

Shape Characterisation of Sheet Metal
Assembly Variation with a View to
Quality Assessment and Dimensional
Control

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A thesis submitted for the degree of Doctor of Philosophy
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To my family

Declaration

The work in this thesis is my own except where otherwise stated.

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Publications

- Matuszyk, T, I., Cardew-Hall, M, J., and Rolfe, B, F. (2006). Observing dimensional variation in an automotive sheet-metal sub-assembly. In *Proceedings of the Society of Automotive Engineers 2006 World Congress, April 3-7, 2006-01-1635, Detroit, Michigan*.
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Abstract

Sheet metal assembly is a complex process involving component-to-component and component-to-tooling interactions. A key characteristic of sheet metal assemblies, the flexibility of components, means that variation does not stack-up according to the additive theorem of variance that applies to rigid bodies. Instead, components can be bent and distorted into conforming or non-conforming shapes by assembly interactions. This characteristic of flexibility also means that in comparison to rigid body assembly, additional aspects of the assembly process, such as clamp sequence and weld sequence, can influence the way in which variation propagates. Through a detailed understanding of the influence of assembly processes on variation propagation, manufacturers can adjust their processes to target particular quality assessment criteria: in this thesis, it is firstly demonstrated how assembly processes such as clamping sequence can be altered to control different variation patterns (and therefore quality) in sheet metal assemblies.

However, in order to truly optimise a sheet metal assembly process for dimensional control, there must be a well defined quality assessment framework from which to select the best processes. The most commonly adopted measures of assembly quality are based on the mean and standard deviation of a set of assumedly statistically independent measurement points. Such approaches are perhaps not the best measure of assembly quality. This is primarily due to their inability to adequately capture a key characteristic of assemblies: correlated variation patterns.

This thesis proposes that assembly quality cannot be simply assessed by the mean and variance of a set of assumedly statistically independent measurement points, and that correlated variation patterns in the form of bows, buckles, twists and ripples also form a large part of assembly quality perceptions. Two key methods were therefore developed to better characterise assembly variation: the multivariate statistical shape model, and the local shape descriptors. These shape characterisation measures overcome key limitations of existing univariate quality measures including an inability to capture correlated variation patterns, monitor non-normally distributed data, interpret high dimensional data, and measure local variation patterns of different sizes or scales. Through addressing these limitations, the proposed shape characterisation methods

provide significant advancements in the ability of manufacturers to accurately measure variation and discriminate between differing levels of assembly quality, and are particularly well suited for the interpretation of high dimensional measurement data made available by optical co-ordinate measuring machines. The new shape characterisation methods therefore provide a framework for achieving new levels of quality assessment, with a view to the ultimate goal of developing optimal dimensional control strategies for sheet metal assemblies.

Contents

| | |
|--|------------|
| Acknowledgements | vii |
| Abstract | ix |
| 1 Introduction | 1 |
| 1.1 Dimensional variation in sheet metal assembly | 1 |
| 1.1.1 Variation and tolerances | 2 |
| 1.1.2 The sheet metal assembly process | 3 |
| 1.1.3 Automotive sheet metal build approaches | 4 |
| 1.1.4 A simple assembly model | 4 |
| 1.2 Problem statement | 8 |
| 1.3 Proposed approaches | 10 |
| 1.3.1 The influence of processes on assembly variation | 10 |
| 1.3.2 Characterizing assembly variation | 10 |
| 1.3.3 A view to optimal assembly process design | 12 |
| 1.4 Thesis overview | 12 |
| 2 Background | 15 |
| 2.1 Introduction | 15 |
| 2.2 Virtual assembly | 15 |
| 2.2.1 Finite element models | 16 |
| 2.2.2 Multi-station models | 19 |
| 2.2.3 Process optimisation | 21 |
| 2.3 Process diagnosis | 23 |
| 2.4 Knowledge-based design | 26 |
| 2.5 Industry measures of assembly quality | 27 |
| 2.6 Limitations of univariate measures of variation | 28 |
| 2.6.1 Model assumptions | 29 |
| 2.6.2 Implications of new measurement technology | 30 |
| 2.7 Characterising assembly variation | 31 |
| 2.8 Conclusion | 33 |

