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

Timothy Ian Matuszyk

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To my family

Declaration

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

Timothy Ian Matuszyk

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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 charaterisation 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.

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