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Fixtureless alignment of joining partners within the assembly of aluminum space frame structures

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Abstract

Light-weight aluminium space frame structures are frequently used for small-volume products, such as sports cars. The assembly of these products has so far been mainly manual and requires the use of complex and expensive fixtures. To increase the profitability, the research conducted at wbk Institute of Production Science is aiming to achieve an automated, fixtureless assembly of such structures by the use of industrial robots. To achieve the required accuracies regarding the alignment of the joining partners, a new approach based on component-inherent markings has been developed. This article describes the approach for the fixtureless positioning of components and the validation of the marking detection.

Keywords: Assembly; Automation; Flexibility; Alignment .

1. Introduction

The reduction of moving masses is of paramount importance for increasing energy efficiency of machinery, vehicles and equipment. Thus, lightweight designs will increasingly gain in importance. A possibility for weight reduction lays in the application of light supporting structures, such as for example aluminum space frame structures, which are already progressively used in the automobile and aviation industry [1-2]. At the same time, the automobile industry experiences a tendency towards considering individual customer demands. This leads to a greater diversity of variants and thus to a reduction of quantity [3-4].

Fully automated process chains that are able of producing various components without interruption are suitable for the cost-efficient production. For economic reasons, however, they are seldom applied when producing light supporting structures due to their lack of flexibility. Special devices or adapted machines are required for the assembly of space frame structures. Their application though is very expensive. To safeguard profitability, it needs to be done without those devices in the future. Therefore, the precise positioning of the joining partners in space constitutes a central challenge to the automated, flexible and to a great extent fixtureless assembly [5-7].

The precise positioning may be realized with flexible handling devices in combination with industrial robots. However, industrial robots do not operate precisely enough. They thus need to be supplemented by a measuring system for determining the exact position of the components to be joined. This scientific paper shall present a system for the fixtureless positioning of rotation-symmetrical components as well as its employability [8].

2. Requirements and state-of-the-art

Systems for the three-dimensional measurement and fixtureless alignment of joining partners must meet the following requirements [8]:

- For the assembly of space frame structures the position and orientation of several components must be measured and aligned in 6 degrees of freedom (x, y, z, A, B, C).
- Both, hardware and software must be useable for different components without requiring a machine

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changeover or adjustments of the algorithms for the evaluation of the measurement data in order to provide maximum flexibility.

- The measurement and alignment of the 6 degrees of freedom are also carried out for rotationally symmetrical components, such as tubes or balls.
- The alignment process must be fail-safe and should allow the alignment of joining partner without force application, if possible.

Approaches that would meet these or similar requirements for fixtureless assembly processes with industrial robots have already been defined. However, these approaches are generally limited to specific applications and offer only limited flexibility. Some of the most important approaches are presented in [9-12]. These approaches use optical measuring systems to measure the spatial location and orientation of the components. In most cases, the detection process for the components is based on the identification of characteristic features such as edges and bores. When the shape of the component is known, it is possible to define the spatial location and orientation of the component based on this knowledge. Rotation-symmetrical parts, such as spheres and all profiles with a circular cross section, do not possess any characteristic features that could be measured accurately for a determination of the component orientation. Therefore, these methods are unsuitable for these kinds of components. Furthermore, the flexibility of the method is limited because the algorithms used for measurement data evaluation and sometimes also the hardware must be adjusted whenever a new and different component is handled [13].

To sum up, the most suitable approach responds to the individual characteristics. However, there is no approach that fulfils the demands of a fixtureless assembly of rotation-symmetrical components.

3. Approach for the fixtureless positioning of components

The following shall present an approach that allows the exact positioning of aluminum extrusion profiles towards each other as fixtureless as possible. The profiles' exact positioning during the assembly process is achieved with a component inherent scale. This scale is applied onto the extruded section's surface with a special marking laser in previously defined intervals.

Figure 1 shows the procedure for aligning the profile. The components to be positioned are pre-arranged by an industrial robot. Afterwards, the markings are read with a stereo camera system and the positioning of the components towards each other is evaluated. The subsequent positioning of one component to another is precisely carried out by industrial robots. This process is repeated until the final joining position has been reached [1], [14-15].

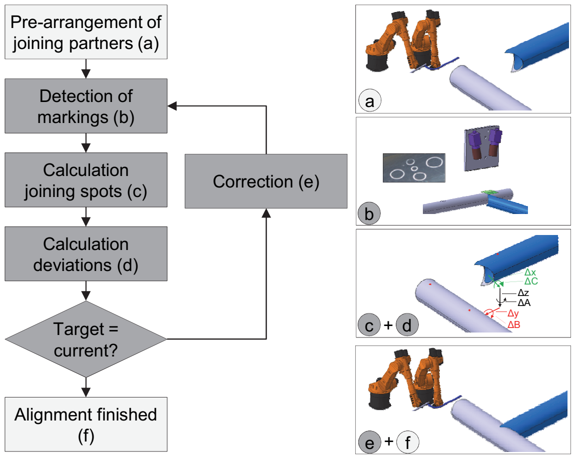

Fig. 1. Closed-loop system for three dimensional alignment of joining partners (6 DOF) with the target value of less than 0.1 mm in Matlab operation [8]

The following shall present the validation of the approach. For this purpose, the accuracy of the detection of the markings is determined first and the employability is derived from this value afterwards. Finally, the validation of the overall approach is presented.

4. Validation of the marking detection

In order to validate the process of the spatial arrangement of joining partners without any fixtures, the first step consists of performing a series of experiments to define the accuracy and the maximum coverage of the measuring system.

For the experiments, a stereo camera system was set up. The stereo camera system for the experiments is mounted on a five-axis micro-machine tool (figure 2). This installation allowed moving the components, on which the markings have been applied, and the measurement system relative to each other in a highly precise way. The markings for the experiments are applied on a plane and a round (radius 40 mm) aluminum part.