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Mobile Assembly Units as Enabler for Changeable Assembly Lines

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Abstract

This paper presents a novel approach to guarantee changeability for assembly lines of an automobile manufacturer which involves the usage of the modular design of a mobile platform as basis for a wide-ranging portfolio of automated and partly-automated solutions within the final assembly. Using mobile platforms as basis for assembly units, production can react to a broad variety of foreseen and unforeseen changes (e.g. relocating the assembly unit, switching from cyclical to continuous flow production). The benefits of using these mobile assembly units enable the ability to react easily on various changes. In order to prove the possibility to react on foreseen and unforeseen changes, a variation of the degree of automation and also a change from cyclical to continuous flow production are demonstrated in a use case about seal-plug assembly with lightweight robots.

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1. Introduction

The ability to react on unforeseen environmental conditions e.g. demand fluctuations is inevitable for original equipment manufacturers (OEM) in order to succeed in a competitive setting. On the production level of an assembly line or of an underlying assembly station changeable production units and in particular reconfigurable assembly systems (RAS) are the keywords in this context [1]. Above all fixed and inflexible partly-automated and automated production units within the final assembly of cars make this task difficult. In order to reach the goal of an RAS the primary changeability enablers “automatibility”, “convertibility”, “scalability”, “mobility” and “modularity” have to be considered during the design process [1]. This paper is focused on proposing a solution to include these enablers in assembly units within the final assembly lines of an OEM by using a modularized, standardized and mobile platform.

Several RAS have been developed. As an example Onori et al. proposed a solution, where manual assembly stations can be extended gradually by automated and standardized assembly modules in the hyper flexible automatic assembly project (HFAA) [2, 3]. Furthermore, in [4] a moveable carrier for lightweight robots has been recently presented. However, with the named solutions it is hardly possible to face all challenges of a final assembly of a car manufacturer. One reason is for example that the systems are designed as static systems. Therewith it is difficult or even impossible to apply them to continuous flow production areas which are very common within automotive sector.

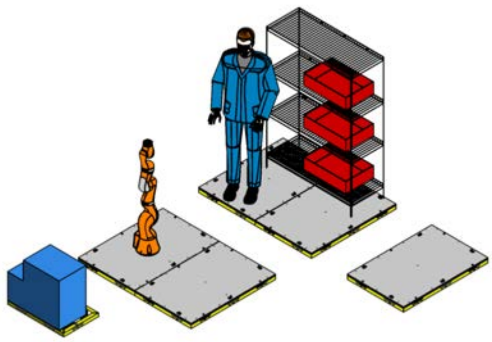

Fig. 1. Mobile and modular assembly units for changeable assembly lines.

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This paper presents a novel approach for an RAS considering the specific requirements resulting from different modes of production and degrees of automation of final car assembly. The central idea consists of creating different assembly units by combining mobile and standardized modules with fixed dimensions (see Fig. 1). For this purpose a cost-efficient mobile platform has been developed that can be built-up in a variety of geometrical configurations and can be extended by different modules (e.g. drive module, load module, etc.) for each application. The major advantage is the easy reconfiguration of the assembly units with these modules involving little effort and short time.

The main contribution of the presented paper is the proposal of an all new RAS. With the benefits of the system presented in the use case it is shown, that it is possible to react on various foreseen and unforeseen changes concerning the assembly line.

2. Previous Work and Research Gap

To make clear which research gap is envisaged to be closed by the proposed system an outline on RAS is given. Furthermore, current technological advances, which enable changeability for final assembly of cars, are presented.

2.1. RAS in Context of Changeable Production Systems

Meanwhile there is a very extensive literature on changeability. According to [1, 5, 6] changeability is an umbrella term for different classes of changeability which can be found on different hierarchical levels of production ranging from station level, where single part elements are machined, to production network level affecting the whole product portfolio. In this context an assembly line of a car manufacturer corresponds to the so called “system level” where flexibility and reconfigurability are the corresponding changeability classes. Flexibility describes logical changes like re-programming, re-routing and re-scheduling. In contrast to this, reconfigurability means physical changes of the structure of manufacturing processes like adding, removing or modifying machine modules [1].

There are two production paradigms addressing this definition of changeability, called reconfigurable manufacturing systems (RMS) and flexible manufacturing systems (FMS). The main difference between these two is the degree of flexibility. Contrarily to an RMS with a customized and limited flexibility, a FMS shows a general flexibility [7]. This high degree of flexibility is on the one hand an advantage and on the other hand also a major disadvantage of FMS due to the high costs caused by much built-in functionality [8, 9]. A reconfigurable assembly system can be characterized analogous to an RMS with its focus on assembly.

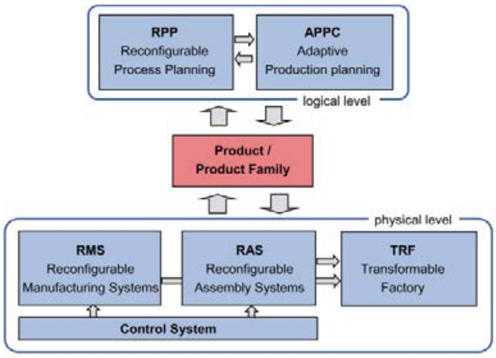

Fig. 2. Elements of changeable manufacturing [1].

Together with RMS and a transformable factory (TRF) RAS build the physical level of a changeable manufacturing (see Fig. 2). In order to design a changeable assembly several change enablers have to be considered. These are modularity, scalability, convertibility, mobility and automatibility. A special focus is on mobility to allow the reconfiguration and relocation of modules or the whole system. Furthermore automatibility is important in order to react to different factors like production rate or wage level [1, 6]. Bi et al. give in [10] an extensive overview of RAS and design guidelines.

Different RAS solutions are described in literature [11, 12, 13, 14]. These contributions address solutions for the assembly of workpieces of relative small dimensions and scope which can be handled by small transfer systems. Major research takes place in the field of modularization methods of changeable production systems [15, 16, 17, 18, 19]. This also emphasizes the importance of modularity to reconfigurable systems. All these proposals are either not applicable in final car assembly because of the small dimensions of the workpiece or are very generic approaches that cannot be easily adapted.

2.2. Technological Advances for Final Assembly of Cars

There are several technological advances which are beneficial for final assembly of cars. One major point is human-robot-collaboration with small sensitive robots like the lightweight robot published in [20]. Their ability of cooperating with workers allows the application without any safety fences. Based on this and because of their low weight and small dimensions robots like these are predestinated for the application in an RAS. A theoretical approach called “robot farming” is published in [21] where several robots are operated, maintained and relocated by one single worker. This idea is supported by systems like a mobile vehicle, where the robot, its controller and some periphery are mounted [4]. This vehicle can easily be relocated by simply moving it manually. A more sophisticated approach is presented with an automated guided vehicle named “rob@work”, which can semi-autonomously relocate the robot [22]. The number of applications of sensitive (and mobile) robots increases steadily.