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Procedia CIRP 44 (2016) 199 – 203

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6th CIRP Conference on Assembly Technologies and Systems (CATS)

Risk Assessment Process for Collaborative Assembly – A Job Safety Analysis Approach

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Abstract

International safety standards state that risk assessment is the first step in understanding and eliminating hazardous work environment. The traditional method of risk assessment using Job Safety Analysis, where sequential tasks of the operator are analysed for potential risks, needs to be adapted to applications where humans and robots collaborate to complete assembly tasks. This article proposes a novel approach by placing equal emphasis on various participants working within their workspaces. An industrial case study wil be used to showcase the merits of the process when used at an early stage in the development of a collaborative assembly cell.

Peer-review under responsibility of the organizing committee of the 6th CIRP Conference on Assembly Technologies and Systems (CATS)
Keywords: Human Robot Collaboration; Risk Assessment; Safety Standards; Collaborative Assembly

1. Introduction

A safe collaborative assembly cell, where operators and industrial robots collaborate to complete assembly tasks is seen as an important technological solution [1,2] for several reasons including: 1. The ability to adapt to market fluctuations. [3]. 2. Improve productivity and 3. Improve ergonomic work environment [4].

Operator safety is an important source of concern for collaborative assembly as impact with a moving robot can cause serious injury. According to the International safety standard, risk assessment is the first step in understanding and eliminating hazardous work environment [5,6]. For non-collaborative robotic cells, risk assessment were carried out with the understanding that robots and operators do not interact. That is, a robots can only be operated in the automatic mode within a designated workspace and intrusion should result in a monitored stop of the robot. Physical barriers such as safety fences were used to ensure operator safety by avoiding the possibility for collision.

In practice, collaborative robotic assembly system seeks to remove these barriers to enable closer interactions between operators and robots, Therefore, risk assessment should consider both operators and robots as valid participants to ensure safety of operators and productivity of the assembly station. With a focus on operator safety, international safety standards defines the use of collaborative task only within a predefined work area called the collaborative workspace [6].

To ensure safety and enable task sharing, safety standards require that the assembly cell is continuously monitored during execution of the task. Therefore, the motion of the robot and the operator within the assembly cell must be monitored using safety sensors [7]. such as vision system, safety mats, proximity sensors, etc.

Before safety devices are selected and installed, a systematic risk assessment will ensure that appropriate devices and procedures are implemented [8]. Additionally, risk assessment can also be used to ensure compliance with various regulatory bodies.

This article presents a work process for risk assessment that emphasizes on the interactions between the operator, robot and the work environment (See Fig:1). As collisions are a major cause of injury and damage [8–10] the article explores the methodology of Job Safety Analysis to dissect an assembly task into subtasks and critically analyse subtasks for hazards and suggest solutions for perceived risks.

This article is structured as follows. Section 2 examines the state of the art that focusses on risk assessment methodologies of robotic systems and will also detail some of the relevant robotic and machinery safety standards. Section 3 provides a generic overview of a collaborative assembly cell in terms of the participants involved, their tasks within the assembly cell and the workspace allocated to complete the tasks. Section 2 and 3 forms the basis for the proposed risk assessment process

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doi:10.1016/j.procir.2016.02.334

which will be described in section 4. Section 5 will briefly detail an industrial case study where the task is to assemble a flywheel housing cover. Also, a detailed description of the application of the assessment process (section 5.1) will show how the design and safety requirements were acquired through this process which resulted in a tool for safely hand-guiding an industrial robot.

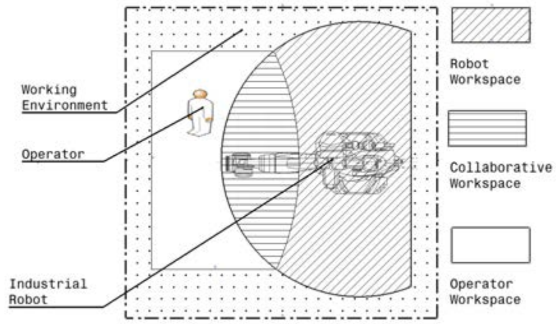

Fig. 1: Illustration of the interaction between the three participants of a collaborative assembly cell within their corresponding workspaces.

