Product flexible car body fixtures with position-dependent load balancing based on finite element method in combination with methods of artificial intelligence

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Abstract

In car-body production, the fixtures used for fixing the car-body panels during the joining processes predominantly consist of rigid constructions that are precise and specific for one car-model. In addition to the already presented automatic adaptation of such fixtures, and specific for the production of many different car-models using same fixture, different clamping robots have been developed. In order to meet the high quality requirements, the positional deviations of these clamping robots are adjusted due to different external loads. This control loop is carried out using a combination of finite element method, mathematical algorithms and modern methods of artificial intelligence.

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1. Introduction

1.1. The motivation

Body shop equipment for series production of large quantities is characterized by a high level of automation - sometimes up to 98%. This percentage is achieved by using devices, fixtures and processes tailored to a single component. As a result, the equipment can only be used for this component and provides little flexibility. This means that on such a production line, only one specific component of a car model can be manufactured. A change in the car model mostly means that a new production line must be designed and installed. In some production lines, a certain level of product adaptability can be achieved by the exchange of component-specific fixtures and fixture parts. It is possible to produce two, three or, in certain cases, even more variants of defined car body parts. But even with this approach to greater product flexibility, component-specific fixtures are still required, demanding adequate storage space for exchanges. The area required for this inventory of fixtures conflicts with the space needed for the production itself and logistic processes.

The requirements for adaptability result from varying sales volumes or changes in the sales market, as well as an increasing number of individual customer demands. It is also the case that production changes for new products must be implemented at sustainably lower cost and higher efficiency to remain profitable in the future. Shorter production run times result in more frequent changeovers in production, and investments need to pay off more quickly. Retooling of the currently highly automated production equipment in the body shop is very time-consuming and expensive. At present, only approximately 30% of a car body shop’s equipment is retained when introducing a new model. [1; 2; 3]
1.2. The objective

The general objective in the widest sense is to retain up to 90% of the existing body shop equipment for the production of the next car model. The equipment in the body shop should also be adaptable to allow parts for several different car types to be produced on a line without changeover times. This is one reason to develop adaptable clamping fixtures, making it possible to produce car body parts using similar manufacturing procedures for different models on a single line without exchanging the clamping fixtures, thereby maintaining the same degree of automation, as well as to introduce new models into the existing line in running production. When developing adaptable clamping fixtures and modules, it is necessary to analyze and define the specific requirements in terms of installation space, working area, load suspension, stiffness values and the economic boundary conditions, and subsequently to intentionally implement them in approaches to adaptable body shop design.

1.3. The benefit

The development of kinematic mechanisms that offer clamping with more flexible positioning of component fixings is an essential step toward greater flexibility in the body shop’s production equipment. In this context, kinematic mechanisms for clamping mean that the commercially available car body tensioners or the position pins are situated on several travelling axes—as shown in Figure 2—rather than a rigid steel console. This way, the tensioners can be moved to various positions within a few seconds. The fixture represents a system of a number of clamping and positioning elements, each of which is situated on its own axes, on a base plate, for safe clamping of the components to be joined. The kinematic structures make it possible to create car body production lines independently of an individual model. The aim is to apply these almost model-independent kinematic clamping mechanisms to different fixtures in the body shop; thus, they follow the same manufacturing procedure and can be defined by a modular toolkit. One production line design to produce a specific car body part can thus be used from one model to the next, as well as at different manufacturing sites. Manufacturing components standardized in this way contribute to significant savings in both time for design and development and costs for a new production line or a new car body shop.

2. The approach to enhance flexibility

2.1. The development of adaptable flexible kinematic clamping systems

Figure 1 shows a current clamping fixture with many locally fixed car body tensioners locating and fixing the components to be joined with accuracy to a tenth of a millimeter.

The Fraunhofer IWU has developed clamping fixtures with 3- and 4-axis serial kinematic structures whose task is to move the tensioners flexibly within a predefined workspace and position them with repeat accuracy to a few hundred millimeters. With these tensioners, different components or car models can be clamped on the same clamping fixture. The development was primarily motivated by requirements for exact and reproducible positioning, specific load-bearing capacity, and an extremely slim design enabling more than 20 kinematic mechanisms to be aligned on the clamping fixture. Figure 2 shows a schematic view of a 3-axis serial kinematic mechanism with a simple design with the main loads applied to the clamping point (also called the Tool Center Point - TCP).

The kinematic mechanisms shown in Figure 2 do not provide the same stiffness as the steel consoles that are currently in use. This lower spring compression when subjected to substantial loads is expected to be compensated for by means of a model-based automatic control. The basic principle is first to record the reasons for the displacements—the external loads at each clamping point. The position-dependent clamping point dislocations are calculated by means of an FEA-based workspace model. The deviations are compensated for by means of the high-accuracy positioning drives of the kinematic axes.
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