CONTENTS

Declaration i
Certificate ii
Abstract iii
Acknowledgement iv
Table of contents v
List of figures x
List of tables xiv
Symbols and notations xvi

1. INTRODUCTION 1
1.1. Sheet metal forming 1
1.2. Formability and its testing 2
1.3.1 Intrinsic tests 3
1.3.2 Simulative tests 5
   1.3.2.1 Simple bending test and stretch bending test 5
   1.3.2.2 Stretching test 5
   1.3.2.3 Hemispherical dome test 6
   1.3.2.4 Limiting dome height test 6
   1.3.2.5 Swift cup test 7
   1.3.2.6 Test on stretch-drawing behavior 7
   1.3.2.7 Conical cup wrinkling test and yoshida buckling test 9
   1.3.2.8 Spring back test 9
1.4 Forming limit diagrams 10
   1.4.1. Hemispherical punch method 10
   1.4.2. In-plane determination 10
1.5 Incremental sheet forming 11
   1.5.1. Forming method 18
   1.5.2. Forming tool 19
   1.5.3 Forming path and tool path strategy 19
   1.5.4 Forming limits 20
1.5.5 Formed sheet
1.6. Aluminium alloys
1.7. Optimization techniques
1.8. Conclusion

2. LITERATURE REVIEW

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Introduction</td>
<td>24</td>
</tr>
<tr>
<td>2.2</td>
<td>Single point incremental sheet forming</td>
<td>24</td>
</tr>
<tr>
<td>2.3</td>
<td>Two point incremental sheet forming</td>
<td>28</td>
</tr>
<tr>
<td>2.4</td>
<td>Forming path in incremental sheet forming</td>
<td>30</td>
</tr>
<tr>
<td>2.5</td>
<td>Forming tool in incremental sheet forming</td>
<td>34</td>
</tr>
<tr>
<td>2.6</td>
<td>Forming limits in incremental sheet forming</td>
<td>36</td>
</tr>
<tr>
<td>2.7</td>
<td>Simulation and optimization of incremental sheet forming</td>
<td>40</td>
</tr>
<tr>
<td>2.8</td>
<td>Parametric study</td>
<td>43</td>
</tr>
<tr>
<td>2.9</td>
<td>Statistical optimization for ISF</td>
<td>49</td>
</tr>
<tr>
<td>2.10</td>
<td>Conclusions</td>
<td>50</td>
</tr>
</tbody>
</table>

3. PLAN OF EXPERIMENTS ON SPIF

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Introduction</td>
<td>52</td>
</tr>
<tr>
<td>3.2</td>
<td>Material selection</td>
<td>53</td>
</tr>
<tr>
<td>3.3</td>
<td>Experimental preparation</td>
<td>53</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Chemical composition and tensile test</td>
<td>54</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Texture study</td>
<td>55</td>
</tr>
<tr>
<td>3.3.3</td>
<td>Incremental forming machine</td>
<td>55</td>
</tr>
<tr>
<td>3.3.4</td>
<td>Forming tool</td>
<td>57</td>
</tr>
<tr>
<td>3.3.5</td>
<td>Lubrication</td>
<td>58</td>
</tr>
<tr>
<td>3.3.6</td>
<td>SPIF clamping system</td>
<td>58</td>
</tr>
<tr>
<td>3.3.7</td>
<td>Limiting strain measurement</td>
<td>59</td>
</tr>
<tr>
<td>3.3.8</td>
<td>Wall angle measurement</td>
<td>60</td>
</tr>
<tr>
<td>3.3.9</td>
<td>Surface roughness measurement</td>
<td>61</td>
</tr>
<tr>
<td>3.4</td>
<td>Plan of experiment</td>
<td>62</td>
</tr>
<tr>
<td>3.4.1</td>
<td>Limited multiple wall angle test</td>
<td>62</td>
</tr>
</tbody>
</table>
3.5 Fractography  
3.6 Conclusion  

4. MULTI OBJECTIVE OPTIMIZATION OF SINGLE POINT INCREMENTAL FORMING 

4.1 Introduction  
4.2 Experimental procedures  
4.2.1 Tool path  
4.2.2 Process parameters  
4.2.3 Multi objective responses  
4.2.4 Taguchi’s experimental design  

4.3 Experimental results and analysis for AA5052  
4.3.1 Multi-objective process optimization of SPIF for AA5052  
4.3.2 ANOVA to weighted GRG’s for AA5052  
4.3.3 Confirmation experiment for SPISF of AA5052  

4.4 Experimental results and analysis for AA6061  
4.4.1 Multi-objective process optimization of SPIF for AA6061  
4.4.2 ANOVA to weighted GRG’s for AA6061  
4.4.3 Confirmation experiment for SPISF of AA6061  

4.5 Experimental results and analysis for AA8011  
4.5.1 Multi-objective process optimization of SPIF for AA8011  
4.5.2 ANOVA to weighted GRG’s for AA8011  
4.5.3 Confirmation experiment for SPISF of AA8011  

4.6 Results and analysis on multi objective optimization of SPIF  

4.7 Parametric study  
4.7.1 Influence of forming tool end type  
4.7.2 Influence of sheet thickness  
4.7.3 Influence of feed rate  
4.7.4 Influence of vertical step down  
4.7.5 Influence of tool diameter  
4.7.6 Influence of spindle speed  
4.7.7 Influence of lubrication
5 FORMABILITY ANALYSIS OF SPIF

5.1 Introduction

5.2 Chemical composition of AA5052 alloy

5.2.1 Microstructure of AA5052 alloy sheet

5.2.2 Tensile properties

5.2.3 Formability in straight groove test of AA5052

5.2.4 Limiting wall angle of AA5052 alloy sheets

5.2.5 Fractography of AA5052

5.2.6 Texture of AA5052 ally sheets

5.3 Chemical composition of AA6061

5.3.1 Microstructure of AA6061 alloy sheet

5.3.2 Tensile properties

5.3.3 Formability in straight groove test of AA6061

5.3.4 Limiting wall angle of AA6061 alloy sheets

5.3.5 Fractography of AA6061

5.3.6 Texture of AA6061 ally sheets

5.4 Chemical composition of AA6061

5.4.1 Microstructure of AA8011 alloy sheet

5.4.2 Tensile properties

5.4.3 Formability in straight groove test of AA8011

5.4.4 Limiting wall angle of AA8011 alloy sheets

5.4.5 Fractography of AA8011

5.4.6 Texture of AA8011 ally sheets

5.5 Conclusions

6 CONCLUSIONS

6.1 Introduction

6.2 Conclusions on groove test

6.2.1 Effect of tool type

6.2.2 Effect of sheet thickness
6.2.3 Effect of feed rate

6.2.4 Effect of vertical step down

6.2.5 Effect of tool diameter

6.2.6 Effect of speed

6.2.7 Effect of lubricant

6.3 Conclusions on formability

6.3.1 Conclusions on formability in plane strain condition

6.3.2 Conclusions on formability in biaxial tension strain condition

6.4 Conclusions on limiting wall angle

6.5 Conclusions on sheet metal chemical composition, microstructure and tensile properties

6.5.1 Conclusions on chemical composition

6.5.1.1 Microstructures of sheets with thickness 1.2 mm

6.5.1.2 Microstructures of sheets with thickness 1.0 mm

6.5.1.3 Microstructures of sheets with thickness 0.8 mm

6.5.2 Conclusions on tensile properties

6.5.3 Conclusions on fractography

6.5.4 Conclusions on texture

6.5.5 Conclusions on surface roughness

6.6 Recommendations and scope for future works

APPENDIX

REFERENCES