| | | |
|----------|--|-----------|
| 3 | An introduction to sheet metal assembly | 35 |
| 3.1 | Introduction | 35 |
| 3.2 | Observing assembly variation | 35 |
| 3.2.1 | Component and assembly potential | 37 |
| 3.2.2 | Variation stack-up | 38 |
| 3.2.3 | Positional shifts | 39 |
| 3.2.4 | Summary of observations | 40 |
| 3.3 | Investigating assembly processes | 41 |
| 3.3.1 | Clamping sequence | 41 |
| 3.3.2 | Weld sequence | 42 |
| 3.3.3 | Summary of assembly processes | 48 |
| 3.4 | Conclusion | 48 |
| 4 | The effects of clamp sequence | 51 |
| 4.1 | Introduction | 51 |
| 4.2 | Simulated assembly | 51 |
| 4.2.1 | Finite element approach | 52 |
| 4.2.2 | Component variation modes | 53 |
| 4.3 | Clamp sequences | 55 |
| 4.3.1 | Clamp sequence selection | 55 |
| 4.4 | Investigating a population of assemblies | 56 |
| 4.5 | Assembly population results | 58 |
| 4.5.1 | Individual variation modes | 58 |
| 4.5.2 | Combination of all variation modes | 60 |
| 4.6 | Conclusion | 61 |
| 5 | Experimental comparison of clamp sequences | 63 |
| 5.1 | Introduction | 63 |
| 5.2 | Experimental clamping study | 63 |
| 5.2.1 | Experimental and FEM clamp sequences | 64 |
| 5.2.2 | Component variation | 65 |
| 5.2.3 | Measurement point extraction | 65 |
| 5.2.4 | Component sampling | 66 |
| 5.3 | Experimental results | 67 |
| 5.3.1 | Differences in the mean shape | 67 |
| 5.3.2 | Comparison cross-sections | 68 |
| 5.3.3 | Mean shifts - univariate approach | 69 |
| 5.3.4 | Mean shifts - multivariate approach | 70 |
| 5.3.5 | Experimental comparison to nominal | 71 |
| 5.4 | Simulated assembly | 72 |

| | | |
|----------|--|------------|
| 5.4.1 | Finite element approach | 72 |
| 5.4.2 | Simulation results | 72 |
| 5.5 | Clamp sequence and variability | 75 |
| 5.5.1 | Population of input components | 75 |
| 5.5.2 | Assembly and variability comparison | 76 |
| 5.6 | Clamp sequence design | 77 |
| 5.6.1 | Clamp sequence comparison | 78 |
| 5.6.2 | Clamp sequence performance | 79 |
| 5.7 | Conclusion | 80 |
| 6 | Multivariate statistical shape model | 83 |
| 6.1 | Introduction | 83 |
| 6.2 | Multivariate process monitoring | 84 |
| 6.2.1 | Computer vision | 84 |
| 6.2.2 | Chemical process control | 85 |
| 6.3 | Methods | 85 |
| 6.3.1 | Measurement of free-form manufactured parts | 85 |
| 6.3.2 | Gaussian distribution | 86 |
| 6.3.3 | Dimensional reduction using PCA | 86 |
| 6.3.4 | Kernel density estimation | 86 |
| 6.3.5 | Statistical shape models | 88 |
| 6.4 | Results | 89 |
| 6.4.1 | Simulated case study | 90 |
| 6.4.2 | Univariate shape model | 92 |
| 6.4.3 | Point Distribution Model | 93 |
| 6.4.4 | Kernel Density Estimate/Point Distribution Model | 95 |
| 6.4.5 | Industry case study | 96 |
| 6.5 | Discussion | 98 |
| 6.5.1 | Creating the KDE-PDM | 99 |
| 6.5.2 | Data mining with the KDE-PDM | 99 |
| 6.5.3 | A tolerancing approach for the KDE-PDM | 99 |
| 6.5.4 | Computational issues | 100 |
| 6.6 | Conclusion | 100 |
| 7 | Local shape characterization | 103 |
| 7.1 | Introduction | 103 |
| 7.2 | Surface classification | 104 |
| 7.3 | Example manufactured components | 105 |
| 7.3.1 | Registration and Normalization | 106 |
| 7.3.2 | Qualitative surface descriptions | 107 |

