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Implementation of Job Safety Analysis at Workplace Assembly

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***Abstract* – International safety standards stipulate that risk assessment is the first step to understand and eliminate hazardous working environments. The traditional risk assessment method using workplace safety analysis, which analyzes potential risks in the sequential tasks of workers, can be adapted to applications where humans and robots work together to complete assembly tasks. In this article, we propose a new approach that takes into account equally the different participants working in each working area. Using an industrial case study, we demonstrate the process used in the early stages of the development of a collaborative assembly cell.**

***Keywords* – Risk Assessment, Safety Standards, Assembly, Job Safety**

I. INTRODUCTION

Safe collaborative assembly cells, where workers and industrial robots work together to complete assembly tasks, are considered an important technological solution for several reasons [1,2]: 1. Ability to adapt to market fluctuations. [3] 2. Increase productivity, and 3. Improve the ergonomic working environment [4]. Operator safety is a major concern in collaborative assembly, as impacts with a moving robot can result in serious injuries. According to international safety standards, a risk assessment is the first step to understand and eliminate hazardous working environments [5, 6]. For the non-collaborative robot cell, the risk assessment was performed assuming that the robot and the operator do not interact, i.e. the robot can only operate in an automatic mode within a specific working area and a supervised robot must stop in case of intrusion. To avoid possible collisions and ensure the safety of the operator, physical barriers such as safety fences were used. In practice, collaborative robot assembly systems try to eliminate these barriers to allow for closer interaction between the operator and the robot. Therefore, to ensure the safety of the operator and the productivity of the assembly station, both the operator and the robot must be considered as valid participants in the risk assessment. With a focus on operator safety, international safety standards define that collaboration should only take place within a predefined workspace, the so-called collaborative space [6]. To ensure safety and enable task sharing, safety standards require that the assembly cell be continuously monitored during the execution of tasks. Therefore, the movements of the robot and the workers in the assembly cell must be monitored using safety sensors [7]. Examples like: vision systems, safety mats, proximity sensors, etc. Before selecting and installing safety devices, a systematic risk assessment ensures that the right equipment and procedures are in place [8]. Furthermore, risk assessment can also be used to ensure compliance with various regulatory authorities. In this article, we present a work process of risk assessment. Emphasis is placed on the interaction between the operator, the robot and the work environment (see Fig. 1). Since collisions are one of the main causes of injuries and damages [8–10], this paper presents a methodology of occupational safety analysis for performing assembly tasks decomposing them into subtasks, critically analyzing the hazards of the subtasks and proposing solutions to the recognized risks. This article is structured as follows: Section 2 provides an overview of the state of the art on risk assessment methods, robotic systems and some related robot and machine safety standards. Section 3 provides a general overview of the collaborative assembly cell, including the participants, their duties within the assembly cell and the assigned work areas to perform the tasks. Sections 2 and 3 form the basis for the proposed risk assessment process described in Section 4. Section 5 presents an industrial case study, in which a flywheel housing cover is installed. Furthermore, the application of the evaluation process (Section 5.1) how this process determines the design and safety requirements which has become a tool for the safe manual guidance of industrial robots.

II. REVIEW OF LITERATURE

The literature describes various methods for conducting risk analysis of robotic systems, which can be roughly classified as quantitative and qualitative. Dhillon & Fashandi [9] and Etherton [8,10] discuss some of the commonly used risk analysis techniques for robotic systems, and Dhillon & Fashandi, in their paper, mention fault tree analysis (FTA) and failure mode and effect analysis (FMEA) as related methods converge. Etherton refers to workplace safety analysis when conducting risk assessments in application areas where the operator's tasks must be considered. Quantitative fault tree analysis requires probability information about the occurrence of failures, which can be used to calculate the combinations of failure events that may lead to a robot accident. Qualitative failure mode and effect analysis is used to understand and document all possible failures (and their effects) and to suggest corrective actions to mitigate the causes of failures. FMEA uses a tabular format to document each failure mode and its effects, as well as the probability of failure and possible solutions. FMEA and FTA are more precise analysis methods compared to Job Safety Analysis (JSA), since the fundamental requirement is to know in advance information about possible risks. Therefore, these methods are often used when information about risks is known or can be better evaluated, but cannot be directly applied to the development of new joint assembly cells. Moreover, these methods do not take into account the tasks to be performed, so Job Safety Analysis [8,10] is more suitable to carry out risk assessment. Job Safety Analysis aims to divide the assembly task into subtasks. This procedure consists of analyzing the hazards of the subtasks and proposing methods and procedures to reduce or eliminate the impact of these hazards. Industrial machines and their use in manufacturing plants must comply with safety standards. In collaborative assembly, additional risks arise when the operator and the robot have to work together. Risk assessment methods must provide the possibility of finding solutions that meet the requirements of safety standards. Some of them are: 1. General machines, such as end effectors, external actuation, power transmission, etc., are covered by the machinery standard SS-ISO 12100: 2010 - Safety of machinery - General principles for design - Risk assessment and risk reduction (ISO 12100: 2010) [5]. This standard defines and lists the requirements and procedures for performing risk assessments.2. The safety design of industrial robots is specified in Part 1 of SS-ISO 10218-1:2011 "Robots and robotic devices - Safety requirements for industrial robots - Part 1: Robots" [6]. This standard focuses on the safety requirements of manipulators and is therefore aimed at robot manufacturers, while Part 2 of Robots and robotic devices - Safety requirements for industrial robots - Part 2: Robot systems and integration is aimed at robot system integrators [11]. 3. The newly published standard ISO/TS 15066 Robots and robotic devices - Collaborative robots[12] specifies requirements for collaborative industrial robot systems and working environments. This technical specification is intended to complement safety standards for industrial robots.

