The Application of AI Techniques to Deformation in Metal Manufacturing

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Abstract

We describe the INMA project, part of which aims to use AI techniques to predict and correct shape deformation in the manufacture of titanium parts using in the aircraft industry.

1 Introduction

The INMA project[1] is a multi-partner project funded by the EU[2] which brings together engineers, materials scientists, computer scientists and industrialists and aims to develop and improve manufacturing techniques for the production of titanium parts to be used in the aircraft industry. Currently the aircraft industry uses complicated and expensive technologies to shape titanium sheet components. The project proposes technology based on the relatively new technique of Asymmetric Incremental Sheet Forming (AISF) aiming to obtain increased flexibility, cost reduction, minimised energy consumption and a speed up in the industrialisation phase.

2 Background

When manufacturing parts using AISF a metal sheet is clamped into a holder and the desired shaped is produced using the continuous movement of a simple round-headed forming tool. The forming tool is provided with a tool path generated by a CAD model and the part is pressed out according to the co-ordinates of the tool path. However, due to the nature of the metal used and the manufacturing process, *spring back* occurs which means that the geometry of the shaped part is different from the geometry of the desired part, i.e. some deformation is introduced. Work package 4 of the INMA project (Liverpool's part) involves analysing the AISF process parameters, the required shape and the formed shape to predict and correct the deformation.

Currently we are looking at the background to this problem and solutions adopted elsewhere. For example Dearden et al. (2006) present an iterative laser forming solution to the problem of correcting such distortion. In Allwood et al. (2005) the authors consider a number of products that could potentially be formed using AISF and show that the accuracy of the formed part needs to be improved before this process could be used in a large number of these products. In Hirt et al. (2004) the authors consider two drawbacks to AISF, namely that of the metal thickness of the resulting shape, and the geometric accuracy, the latter relating to the problem we study. Regarding the geometric accuracy, a part is produced and measured. Then the deformation is calculated and the tool path corrected using the inverse of the deformation at each point. This process is applied iteratively until the deformation is small enough. In Bambach et al. (2009) the authors propose a multi-stage forming technique, i.e. rather than a single pass by the machine tool several are made. Further, they consider the effect of different initial geometries with respect to the deformation produced on the desired shape. As a case study they consider a flat topped pyramid shape. The initial geometry with a corner radius larger than the desired shape and a number of forming stages produced the least deformation.

3 Proposed Solutions

The main tasks are as follows:

- investigating or developing good representations for the data;

[1] www.inmaproject.eu
[2] http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=1&CAT=PROJ&QUERY=012eb403bac5:d891:5cf7dbdc&RCN=96396

- the application and development of AI techniques to the data to propose tool paths that account for the effects of spring back to minimise deformation;
- experimentation with these techniques and analysis of the best or combination of techniques.

3.1 Representation

Co-ordinate Points Currently the data (both the desired shape and the actual shape) is represented as sets of 3-D (x, y, z) co-ordinates. Input to the machine tools is a standard CAD/CAM file in APT (Automatically programmed Tool) code. Due to the volume of data involved we may have to reduce the number of co-ordinate points by considering points at particular co-ordinates in a mesh rather than the full co-ordinate set.

Registration We need to ensure that the 3-D co-ordinates are relative to the same origin otherwise we won't be comparing related parts of the geometry and the deformation may appear larger than expected.

Deformation The deformation of the resultant part with respect to the required part can be calculated a number of ways. One example is to calculate the difference in z co-ordinates for given x, y co-ordinates. We will need to be able to provide a measure of overall deformation, for example, the average per point for a grid like-representation to allow analysis of our results.

Parameters It is likely that a number of parameters will affect the deformation, for example, the type of metal, the composition of the metal, the processing of the sheets prior to part forming etc. We also need to represent data about these parameters to investigate whether they do have some affect on the deformation. Additionally we anticipate having to utilise derived data, for example, to differentiate parts of the shape representing peaks, troughs, ridges, flat portions etc as we expect the deformation will be affected by such factors.

3.2 Predicting Deformation

Given the data and a representation of this for a specific shape we need a way of predicting the deformation to generate a new tool path such that the resultant shape, once manufactured, is close enough to the required shape. An obvious first attempt would be to invert the deformation at each point. That is, if for some x, y point the z co-ordinate for the obtained shape is h units greater than expected, then to correct this in the new tool path we would subtract h from the z value of the desired shape. This is the approach taken in Hirt et al. (2004) on which we hope to improve by applying AI techniques. We will consider a number of techniques but are considering data mining, neural networks, statistical methods. Obviously the collection of a large amount of data on which to develop and test our ideas is expensive when dealing with titanium. We hope to be able to initially use data from parts formed in aluminum before moving on to testing with titanium.

3.3 Experimentation and Analysis

Here we would like to compare a number of techniques developed above at predicting and correcting the tool path for a particular shape and, if possible, combine the best of these.

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