| | | |
|----------|--|------------|
| 7.4 | Approach to local shape characterization | 111 |
| 7.5 | Average curvature energy | 112 |
| 7.5.1 | Surface curvature | 112 |
| 7.5.2 | Curvature energy | 113 |
| 7.5.3 | Surface assessment | 114 |
| 7.6 | Multi-scale surface assessment | 115 |
| 7.6.1 | The continuous wavelet transform | 115 |
| 7.6.2 | Surface example | 116 |
| 7.6.3 | Selecting scales | 118 |
| 7.6.4 | Average power | 119 |
| 7.6.5 | Surface assessment | 120 |
| 7.7 | Curvature segmentation | 121 |
| 7.7.1 | Surface assessment | 122 |
| 7.8 | Local shape characterization vector | 123 |
| 7.9 | Future developments | 123 |
| 7.9.1 | Registration and Normalization | 124 |
| 7.9.2 | Curvature-based methods | 124 |
| 7.9.3 | Multi-scale surface analysis | 125 |
| 7.9.4 | A view to surface classification | 125 |
| 7.10 | Conclusion | 126 |
| 8 | Conclusion | 127 |
| 8.1 | Introduction | 127 |
| 8.2 | A framework for quality assessment | 127 |
| 8.2.1 | Multivariate statistical shape model | 128 |
| 8.2.2 | Local shape descriptors | 133 |
| 8.2.3 | Summary of quality assessment framework | 135 |
| 8.3 | Contributions | 135 |
| 8.3.1 | Clamp sequence simulation | 136 |
| 8.3.2 | Clamp sequence design | 136 |
| 8.3.3 | Multivariate statistical shape model | 136 |
| 8.3.4 | Local shape descriptors | 137 |
| 8.3.5 | Dimensional assessment framework | 137 |
| 8.4 | Suggestions for further work | 137 |
| 8.4.1 | Mechanistic simulation | 137 |
| 8.4.2 | Virtual assembly and metal forming | 138 |
| 8.4.3 | Stochastic simulation | 138 |
| 8.4.4 | Multivariate shape model | 138 |
| 8.4.5 | Localized shape model | 139 |

| | | |
|----------|--|------------|
| 8.4.6 | Application of quality assessment framework | 139 |
| A | Experimental assembly setup | 141 |
| A.1 | Channel section fabrication | 141 |
| A.2 | Bending tool | 142 |
| A.3 | Channel with bow | 143 |
| A.4 | Assembly rig | 144 |
| B | Virtual assembly | 147 |
| B.1 | Nonlinear finite element model | 147 |
| B.2 | Finite element model mapping | 148 |
| C | Clamp sequence study | 151 |
| D | Local shape descriptors | 153 |
| D.1 | Continuous wavelet transform: Signal extension | 153 |
| E | Statistical tools | 155 |
| E.1 | Statistical inference | 155 |
| E.1.1 | Comparison of means | 155 |
| E.1.2 | Comparison of variances | 156 |
| F | Data fitting | 157 |
| F.1 | Simple linear regression | 157 |
| F.2 | Cubic piece-wise splines | 158 |
| F.3 | Thin-plate splines | 159 |
| G | Mean shifts | 163 |
| H | Other methods | 165 |
| H.1 | Linear discriminant analysis | 165 |
| H.2 | Discrete cosine transform | 167 |
| | Bibliography | 168 |