2. State Of The Art

Academic literature describes various methods to conduct risk analysis for robotic systems which can be broadly described as quantitative and qualitative. Dhillon & Fashandi [9] and Etherton [8,10] has outlined a few of the commonly used risk analysis methods for robotic systems though Dhillon & Fashandi focuses on Fault-Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA) as relevant methods in their article. Etherton refers to Job Safety Analysis for conducting risk assessment in application areas where operator tasks have to be considered.

The quantitative Fault-Tree Analysis require probabilistic information about occurrence of failure, which can then be used to calculate a combination of fault-events that could lead to a robot related accident. The qualitative Failure Mode and Effect analysis is used to understand and document all possible failures (and its effects) so that corrective actions can be suggested to mitigate the sources of failure. FMEA uses a tabular form to document each failure mode and its effect along with the probability of failure and possible solution.

Compared to Job Safety Analysis (JSA), FMEA and FTA are higher fidelity analysis methods as the basic requirement for their usage is that information of possible risk must be known beforehand. Therefore, for the development of new collaborative assembly cells, these methods are not immediately applicable, though they are widely used when information of the risks are known or can be better estimated. In addition, these methods do not consider task that has to be performed and therefore Job Safety Analysis [8,10] is a better choice to conduct risk assessment. Job Safety Analysis aims to break down an assembly task into subtasks. The procedure is to analyse the subtasks for hazards and suggest methods or procedure to reduce or nullify the effects of these hazards.

Industrial machinery and their use within a manufacturing plant are required to adhere to safety standards. Collaborative assembly brings forth additional risks that arise when operators and robots have to work together. Risk assessment methodologies should allow for the possibility of arriving at solutions that meets the requirement of safety standards, some of which are:

1. General machinery such as end effectors, external actuation, power delivery are expected to follow the Machinery standard – *SS-ISO 12100:2010 – Safety of Machinery – General principles of Design – Risk assessment and risk reduction (ISO 12100:2010)* [5]. The standard defines and lists out the requirements and procedure to conduct risk assessment.

2. Industrial robot safety design are governed by part one of *SS-ISO 10218-1:2011 – Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots*[6]. This standard focusses on safety requirements of manipulators and therefore is targeted at robot manufacturers whereas part two of *Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration* is focussed on robotic system integrators [11] .

3. The newly released ISO/TS 15066 *Robots and robotic devices – Collaborative robots* [12] specifies requirements for collaborative industrial robot systems and the work environment. This Technical specification is intended to act as supplement to the Industrial robot safety standards.

3. Collaborative Assembly Cell

In this section, a collaborative assembly cell will be characterized in terms of the tasks that will be performed, the participants that are responsible for the tasks and the workspace to complete the task. The main purpose of describing an assembly cell in terms of tasks and participants is to map the interactions between them (See Figure: 1).

3.1. Workspace in a Collaborative Cell

International safety standards suggest the following workspaces for a collaborative assembly cell [6,13]:

1. **Robot Workspace:** Within the robot workspace, an industrial robot can be programmed to move in automatic mode at rated speed and must stop if the there is an intrusion. Traditionally, the robot workspace is closed off from external interaction using physical fences or safeguards [6].

2. **Operator Workspace:** The area assigned to the operator to do his task can be termed as operator workspace and can be monitored for safety with corresponding reduction of speed if the operator goes near the robot and complete stop if the operator is close to the robot to warrant a complete stop.

3. **Collaborative Workspace:** The collaborative workspace allows the robot and the operator to work together, which means that the robot and operator share a common workspace. The nature of assembly task is described in