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**Safe Assembly Cell Layout through risk assessment – An Application with
Hand Guided Industrial Robot**

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Abstract

Risk assessment is a systematic and iterative process which involves risk analysis where the probable hazards are identified and corresponding risks are evaluated along with solutions to mitigate the effect of these risks. In this article the outcome of a risk assessment process will be detailed where a large industrial robot is being used as a intelligent and flexible lifting tool that can aid operators in assembly tasks. The realization of a collaborative assembly station has several benefits such as increased productivity and improved ergonomic work environment. The article will detail the design of the layout of a collaborative assembly cell which takes into account the safety and productivity concerns of automotive assembly plants.

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1. Introduction

Recent advances in industrial robot design, control systems as well as sensor technologies have made it possible for industrial robots to be used safely within final assembly lines [1,2]. Such an application of industrial robots are referred to as collaborative assembly and are expected to enable manufacturing flexibility[3,4] as well as improve the ergonomic work environment [5] of operators. The functional principle of collaborative assembly is to combine the characteristics of industrial robots with the superior cognitive and decision making skills of the operator with the aim of efficiently completing assembly tasks.

Large industrial robots can carry higher payload and have longer reach than robots specifically designed for collaborative work such as UR10 [6] or Kuka Iiwa [7]. These physical characteristics coupled with the possibility to work without physical barriers broadens the possibility of application of these robots. However, such robots pose serious risk resulting in injury [8–10]. To ensure a safe work environment, International safety standards [11–13] suggest that a detailed risk assessment be carried out to mitigate risks through inherent safe design or through risk reduction measures.

Risk Assessment is a structured and detailed process of

identifying hazard, estimating the risk and recommending effective solutions to mitigate the risks. This article aims to detail the final design of a collaborative assembly cell which is the outcome of an extensive risk assessment process. The risk assessment is focused on an assembly cell where the task is the installation of a flywheel housing cover on a heavy vehicle engine.

This article is structured as follows. In section 4, an overall description of the methodology used to conduct the research will be presented along with limitations for the analysis and will be based on a theoretical description elaborated in section 2. A brief description of a manual assembly station will be made in section 3 and a detailed description of the layout of the collaborative assembly station in section 5. The design choices will be further discussed in section 6 and will conclude by highlighting the role of standards in the overall design of the layout.

2. Theoretical Background

Cognitive skill such as hand-eye coordination has been cited as the main reason for the low level of automation within automotive assembly lines. Within the context of an assembly station, a robotic cell can include one or more

robots and associated machinery designed with the purpose of completing assembly tasks [12]. When the nature of the task is unergonomic and repetitive, an operator can benefit with an industrial robot to help with carrying out such tasks, and such an assembly station is called a collaborative assembly station. In this respect, a collaborative assembly cell (fig. 1) is a predefined workspace for participants (operators, robots, other integrated machinery) to complete tasks [14].

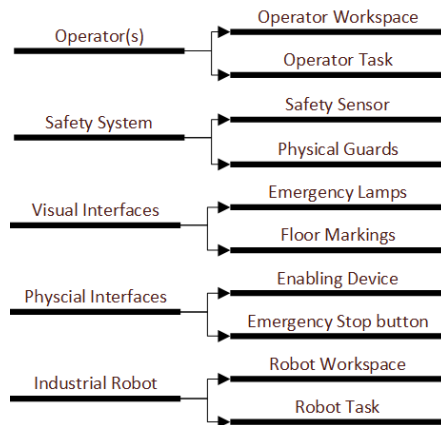


Fig. 1: Elements of a collaborative robotic workstation.

2.1. Risk Assessment & Risk Reduction

Introduction of a robot into a manual assembly cell brings forth additional hazards whose potential to cause harm needs to be eliminated or minimized [11,12,15]. The machinery safety standard [15] suggest the practice of conducting risk assessment coupled with risk reduction measures to ensure the safety of the operator. Risk assessment is an iterative process of risk analysis following by risk evaluation. The risk analysis process consists of determining the limits of the machinery, identifying hazards along with an estimation of risk associated with the hazards.

The risk evaluation process aims to determine if a risk reduction is required and if so, propose safety-rated solutions as measures to eliminate or mitigate the risks. To effectively manage risks, the designer has the choice of implementing safe solutions through three steps: 1. Inherently safe design measures 2. Safeguarding and/or complementary protective measures 3. Information for use.

The risk assessment process is an iterative process that concludes when all probable hazards have been identified along solutions to mitigate the effects of these hazards have been implemented. There exists standardized practises to document the process such as [16], which also proposes that risk assessors, designers and users (operators, maintenance, line managers) with various expertise in the risk assessment process.

2.2. Robot and robotic system safety

Robot safety standards recognises the implementation of one or more of the following four different modes of collaborative operation 1. Safety rated monitored stop. 2. Hand Guiding 3. Speed and separation monitoring 4. Power and force limiting



Fig. 2: Examples of safety equipment. The SICK scanner [20] is able to monitor multiple planar zones. The RecR [21] (right) laser curtains consisting of an emitter and receiver is able to monitor a planar region and is used to detect full/partial body (hands) intrusions.

These modes are in addition to the automatic mode, where the robot is moving along a preprogrammed path within a predefined robot workspace. Within the collaborative workspace – where the operator and the robot can collaborate to complete tasks – needs to be monitored as there is a high risk for hazards. To assist in the risk assessment, the standards specifies the performance requirements for the robot as well as the equipment such as safety-rated stop and contact force limitation [11–13].

2.3. Sensitive protective Equipment (SPE)

For industrial applications, the selection, positioning, configuration and commissioning of sensitive protective equipment (SPE) has been detailed in [17], and aims to define the performance requirements for these equipment. They include provisions for two specific types 1. Electro-Sensitive protective Equipment (ESPE) and 2. Pressure-Sensitive protective Equipment (PSPE). . These are to be used mainly for the detection of the presence of human beings and can be used as part of the safety-related system [17,18].

The IEC 62046 also states the performance requirements for the SPE in terms of performance level (PL) with a rating ranging a to e. The SPE such as a laser scanner will correspond to a specific performance level and therefore, the selection of the equipment depends on the the application. SPE are designed to monitor a predefined space and needs to be triggered for the hazardous machine to be shut down or stopped. Therefore, the positioning and installation dictates a minimum distance that needs to maintained from the hazardous zone. The reasoning being the safety system takes time to activate (also referred to as *response time* and take necessary evasive procedure.

As noted by [18], when triggered, these sensor use electrical safety signals and include laser curtains (fig. 2 (right)), laser scanners (fig. 2 (left)) and vision based safety systems such as the SafetyEye [19]. Compared to a physical fence, where the operators and the machinery are physically separated, ESPE relies on the human being to occupy a predefined zone for the sensor to be triggered.

Pressure-Sensitive Protective Equipment (PSPE) have been standardized in part 1 to 3 of ISO13856 [22–24], and works on the principle of an operator physically engaging a specific part of the workstation. These include 1. ISO 13856-1 – Pressure

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