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Robot-based guiding of extrusion profiles - Increase of guiding accuracy by considering the temperature-dependent effects

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Abstract

Three-dimensionally curved extrusion profiles are used to manufacture lightweight frame structures. These profiles have to be flexibly manufactured, especially for a small batch production. For this reason, a flexible process chain with an automated extrusion process was build up. In this paper an approach for offline calculation of path data for the guiding of unsteady extrusion profiles with industrial robots is presented. This approach includes a consideration of the profile deformation caused by cooling during production. The required correction values are determined by using a coupled kinematic and thermal FEM simulation.

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Keywords: path data, thermomechanical simulation, extruded profile, industrial robot

1. Introduction

The energy efficiency of machinery, vehicles and equipment can be increased by reducing the weight of the moving masses. Therefore, lightweight construction concepts will gain more and more importance in the future. One possibility of reducing weight is to optimize the supporting structure, for example, by using aluminum space frame structures. These aluminum space frames are already being used in the automobile and aviation industry [1, 2].

In addition, there is for example a trend in the automotive industry towards a greater variant diversity, which results in smaller quantities [3, 4]. For this reason, the quantity-flexible production of lightweight supporting structures becomes more and more the centre of attention. However, fully automated production lines are rarely used in low volume production of lightweight supporting structures due to the lack of flexibility.

Therefore, the groundworks for setting up a product-flexible process chain are investigated in the Collaborative Research Centre Transregio 10. As part of this research work, a flexible facility was built to manufacture three-dimensionally rounded aluminum profiles which form the basis for lightweight supporting structures (Figure 1).

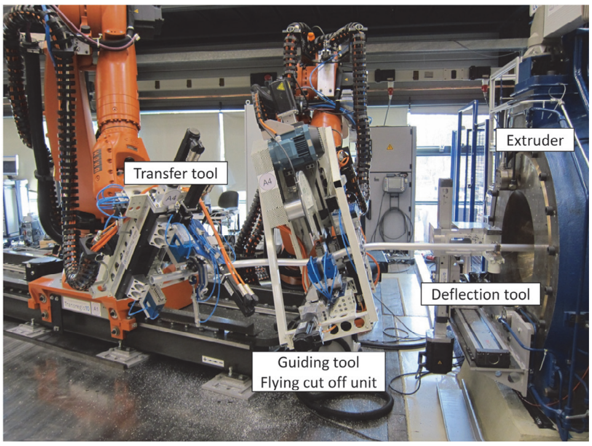

Fig. 1. Extruder and moving cut-off unit

The production of these profiles is carried out by using the method of "multi-axis rounding during extrusion". During this process, the three-dimensionally rounded aluminum profiles can be manufactured with

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the help of an extruder that has been modified accordingly. The pieces are shaped by a special deflection tool that is located at the outlet of the extruder. Synchronously with this process, the emerging profile is guided through the room by two tools, each of them mounted on industrial robots (Figure 1). This procedure prevents the influence of gravity caused by the already manufactured profile on the emerging limp profile. The desired length of the profile is produced by the flying cut-off unit [5] which is cutting off the continuously emerging profile with a circular saw mounted on the effector of the first industrial robot (Figure 1).

2. State of the art

2.1. The flying cut-off

The flying cut-off system displayed in Figure 1 and its control concept will be described in more detail below. The non-reactive guiding and cutting of the rounded profile is carried out by a combined device for guiding and circular sawing and a transfer tool that also allows guiding and clamping of the extruded profile. Both tools are operated by two six-axis industrial robots. The guiding units are mounted onto controllable additional axes [8].

The system is controlled by a numerical control that is supervising the individual controls of the industrial robots and guiding units. This way, the movements of all kinematics consisting of 23 axes are highly synchronous.

2.2. Path data compilation

The control data for the numerical control and the path data for both industrial robots and for the additional axes of the guiding units are created offline. The basis for the offline creation of the path data is a kinematic CAD model in the CAD program Catia V5. In this program, a CAD model of the profile to be manufactured manipulates the individual components of the model which are connected via kinematic constains. The model depicts the freedom of movement of the prototype installation. Coordinate systems are defined for every TCP of the robot in the model. The movement of the coordinate systems is registered relative to the initial positions of these coordinate systems. This path data can then be directly read by the robot control. The thermal expansion of the profile is already taken into consideration in this installation. For this purpose, the contour data which is available in the form of a CAD model of the profile is extended by a constant elongation factor. With a thermal expansion coefficient of 23 µm/K•m and at a production temperature of 400°C, for example, this means a change in length of approx. 8,7 mm/m [9].

3. Requirements

In order to ensure a high contour quality of the profile to be manufactured, the robot paths have to be exactly adjusted to the contour movement of the extruded profile. But during its production, the profile is subject to transient effects. The essential reason for this is the cooling of the profile that starts directly after its extrusion. As a consequence, a distortion of the profile occurs. This effect is reinforced even more by a variable cross section of the profile which is an extension of the installation presented at the beginning [6]. For the production of load-adjusted profiles, the wall thickness can be increased on one side over a defined length to twice its original thickness. In profiles with a one-sided thickening of the wall, a deflection occurs during cooling. This deflection of the profile is the result of the different temperature gradients when cooling profiles with locally thicker walls [7].

This problem cannot yet be taken into consideration in the current path creation. Therefore, this scientific paper presents an approach that takes a thermal distortion into account when creating the path data offline.

4. Approach for creating path data by taking thermal distortion into account

The approach of extending the path data creation includes the superimposing of correction values for the dynamic profile movement due to cooling onto the already existing path data. In order to consider the dynamic profile movement during the manufacturing process due to thermal distortion, correction values from a thermomechanical FEM simulation are added to the path data from the CAD simulation of the kinematics.

This is done by using a temporal and kinematic coupling. Figure 2 shows the connection.