt% and PA2200  112
Figure 3.33  Particle size measured through SEM micrographs of Magnesium Oxide 10 wt% and PA2200 composite 113
Figure 3.34  Particle size measured through SEM micrographs of Magnesium Oxide 15 wt% and PA2200 composite. 113
Figure 3.35  XRD of SMMT nanoclay/ PA2200 composite non heat treated 114
Figure 3.36  XRD of SMMT/ PA2200 composite heat treated 115
Figure 3.37  XRD of Aluminium Oxide/ PA2200 composite non heat treated 115
Figure 3.38  XRD of Aluminium Oxide/ PA2200 composite heat treated 116
Figure 3.39  XRD of Magnesium Oxide/ PA2200 composite non heat treated 116
Figure 3.40  XRD of Magnesium Oxide/ PA2200 composite heat treated 117
Figure 3.41  DSC of PA2200 ((Non heat treated) 120
Figure 3.42  DSC of SMMT nanoclay 5wt% / PA2200 composite (Non-heat treated) 121
Figure 3.43  DSC of Aluminium Oxide 5wt% /PA2200 composite (Non-heat treated) 121
Figure 3.44  DSC of Aluminium Oxide 10wt% /PA2200 composite (Non-heat treated) 122
Figure 3.45  DSC of Magnesium Oxide 5wt% /PA2200 composite (Non-heat treated) 122
Figure 3.46  DSC of Magnesium Oxide 10wt% /PA2200 composite (Non-heat treated) 123
Figure 3.47  Variation of $T_g$, $T_c$, and $T_m$ with SMMT Nanoclay/PA2200 composite 123
Figure 3.48  Effect of temperature and time on $T_g$ of SMMT Nanoclay/PA2200 composite 124
Figure 3.49  Effect of temperature and time on $T_c$ of SMMT Nanoclay/PA2200 composite 124
Figure 3.50  Effect of temperature and time on $T_m$ of SMMT Nanoclay/PA2200 composite 125
Figure 3.51  Variation of $T_g$, $T_c$, and $T_m$ with Aluminium Oxide/PA2200 composite  125

Figure 3.52  Effect of temperature and time on $T_g$ of Aluminium Oxide/PA2200 composite  126

Figure 3.53  Effect of temperature and time on $T_c$ of Aluminium Oxide/PA2200 composite  126

Figure 3.54  Effect of temperature and time on $T_m$ of Aluminium Oxide/PA2200 composite  127

Figure 3.55  Variation of $T_g$, $T_c$, and $T_m$ with Magnesium Oxide/PA2200 composite  127

Figure 3.56  Effect of temperature and time on $T_g$ of Magnesium Oxide/PA2200 composite  128

Figure 3.57  Effect of temperature and time on $T_c$ of Magnesium Oxide/PA2200 composite  128

Figure 3.58  Effect of temperature and time on $T_m$ of Magnesium Oxide/PA2200 composite  129

Figure 3.59  Melt flow index of SMMT nanoclay/PA2200 composite  131

Figure 3.60  Melt flow index of Aluminium Oxide/PA2200 composite  132

Figure 3.61  Melt flow index of Magnesium Oxide/PA2200 composite  132

Figure 4.1  Three sphere sintering model (A) original point contacts; (B) neck growth, (C), and (D) pore rounding  137

Figure 4.2  Photomicrographic illustration of change from interconnected to isolated porosity, (A) early phase with interconnected porosity; (B) later phase with closed porosity  138

