Case Study - Safeguarding

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Professional Background:
Mechanical Engineering Degree from:
Michigan Technological University.
27+ years in the Automation Industry.
Over 18 years at FANUC – all related to applying
Robotic Automation Solutions.
Assumed leadership role at FANUC in 2001 related to
Safety of Robot Systems.
An active member of the RIA R15.06 Safety Committee since 2006.
Safety Standard Review

“American National Standard for Industrial Robots and Robot Systems Safety Requirements”

ANSI/RIA R15.06-2012

Based on:
ISO 10218-1 for Robot Manufacturers
ISO 10218-2 for System Builders/Integrators.

Safety Standard Review

ANSI/RIA R15.06-2012 Definitions

Part-1

3.24.1 Maximum Space: space which can be swept by the moving parts of the robot as defined by the manufacturer plus the space which can be swept by the end-effector and the work piece.

“Maximum” Space
Part-2

3.13.2 Restricted Space: portion of the maximum space restricted by limiting devices that establish limits which will not be exceeded.

NOTE: The maximum distance that the Robot, end-effector, and work piece can travel after the limiting device is actuated defines the restricted space boundaries.

"Restricted" Space

Add Hard-stops, Limit Switches, Safety Encoders, Safety-Rated Axis Limits, etc.

The Restricted Space is generally considered a Hazard.

Part-2

3.13.1 Operating Space: That portion of the restricted space (3.13.2) that is actually used while performing all motions commanded by the task program

"Operating" Space

Path Program
3.13.3 Safeguarded Space: space defined by the perimeter safeguarding.

Safeguarded Space location depends on Size of openings in Guards, Safe Distance Calculations, AND must be outside the Restricted Space per Part-2 Clause 5.4.2.

Part-2

Safety Standard Review
ANSI/RIA R15.06-2012 Definitions

3.13.3 Safeguarded Space: space defined by the perimeter safeguarding.

5.4 Limiting Robot motion
5.4.2 Establishing Safeguarded and Restricted Spaces

The safeguarded space shall be established by perimeter guarding. This shall be sited with due consideration of the location and layout of the machines and the hazards within the safeguarded space.

The restricted space of the robot system shall be established by means which limit the motion of the robot, end - effector, fixture, and work piece. The restricted space should be made smaller than the maximum space. The restricted space shall be within the safeguarded space and should match the operating space as close as is reasonably practicable.

The perimeter safeguards shall not be installed closer to the hazard than the restricted space. If the perimeter safeguard is designed to be the limiting device in accordance with 5.4.3, then the perimeter safeguard establishes a portion of the boundary for both the safeguarded and restricted spaces.
Part-1 5.12.3 Safety-Rated Soft-Axis and Space Limiting

Part-2 5.4.3 Means for Limiting Motion
Limiting the motion of the robot system may be accomplished by means integral to the robot (e.g. safety-rated soft axis and space limiting or hard stops provided by the manufacturer), by installing external limiting devices, or by a combination of both. Limiting means are used to restrict the space in which a robot may perform its task, i.e. the Restricted Space is made smaller than the maximum space by use of limiting devices.

Robot System Safeguarding Development

1) Define the Operation – How do parts enter, move thru, and exit the operation? What automation, fixtures, etc. are envisioned? What robot motion is needed?

2) Define the robot Operating Space – the volume of space swept by the Robot, EOAT, and Part during operation.

3) Define the robot Restricted Space – add limiting devices (Hard stops, Safety-Rated Soft-Axis Limiting Restrictions, etc.) to limit robot motion while allowing the system to operate as defined in step 1). The Restricted Space is the largest possible volume of space swept by the Robot, EOAT, and Part after the limiting devices have been actuated.
Robot System Safeguarding Development

4) Define Human Interaction – What access is needed; when, where, for what purpose, and under what operational conditions (full auto, power on in manual, no-mode, power off, other?)

5) Define the Safeguard Space – add Perimeter Safeguards (Fencing, Light Screens, Gates, Mats, etc.) constructed and located as defined by RIA R15.06.

NOTE: A preliminary system layout may sometimes be created with the perimeter safeguards defined but without accommodation for the necessary Restricted Space. This can become a contractual challenge in that the customer usually has allocated a minimum floor-space for the system even though more space is necessary.

Robot System Safeguarding Development

Need to answer the following questions:
- What will the EOAT with part look like and what robot motion is required for the operation / process?
  ** These define the Operating Space **

- What human interaction is expected and how does it impact the operation?
  ** Risk Assessment is used to define the required Restricted Space and Safeguarding Method. **
Also keep in mind what a Wise Man once said:

“It is easy to make something complex but it also can be complex to make something easy.”

There are many ways to achieve an acceptable level of risk. Choose safeguarding functions carefully to ensure ease-of-use and long-term acceptance.

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**Case Study - Body Transfer System**

**Case Study Process:**

* Vehicle Manufacturer needs to transfer bodies through underbody sealant apply & manual inspection/ process stations prior to final paint.

Underbody Sealant for corrosion protection.
Case Study - Body Transfer System

Traditional *Non-Robotic* Method utilizes fixed-automation to:

- Lift body from floor-level conveyor to overhead conveyor.
- Overhead Conveyor indexes the body through Robotic Sealant and Manual Inspection & Process stations.
- Lower body & return to floor conveyor.