III. METHODOLOGY FOR JOB SAFETY ANALYSIS OF ASSEMBLY CELL

Other factors that aid in hazard analysis and engineering include the CAS (Chemical Abstract Service) number (110-54-3). This number can be used to find jobs and accidents involving hexane. For example, CAS numbers can be entered into the search engine with the desired physical properties and shorten the time required to find properties such as viscosity (0.31 mPa•s).

Another section, 14, provides marketing information. This is the international standard that is proposed to be installed on hexane transport trucks. It is red, and stands for diamond.

The word "flammable water" is used in the native language of the country.

For example, in Spanish, "láquido inflammable" is under the fire symbol.

In addition, four common pictures appear on hexane safety data sheets, such as Figure 1. OSHA's new guidance on hazard communication provides some information about pictures.

Pictograms are a set of graphics that can include symbols and other graphic elements such as borders and background colors. Pictograms are communication tools designed to convey a specific message. The proposed law includes requirements for the use of eight different pictures. Each picture contains a different black symbol on a white background that is inside a red square somewhere (ie, a red diamond). The specific picture of the label is determined by the hazard classification of the substance. OSHA has found sufficient evidence to support the pictorial requirement.

A long-standing requirement of the GHS is the use of pictures as a quick way to communicate information about diseases associated with chemical substances. As shown in Figure 3, the first picture on the left indicates that n-hexane has one of the following properties: flammable, self-reactive, self-igniting, and self-heating , release flammable gas or carbon peroxide. In this case, n-hexane is flammable. The second picture from the left represents a substance that exhibits one of the following properties: carcinogenicity, respiratory sensitization, reproductive toxicity, organ toxicity, mutagenicity, or inhalation toxicity. If n-hexane is used, breathing problems may occur. The third picture from the left represents a substance that exhibits one of the following properties: irritation, skin sensitivity, acute toxicity (danger), narcotic effects, inhalation, or radiation. Hexane can cause skin irritation and is toxic if ingested. The fourth picture from the left shows that n-hexane is toxic to aquatic life and has long-term effects.

Risk analysis can be used to customize the design of the robotic system to ensure operator safety and a productive assembly cell. This must therefore be understood as an iterative process that begins when the basic functions of the assembly cell [14] are defined. h. The cell layout for performing the assembly tasks is defined. The proposed work process, with emphasis on the interaction between participants and their tasks, can be described as follows: Step 1: The assembly functions of the production cell can be reformulated into separate sequential sub tasks.The subtasks are assigned to participants who will perform it in their assigned workspaces. That is, the first step is to break down the assembly task into subtasks and specify participants and workspaces for each subtask. Step 2: The occupational safety analysis should thoroughly analyze the hazards of the subtasks. In the second step, the goal is to analyze the subtasks assigned to each participant. To assess all possible hazards, each subtask associated with a participant can be critically analyzed by focusing the analysis on the interaction of the participant with other participant groups. For example, if T1 is a subtask performed by an operator, the analysis should capture the interaction of T1 with the robot and the work environment. Step 3: In the final step, the causal factors and risk impacts of each hazard can be documented. Information on causal risks and their impacts can be used to suggest solutions to mitigate the risks. Possible solutions include assembly cell monitoring solutions, safety by design, and safety standard guidelines that can be used to define design requirements for the robotic system.

IV. Conclusion

The overall goal of a risk assessment is to document all potential hazards and suggest ways to mitigate them. Hazards can occur for a variety of reasons, including equipment failure and unexpected collisions. Hazards can be avoided through safety-focused design and work procedures that avoid possible risks. Due to the complex interactions between operators and machines in a collaborative assembly cell, it is possible to accidentally fail to anticipate hazards. To enable risk assessors to anticipate potential hazards, a structured approach to risk assessment is required. To support this identification of hazards, the assembly cell was characterized as a work area where participants can perform tasks. As shown in the article, such a characterization places equal emphasis on the participants and allows mapping their interactions with the work environment, facilitating a precise analysis of hazards and solutions to eliminate them. Each participant's assembly tasks were documented and analyzed using workplace safety analysis methods to mitigate risks. Safety standards indicate that risk assessments should be performed in collaboration with the user. Within an assembly line, the user may be an operator, a line manager, or other expert who may be familiar with technical risks and may not have the knowledge or experience to suggest proactive measures to avoid potential hazards. For example, a robotics systems expert may have the necessary knowledge to suggest design requirements for an end effector, but may not have the expertise required to suggest a layout of vision sensors that can be used to safely monitor an assembly cell. The risk assessment process therefore requires the involvement of both experts and users. It can also be argued that collaborative robot systems are more vulnerable and therefore more likely to experience accidents due to the lack of physical fences. It is therefore important to make design decisions with a focus on safety. It has been demonstrated that carrying out a risk assessment at an early development stage allows the realization of not only safety requirements in compliance with legal safety standards, but also requirements that ensure production quality. Finally, the risk assessment proposed in this article is aimed at the early development stage of co-assembly, where appropriate equipment and procedures are implemented from the very beginning, so that insights into the robotic system can be gained. Then, more accurate analytical methods can be used to assess risks, leading to the development of safe and productive co-assembly stations. Work processes are aimed at ensuring that the design requirements of the robotic system are met.

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