Being safe around collaborative and versatile robots in shared spaces

Being safe around collaborative and versatile robots in shared spaces

Case story: Is my cobot a robot or a load-handling device ?

Domain: manufacturing, logistics, building

Author: Sylvain Acoulon

Grant agreement no. 779966
Date 2019-02-27

1 Overview

In various collaborative robotics application, cobots are used in certain working phases to support the operator, enabling him to move a part or a load. As a machinery safety expert, I have been involved in several COVR projects (Prosax, Rocable, Coshco) where the question of whether or not to consider the cobot as a load handling device was raised. This Case story tell how the question was addressed.

COSHCO application

ROCABLE
in co-manipulation mode

2 Challenges

The modes considered here differ from the modes in which the cobot operates autonomously in the close proximity of an operator, being under the direct control of the operator. This raises the question of the regulatory framework and the prevention measures to be put in place at the design stage. Like all equipment, these cobots must comply with the Machinery Directive 2006/42/EC and all its essential health and safety requirements, but are they to be considered as lifting devices in these phases?

3 Solution

To try to answer this question, it is necessary to check what determines whether an equipment is considered a lifting device and therefore what standards or technical solutions can be applied to ensure conformity.

3.1 EC directive and national regulation

The Machinery Directive 2006/42/EC does not provide any elements to exclude cobots from lifting equipment; indeed, part 4 of the requirements requires lifting operations to be taken into account in the risk assessment for any equipment in addition to part 1 and gives as definition :

" *'Lifting operation' means a movement of unit loads consisting of goods and/or persons necessitating, at a given moment, a change of level.* "

Thus, on first reading, it appears that many items of equipment may fall within the definition given, and that it is therefore necessary to comply with additional requirements (part 4) to address the hazards of lifting operations on the equipment concerned. The additional requirements are mainly aimed at ensuring that no instability of the equipment is to be feared, that no breakage of structural elements or intermediary with the load can occur or that the operator keeps control over the load handled.

At national level, in France, a decree[1] fixes the nature and periodicity of the controls that must be carried out on lifting equipment. It provides more precise answers to the question of the perimeter of lifting equipment, with the following elements for robotics: This decree excludes lifting equipment integrated into automated machines or production lines and operating in an area inaccessible to persons during the production phase. It also gives a more precise definition of the equipment concerned which is under the direct control of an operator who acts on the movements. This definition excludes any autonomous operation of the equipment, such as programmed robot trajectories. However, when operating in "Hand Guiding" mode, the doubt reappears, and the exclusion of the cobot from the scope of lifting devices is hardly justified in this mode.

3.2 Robotics standards

In parallel with the regulatory aspect, a look at the standards may give us a better understanding of whether the risks associated with lifting operations are integrated into the proposed technical solutions to be implemented to ensure safety.

The standards related to collaborative robotics and concerning the safe design of all types of industrial robots are the following (see the Directive and Standard section of the COVR toolkit):

- EN ISO 10218-1 (for the robot alone),
- EN ISO 10218-2 (for the robot cell),
- ISO TS 15066 (collaborative robotics).

After reviewing the content of these standards and for the purpose of simplification, apart from a specific process, all safety prevention solutions to be implemented on robots in a collaborative application have to comply mainly with the following requirements of the Machinery Directive 2006/42/EC:

- Moving parts (EHSR 1.3.7) : implies that all moving parts of the robot must not injure the operator,
- Ergonomics (EHSR 1,1.1.6): implies that operator must be able to handle the robot without having to exert too much effort or in uncomfortable postures.

Thus, apart from the specific risks linked to the use of electrical, pneumatic or hydraulic components, or to processes involving specific risks (burns, noise, vibrations, etc.), as well as the risks of access to the movement drive systems (EHSR 1.3.8.1), the main risks on a robot or robotic cell are that the operator collides with the moving parts of the robot (or the gripper or the tool), or is trapped or crushed by one of these parts, whatever the mode of operation considered, in normal operating conditions (taking into account the reasonably foreseeable actions of the operator) or in the event of a robot failure.

[1] Arrêté du 1 mars 2004 relatif aux vérifications des appareils et accessoires de levage.

3.3 Lifting equipment standards [2]

On the lifting equipment front, there are many standards, either standards that apply to clearly identified equipment (called "product" standards), either generic standards that feed into previous standards or can be used to design new equipment (see tables in Annex).

A reading of all these standards will show how the specific risks of lifting operations are addressed and what design solutions are proposed. Thus, after a close look at the content, the main hazardous phenomena remain fairly identical to those listed in the robot standards mentioned above, with the difference that the focus is on the mechanical hazardous phenomena linked to lifting operations, which are approached from the standpoint of risks:

- The risks resulting from the fall of the load, collision with the load or tipping of the machine caused by :
  - Lack of stability,
  - Excessive stresses: overloading, excessive tipping torque,
  - Inadequate slinging (gripping) equipment/accessories,
- The risks arising from insufficient mechanical strength of parts
- The risks due to an inadequate match between the machine and the (gripping) accessories,
- The risks resulting from abnormal conditions of assembly, testing, use, maintenance.

What is important to note is that the main risks listed in the lifting equipment standards focus on a mismatch between the loads handled and the lifting equipment, which could lead to various mechanical failures in the lifting equipment (or deterioration over time). Regarding the proposed solution, the emphasis is mainly on oversizing certain mechanical elements and monitoring any failures over time. This monitoring is mainly carried out by human interventions for periodic checks on correct operation and not by safety functions, which remain rare because they are not adapted. In addition, the lifting device is generally under the direct control of an operator, unlike a robot cell, which makes a fundamental difference to the level of safety to be achieved for the safety functions (PL according to NF EN ISO 13849-1).

These are the main differences between the standards for lifting equipment and those for robots or robot cells.

3.4 Industrial manipulators versus cobots

Furthermore, if we identify more specifically the standard in lifting equipment, the closest to the equipment represented by the cobot when used in the "hand guiding" mode, one finds the EN 14238+A1 standard relating to industrial manipulators as "Manually controlled load manipulating devices"[3].

Even if the functionalities offered by cobots to assist in carrying loads or tools are more important than those offered by industrial manipulators, we find in the latter, the same capacity to move a load of a weight in accordance with the maximum admissible load. In each case, the proposed functionality

[2] These standard are referenced as "cranes" standards in English, also "Krane" in german, while in French the term used is "Appareils de levage à charge suspendue" which can be translated as "Suspended load lifting devices"

[3] in french ''Manipulateurs de charge à contrôle manuel'' , in german ''Handgeführte Manipulatoren''

will be the lifting of the load by a power transmission, while its movement will be mainly ensured by direct commands from the operator on the free axes of the manipulator, or by specific commands for each axis at generally fixed speeds, or even a direct action on the handled load. This is specified in the definition given in the EN14238 standard:
”Manipulator: powered machine where the operator has to be in contact with the load or handling device, in order to guide and/or control the motion of the load to bring it to a position in space”.

With cobots, the functionalities are higher since all axes are generally motorised, which not only makes it possible to support the load to be moved by counteracting gravity, but also to guide and possibly define a path for the movement, thus greatly limiting the risks inherent in moving a load. We can even envisage virtual guidance (the operator handling the cobot feels that the equipment is having more or less difficulty moving in a given direction), but also preventing the cobot from passing through a defined area (the operator cannot bring different points of the cobot into an area of space, as the cobot refuses to move in order to reach them). It can also be used to absorb axial forces from the load being handled (e.g. gyroscopic effect) or to transmit axial forces (working with a tool). The movement of all the axes is subject to only one centralized control, and not to a separate control per axis. The speeds and accelerations can be higher than those of a manipulator for the movement axes. The speed is variable to follow the operator's movements and make the collaboration fluid (notion of cobot transparency).

Such different functionalities also entail different risks and therefore different technical preventive measures: This is why the standards relating to industrial manipulators and collaborative robots currently differ and the manipulator standard (NF EN 14238+A1) is insufficient to cover all cobot risks.

4 Considerations

In this context, the most suitable standard for the cobot remains the current industrial robotics standard[4], while adding to it (if necessary), the possible elements of solutions to avoid the specific risks linked to the lifting of loads. These elements are based on a specific mechanical dimensioning (with a safety coefficient) and a periodic verification.

At present, there are no recommendations in the "robot" standards on the mechanical strength of the elements in the event of overloading or alteration over time, which could lead to the failure of a mechanical element, only verification of sufficient anchoring to the ground. While it seems easy to define dimensioning rules for cobots, periodic verification does not necessarily seem to be the most appropriate in its current state.

Indeed, the verification of a lifting device is essentially based (apart from a visual inspection) on periodic static tests (1.25 times the maximum load for 1 hour) and dynamic tests (1.1 times the maximum load in all configurations of the device) which make it possible to determine whether a lifting device can still operate safely and within the permitted load capacity. However, these tests, which are essentially based on a periodic (minimum 6 months) post-test, do not seem appropriate for a cobot-type device that can detect any overloads or anomalies in real-time and then promptly alert the operator or any controller about the problem.

[4] ISO 10218(part 1 and 2) together with ISO TS 15066 or the upcoming revision of ISO 10218 which is incorporating the content of TS15066.

Finally, the loads handled are also significantly lower than those handled by lifting devices, and are related to the capabilities of the collaborative robots currently on the market.

At the level of the French control institutions, this point is still under discussion. As the purpose of the consultancy given to COVR projects was not to establish a position, we did not take it into consideration and we first considered all the technical measures that seem appropriate to guarantee safety, even if it means adding elements of verification and guarantee of safety relating to lifting devices on a cobot and evaluating their actual impact on the design of current cobots. In parallel, a revision of the industrial manipulators standard will begin and will perhaps provide more precise answers.

Annex

"Product" standards for cranes safety	
EN 12999:2020 Cranes - Loader cranes	**EN 13852-1:2013** Cranes - Offshore cranes - Part 1: General-purpose offshore cranes
EN 13000:2010+A1:2014 Cranes - Mobile cranes	**EN 13852-2:2004** Cranes - Offshore cranes - Part 2: Floating cranes
EN 13155:2020 Crane - Safety - Non-fixed load lifting attachments	**EN 13852-3:2021** Cranes - Offshore cranes - Part 3: Light offshore cranes
EN 13157:2004+A1:2009 Cranes - Safety - Hand powered cranes	**EN 14492-1:2006+A1:2009** Cranes - Power driven winches and hoists - Part 1: Power driven winches
EN 14238:2004+A1:2009 Cranes - Manually controlled load manipulating devices	**EN 14492-1:2006+A1:2009/AC:2010** Cranes - Power driven winches and hoists - Part 1: Power driven winches
EN 14439:2006+A2:2009 Cranes - Safety - Tower cranes	**EN 14492-2:2019** Cranes - Power driven winches and hoists - Part 2: Power driven hoists
EN 14985:2012 Cranes - Slewing jib cranes	**EN 15056:2006+A1:2009** Cranes - Requirements for container handling spreaders
EN 15011:2020 Cranes - Bridge and gantry cranes	**EN 16851:2017+A1:2020** Cranes - Light crane systems

Generic standards for cranes safety	
EN 12077-2:1998+A1:2008 Cranes safety - Requirements for health and safety - Part 2: Limiting and indicating devices	**EN 13001-1:2015** Cranes - General design - Part 1: General principles and requirements
EN 12644-1:2001+A1:2008 Cranes - Information for use and testing - Part 1: Instructions	**EN 13001-2:2021** Crane safety - General design - Part 2: Load actions
EN 12644-2:2000+A1:2008 Cranes - Information for use and testing - Part 2: Marking	**EN 13001-3-1:2012+A2:2018** Cranes - General Design - Part 3-1: Limit States and proof competence of steel structure
EN 13135:2013+A1:2018 Cranes - Safety - Design - Requirements for equipment	**EN 13001-3-2:2014** Cranes - General design - Part 3-2: Limit states and proof of competence of wire ropes in reeving systems
EN 13557:2003+A2:2008 Cranes - Controls and control stations	**EN 13001-3-3:2014** Cranes - General design - Part 3-3: Limit states and proof of competence of wheel/rail contacts
EN 13586:2020 Cranes - Access	**EN 13001-3-4:2018** Cranes - General design - Part 3-4: Limit states and proof of competence of machinery - Bearings
EN 14502-1:2010 Cranes - Equipment for the lifting of persons - Part 1: Suspended baskets	**EN 13001-3-5:2016+A1:2021** Cranes - General design - Part 3-5: Limit states and proof of competence of forged and cast hooks
EN 14502-2:2005+A1:2008 Cranes - Equipment for the lifting of persons - Part 2: Elevating control stations	**EN 13001-3-6:2018+A1:2021** Cranes - General design - Part 3-6: Limit states and proof of competence of machinery - Hydraulic cylinders
EN 17076:2020 Tower cranes - Anti-collision systems - Safety requirements	