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Traditional Method

Floor conveyor thru UBS & Manual Stations

- Floor Conveyor directly under Sealant apply Station.
- Special platforms required to cover conveyor in Manual station(s).
Traditional ‘Drop-Lifter’ Device
Requires significant maintenance at elevation

Many Mechanisms

Traditional Fixed Automation

UBS System
Drop Lifter
Case Study - Body Transfer System
Disadvantages of Fixed-Automation

- Purpose built equipment limits change-over & layout flexibility.
- High Life-Cycle Cost; purchase + tooling + maintenance.
- Requires long-duration downtime for preventative maintenance.
- Mechanisms are elevated which require special equipment & procedures for safety of maintenance personnel.
- Floor conveyor is directly under the sealant apply station making clean-up of drips difficult.
- Special platforms and stairs are required in order to provide manual access to overhead bodies.
- Cells are congested preventing easy access for maintenance.

Case Study - Body Transfer System
Why Use Robots to Transfer Bodies?

- More flexible than existing fixed automation, conveyors, lifters, etc.,
- Improved Reliability & Maintainability,
- Prevents sealant drips to floor automation,
- Allows for degrade-mode operation.
- Less equipment at elevation improves maintenance accessibility and safety.
Case Study - Body Transfer System
Customer Specified Requirements

- Minimize Floor Space Usage,
- High Reliability = Maximized Uptime,
- Flexible = Ease of Re-Purposing,
- Consistent = Repeatable Quality,
- Ease of Use = Fast Launch & Max Uptime,
- Manual Operation Tasks Each Cycle,
- Safe to Operate, Maintain, & Observe.

Case Study - Body Transfer System
Engineering and Design Challenges

- Parts are Large & Heavy (over 550 kg),
- Systems usually need much floor space,
- Production Rate: ‘Short’ Cycle-Time,
- Human-to-Part Interaction Required During Each Automatic Cycle,
- Safeguarding Strategy.
Case Study - Body Transfer System
General Arrangement & Process

1) Pick Body from Carrier
2) Place to Under Body Seal (UBS)
3) Pick from UBS & Place to Manual Station
4) Place to Manual Station
5) Pick from Manual Station
6) Place Body to Carrier

Case Study - Body Transfer System
Operation through UBS and Manual Stations

- Operation / Process Sequence:
  - Body enters work cell & stops at pick location.
  - 1\textsuperscript{st} Robot picks the body off the carrier and transfers to the UBS cell
    - UBS robots apply sealant
  - 2\textsuperscript{nd} Robot picks the body from the UBS cell and transfers to the Manual Station
    - Operator enters Manual Operation Area to inspect and/or touch-up certain locations on the underbody.
  - 3\textsuperscript{rd} Robot picks the body from the Manual Station and places it to the outgoing carrier.
Case Study - Body Transfer System

Safeguarding Challenges

- Large robot footprint with limited floor space available.
- Part being transferred creates large operating space and poses significant safety hazard if body falls from EOAT or part stands.
- Body doors may not be secure; robot motion may cause the doors to open during transfer
  - An open door expands the Restricted Space
  - An open door is exposed to potential damage.
- Manual Operator and Robots share a common space.

Case Study – Body Transfer System

Movie of Simulated System Process:
Case Study - Body Transfer System
Maximum Space – Without Limiting Devices

- Robot Only Space
- Maximum Space: Robot, EOAT, and Part

Pick Area
Pick & Place Areas
Place Area

Case Study - Body Transfer System
Operating Space – Desired Path

- Operating Space
- Maximum Space: Robot, EOAT, and Part

Pick Area
Pick & Place Areas
Place Area
Case Study - Body Transfer System
Restricted Space – Adding Limiting Devices

* Robot-Based Safety-Rated Soft Axis & Space Limiting Applied:
  * Cartesian-based Space Limits to monitor Robot, EOAT, and Part relative to a 3D prismatic volume.
  * Joint-based Soft Axis Limits to restrict robot motion to rear; i.e. “Boom Back”.
  * Cartesian-based Speed Limits to minimize motion stop-time.

** Produces shorter Safe Distances

Case Study - Body Transfer System
Restricted Space Definition by Adding Safety-Rated Soft-Axis & Space Limiting

Virtual Engineering

Green = “Stay Inside”
Red = “Stay Outside”

EOAT + Part

Zone for Manual Area is Active when an Operator is Present

Robot 1
Robot 2
Robot 3

Zones at Conveyor prevent robot motion above top of perimeter guarding
Case Study - Body Transfer System
Safety-Rated Space Limiting for Manual Operation Area

A light curtain & safety scanners are employed to detect operator entry and presence in the manual operation area.

If operator is detected, Space Limiting zone becomes active and the robots are not allowed to enter. If a robot does attempt to enter while zone is active, or if the operator attempts to enter the manual area while a robot is in the zone, a robot Protective Stop is initiated.

Case Study - Body Transfer System
Safeguarded Space Determined based on Resulting Restricted Space

Perimeter guarding is positioned to meet the required safety distances.
Case Study - Body Transfer System
Prevention of Unauthorized Access

All manual access gates have safety-rated interlock switches that initiate a robot protective stop if gate is not-closed.

Large openings, for part pass-through use safety-rated Light Curtains to initiate a robot protective stop if violated when not muted. Floor-mats are used to detect if a person enters the work cell in an unauthorized manner.

Case Study - Body Transfer System
Open Door Sensing
Impact to Restricted Space

A safety-rated sensor is mounted at the Place Area, near the passenger side of the body, to detect if a door is not closed. A robot protective stop is initiated if a door opens while loading the body to the carrier. This sensor, in conjunction with a safety-rated robot speed limit, causes robot motion to stop before the door is driven into the fence. Momentum may cause the door to continue to swing open and contact the fence. