ReconCell workcell design

MARTIN BEM
BARRY RIDGE

Jožef Stefan Institute

1. Introduction

Constantly increasing competition and pricing pressures in industry lead to an intensified demand for higher productivity and shorter time-to-market strategies [1]. Rising diversity, model variety and shorter life cycle times require more flexible production plants. This leads to an intensified demand for new production concepts. Current robotized plant concepts are characterized by flexible robot systems with the possibility of exchanging tooling systems. The tooling systems themselves can also be made flexible [2]. However, the peripheral elements are still inflexible. In order to better cope with the issues described above, the ReconCell project was started. The goal is to introduce innovative concepts such as flexibility, modularity and reconfigurability to robot cell periphery. These solutions are intended for use by small and medium sized enterprises (SMEs) so affordability is also a key issue.

2. Innovative ReconCell concepts

1.1. Reconfigurable fixtures

Currently, fixture systems are designed for a certain workpiece or piece family and precisely defined manufacturing processes. Improvements can therefore be achieved by the introduction of flexible fixtures capable of securely locating a variety of workpieces, thus lowering the cost and changeover times.

To achieve this, ReconCell workcell uses reconfigurable fixtures called hexapods that are based on extensive prior research [3]. Some crucial parts of the hexapods, i. e. joints, are currently in the process of being patented by the Jožef Stefan Institute (JSI). Such systems have never been used before for the assembly of automotive lights (one of the use cases).

Hexapods are passive Gough-Stewart platforms with six degrees of freedom (three translatory and three rotational). They are composed of an upper and a lower plate connected by six links. The lower plate is fixed to the robot workcell while the position and orientation of the upper plate is reconfigurable. The upper plate serves as a platform for clamps or supports (described in detail the next chapter) that hold the actual workpiece in place during robotic operations. The hexapod prototype is composed of standard elements. No position measuring equipment or actuators are used. The reconfiguration can be performed manually or by an external mechanism, e. g. a robot.

To fix the required position, a special brake, integrated in each of the six links, is used. The locking force is provided by an internal hydro-mechanical system. An air-oil pressure intensifier is used as an interface between pneumatic and hydraulic subsystems. For safety reasons, the brakes are normally locked while no external pneumatic pressure is being applied.

1.2. Hexapod mounted clamps and supports

To comply with the flexible approach, the clamps and supports used in the ReconCell workcell have to adapt to different parts in a product family. For the automotive light industry, JSI developed a special clamping system. It is used to precisely locate and hold in place different models of car light housings during robotic assembly. The clamping and supporting system are mounted on the hexapod's top plate.

On each model, two mounting holes are used as clamping points. Each model has different diameters and relative positions of the mounting holes. Centering pins are used to locate the mounting holes precisely. The housing is held in place by pneumatic clamps. The mounting hole clamping is shown on Figure 1.

Additionally, the light housings are supported by seating the central hole on an appropriate central support shaft (without any clamping). Central hole diameters differ between models. Central support is shown in Figure 2.

Central supports as well as centering pins are exchangeable by robot to enable different models of light housings to be positioned precisely. Locators are inserted in a bushing and held in place by a ball and spring plunger. The robot can grasp and replace them using a parallel gripper with specially developed fingers.

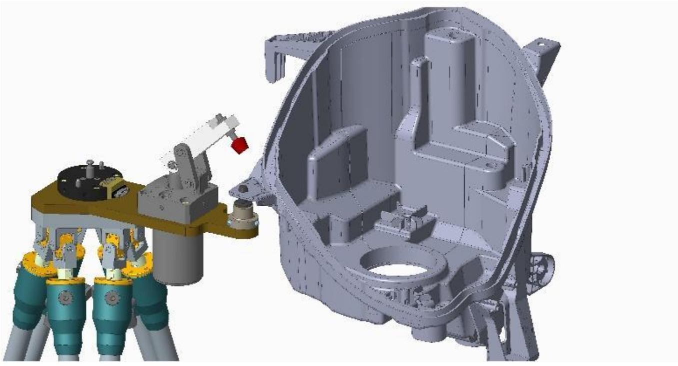

Figure 1: Mounting hole clamp

Figure 2: Central support

The change in position of the clamping (and central support) points is achieved by reconfiguring the hexapod. To make the reconfiguration automatic, the clamping and central support system is equipped with a robot tool changer. The tip of the robot can be connected to the tool changer in order to move the hexapod. This enables the fixtures to be reconfigured without human intervention. The implementation of reconfigurable fixtures for light housing assembly is shown in Figure 3.

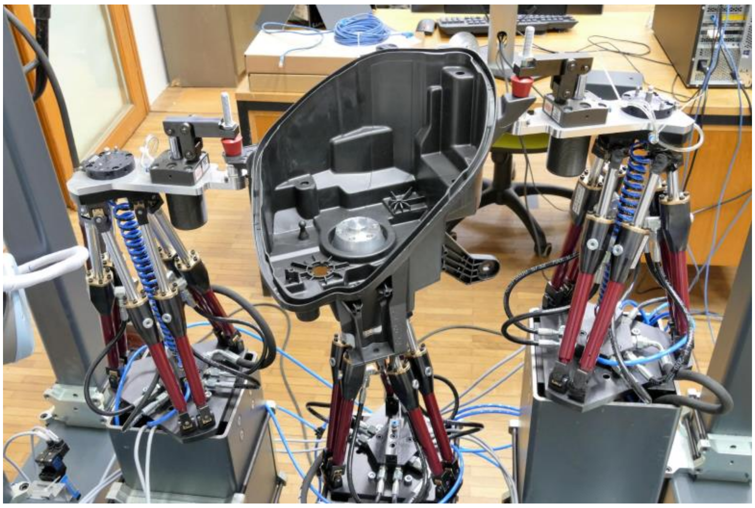

Figure 3:Use of reconfigurable fixtures for light housing assembly

1.3. Reconfigurable frame

The frame of the robotic workcell is the structure that connects the robot with peripheral modules. It must be as stiff as possible because even small frame deformations can cause errors in the position and orientation of the robot end-effector. This can result in failures that impair throughput rate and product quality. However, when a change in the production process occurs, changes should be made simply, efficiently and affordably. This flexibility means that most of the workcell can be kept intact and just the necessary additional components can be added or the existing ones reconfigured.

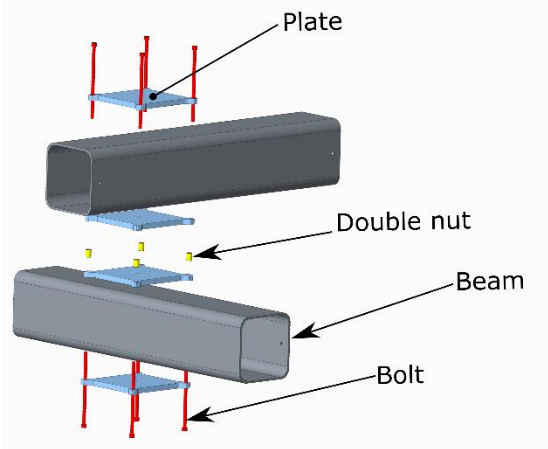

Figure 4: BoxJoint double box exploded view

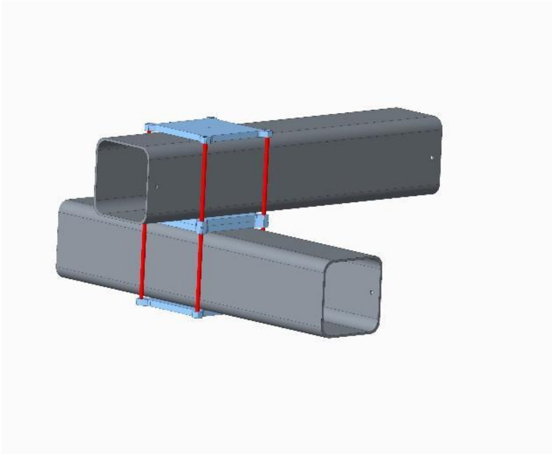
Figure 5: BoxJoint double box

To comply with the above mentioned requirements, the ReconCell workcell frame was made of square steel beams connected with the BoxJoint joints [4]. They use metal plates, nuts and bolts to connect rectangular beams of different sizes together. The use of metal beams and BoxJoint connectors results in a stiff frame structure. The frame is easy and quick to assemble as no welding is required. All BoxJoint joints are disassemblable which means that in case the design changes, all material (BoxJoints and beams) can be reused. Figures 4 and 5 show an example of a BoxJoint joint.

1.4. End-effector hanger module

Robots in the ReconCell workcell use tool changers to quickly and efficiently change end effectors. To store disused ones, a custom made hanger module was developed by JSI. It is made of a cut plate of steel sheet and uses two centering pins to accurately position the end effector during storage. The centering pins minimize the chance of accidentally dropping an end effector as well. The hanger can be attached to an arbitrary beam using a BoxJoint plate, nuts and bolts. The designed end-effector used in the ReconCell workcell is shown in Figures 6 and 7.

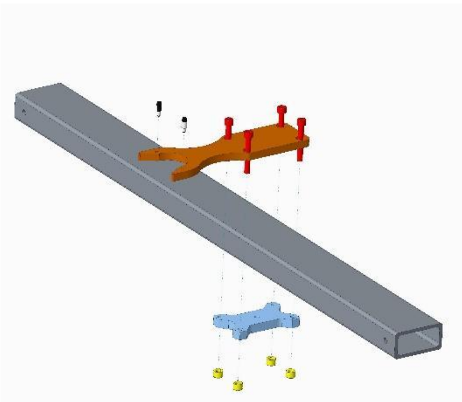
Figure 6: End-effector hanger module exploded

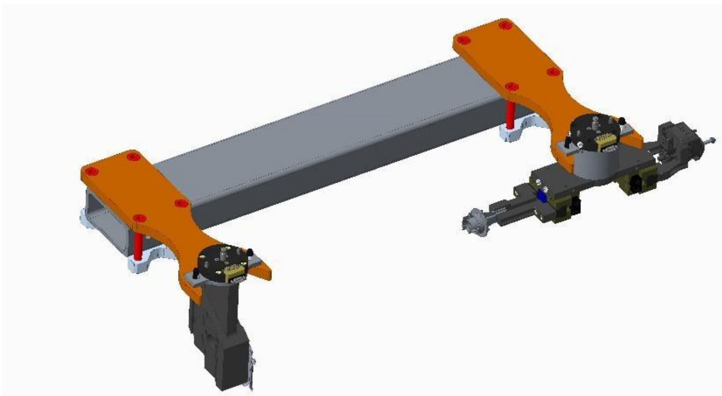
Figure 7: End-effector hanger module storing different end effecotrs

1.5. Plug & Produce

The term “plug-and-play” carries an expectation of ease of use and reliable, foolproof operation. The practical extension of plug-and-play products, when applied to industrial automation, has given way to the new term: plug-and-produce (P&P).

Plug-and-produce offers a practical solution to the issues of increasing competition in the global marketplace, which demands flexibility, as well as higher resource and energy efficiencies in the way in which goods are produced. As companies work to get products to market faster and cheaper, simple solutions are needed to enable near-immediate implementation – with no special tools or highly trained engineers or electricians required [5].

The key component for the implementation of P&P in the ReconCell workcell is the P&P connector. No viable commercially available connector was found so the connector was developed by Precizika Metal (PRZM), one of the ReconCell industrial partners. In the ReconCell project the P&P connector is used to connect peripheral application-specific modules to the main cell. The connector transmits power to, and provides pneumatics and Ethernet connections for, the peripheral modules, as well as providing mechanical coupling. Once the peripheral module is connected it is ready to use.

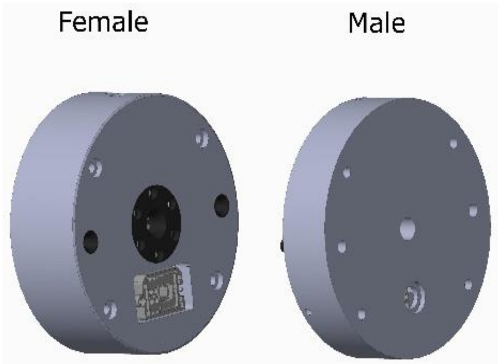

Figure 8: Plug & Produce connector

Modules include reconfigurable jigs, trolleys with assembly components, trolleys with end effectors, robotic screwdrivers etc.. Although not officially envisioned in the ReconCell project, all peripheral modules will be equipped with smart functionality and will communicate via the industrial internet of things (IIoT). The implementation of the P&P connector to connect a trolley to assembly components is shown in Figure 9.

Figure 9: Plug and produce connector implementation

1.6. Passive linear unit

Linear units increase the robot's work envelope significantly. Commonly used linear units are actuated, and therefore expensive. They are useful when there is a need for high precision and frequent robot base motion.

In order to avoid high costs, ReconCell workcell uses a passive linear unit proposed and implemented by JSI. The motion of the linear unit is achieved by using the robot's own actuators. To further reduce cost, the unit uses no measuring equipment. It works by attaching the tip of the robot to a known position of the frame using the tool changer. The robot can then move its base once the brakes are released. To determine the position of the base, direct kinematics are used. The linear unit is designed as an independent peripheral module. A P&P connector is used to connect it to the main cell. Such a system has never been implemented before and is currently in the process of being patented by JSI. The design is shown in Figure 10.

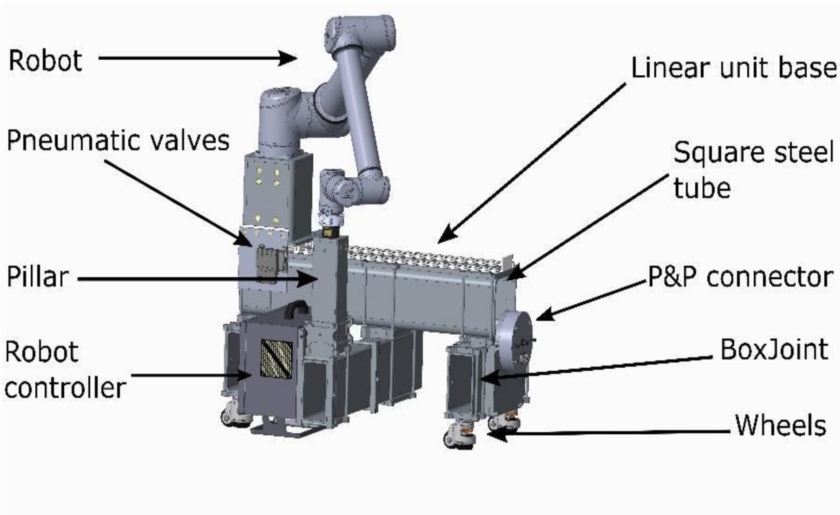

Figure 10: Passive linear unit

3. Concept implementation

As part of the ReconCell project, innovative concepts will be used to solve different use cases. The use cases come from different industrial backgrounds as part of the proof-of-concept to demonstrate that the ReconCell workcell is able to change its functionality quickly and efficiently. Figure 11 shows the ReconCell workcell configured for car light assembly.

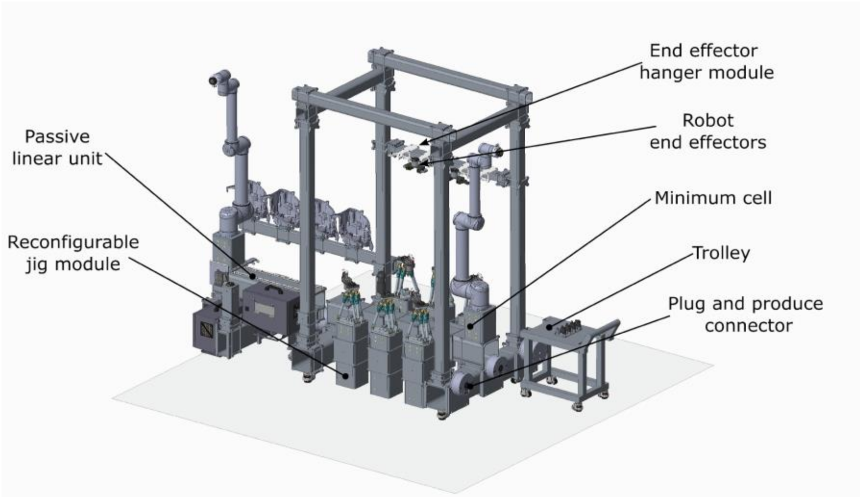

Figure 11: ReconCell cell configured for car light assembly

4. Conclusions

The innovative concepts of ReconCell project have shown great potential in making robotic cells modular and reconfigurable. Currently we have evaluated the cell's feasibility on the automotive light assembly use case. The cell shows great potential as different models of lights can be produced on the same cell. The reconfiguration between models requires no human intervention and can be performed in a short period of time.

The full potential of the ReconCell workcell will be known once other use cases from different backgrounds are implemented. The most important aspect will be the reconfiguration time from one use case to another. The main goal is to prove that the reconfiguration, although manual, can be done efficiently, in a short time, with no special tools or expertise. This would make robotic solutions feasible for small and medium sized enterprises, as they produce a high variety of products in relatively low volumes.

References:

[1]. Frank. "Fertigungstechnik gestern, heute, morgen". In: Technik Report 3 (1994), 39-42.
[2]. Kovač, M. Gödl, et. al. "Flexible stacking robot Octopus 350-400". In: BTF Concrete plant + Precast Technology 70.4 (1994), 22-28
[3]. H. Trantin, I. Kovač, A. Frank, and M. Szaniawski. "Robot guided reconfiguration in the car body assembly". In: International Conference on Changeable, Agile, Reconfigurable and Virtual Production (2009).
[4]. boxjoint.se, 'BoxJoint products',http://www.boxjoint.se/boxjoint/BoxJoint_Plates.html. 5.1.2017.
[5]. T. Schoepf. Plug-and-Produce is Key for the Smart Factory of the Future - Part 1. http://www.belden.com/blog/industrialethernet/Plug-and-Produce-is-Key-for-the-Smart-Factory-of-the-Future-Part-1.cfm. Accessed: 2016-31-10.