Figure 4.3  Schematic illustration of the casting structure  140
Figure 4.4  Die for the production of cast specimens  142
Figure 4.5  Tensile strength of SMMT nanoclay/PA2200 composite  146
Figure 4.6  Tensile modulus of SMMT nanoclay/PA2200 composite  146
Figure 4.7  Elongation at break % of SMMT nanoclay/PA2200 composite as a function SMMT nanoclay wt%.  147
Figure 4.8  Flexural strength of SMMT nanoclay/PA2200 composite as a function of SMMT nanoclay wt%.  147
Figure 4.9  Flexural modulus of SMMT nanoclay/PA2200 composite for various concentration of SMMT nanoclay  148
Figure 4.10  Compressive strength of SMMT/PA2200 composite for different wt% of SMMT nanoclay  148
Figure 4.11  Impact strength of SMMT/PA2200 composite containing different wt% of SMMT nanoclay  149
Figure 4.12  Density of SMMT Nanoclay/PA2200 composite  151
Figure 4.13  Tensile strength Aluminium Oxide/PA2200 composite  154
Figure 4.14  Tensile modulus Aluminium Oxide/PA2200 composite  154
Figure 4.15  Elongation at break % of Aluminium Oxide/PA2200 composite as a function Aluminium Oxide wt%  155
Figure 4.16  Flexural strength of Aluminium Oxide/PA2200 composite as a function Aluminium Oxide wt%  155
Figure 4.17  Flexural modulus of Aluminium Oxide/PA2200 composite as a function Aluminium Oxide wt%  156
Figure 4.18  Compressive strength of Aluminium Oxide/PA2200 composite for different wt% of Aluminium Oxide  
Figure 4.19  Impact strength of Aluminium Oxide/PA2200 composite containing different wt% of Aluminium Oxide  
Figure 4.20  Density of Aluminium Oxide/PA2200 composite  
Figure 4.21  Tensile strength Magnesium Oxide/PA2200 composite  
Figure 4.22  Tensile modulus Magnesium Oxide/PA2200 composite  
Figure 4.23  Elongation at break % of Magnesium Oxide/PA2200 composite as a function of Magnesium Oxide wt%  
Figure 4.24  Flexural strength of Magnesium Oxide/PA2200 composite as a function of Magnesium Oxide wt%  
Figure 4.25  Flexural modulus of SMMT Magnesium Oxide/PA2200 composite for various concentration of Magnesium Oxide  
Figure 4.26  Compressive strength of Magnesium Oxide/PA2200 composite for different wt% of Magnesium Oxide  
Figure 4.27  Impact strength of Magnesium Oxide/PA2200 composite containing different wt% of Magnesium Oxide  
Figure 4.28  Density of Magnesium Oxide/PA2200 composite  
Figure 4.29  Comparison of tensile strength of Aluminium Oxide, Magnesium Oxide and Nanoclay fillers/ PA2200 based composites  
Figure 4.30  Comparison of tensile modulus of Aluminium Oxide, Magnesium Oxide and Nanoclay fillers/ PA2200 based composites  

xxii
Figure 4.31  Comparison of elongation at break % of Aluminium Oxide, Magnesium Oxide and Nanoclay fillers/ PA2200 based composites 170

Figure 4.32  Comparison of flexural strength of Aluminium Oxide, Magnesium Oxide and Nanoclay fillers/ PA2200 based composites 170

Figure 4.33  Comparison of flexural modulus of Aluminium Oxide, Magnesium Oxide and Nanoclay fillers/ PA2200 based composites 171

Figure 4.34  Comparison of impact strength of Aluminium Oxide, Magnesium Oxide and Nanoclay fillers/ PA2200 based composites 171

Figure 4.35  Comparison of compressive strength of Aluminium Oxide, Magnesium Oxide and Nanoclay fillers/ PA2200 based composites 172

Figure 4.36  Comparison of density of Aluminium Oxide, Magnesium Oxide and Nanoclay fillers/ PA2200 based composites 174

Figure 5.1  SLS process materials particle size (μm) range 187

Figure 5.2  SLS materials tensile strength (MPa) range 188

Figure 5.3  SLS tensile modulus/ elastic modulus (MPa) range 188

Figure 5.4  SLS materials elongation % at break/yields range 189

Figure 5.5  SLS materials impact strength (J/m) range 189

Figure 5.6  SLS materials hardness (ShoreD-scale) range 190

Figure 5.7  SLS polymer materials glass transition temperature (°C) range 190

Figure 5.8  SLS materials melting point temperature (°C) range 191

Figure 5.9  SLS materials density (g/cm³) range 191

Figure 5.10 Factors considered for SLS process appropriate material selections 202

Figure 5.11 Common fluorescent lamp holder (15.3 x 19.5 x 28.2 mm) 205
Figure 5.12  Redesigned common fluorescent lamp holder (15.3 x 19.5 x 28.2 mm) fabricated on SLS process 206

Figure 5.13  Redesign common fluorescent lamp holder (15.3 x 19.5 x 28.2 mm) using EOS PA 2201 FR material 208

Figure 5.14  Redesign common fluorescent lamp holder (15.3 x 19.5 x 28.2 mm) fabricated on SLS (EOS P390) machine using EOS PA 2201 FR material 208

Figure 5.15  Build orientations of specimen 216

Figure 5.16  Part builds direction 216

Figure 5.17  Schematic illustration of sintering in the laser sintered process, with (a) showing necking between particles in a single vector, (b) necking between two parallel vectors and (c) necking between different layers 218

Figure 5.18  Main Effect Plot for Means 219

Figure 5.19  Main Effect Plot for S/N Ratios 219

Figure 5.20  Contour plot for tensile stress with respect to X-Y orientation 220

Figure 5.21  Contour Plot for tensile stress with respect to Y-Z orientation 220

Figure 5.22  Contour Plot for tensile stress with respect to Z-X orientation 220

Figure 5.23  PA 2200 material properties comparison between specimens fabricated by SLS process and prepared by casting process 224

Figure 5.24  PA 2200/nanoclay 5wt% material properties comparison for SLS process and Casting process fabricated specimens 225

Figure 5.25  % of cost saving per kilogram with addition of filler materials 228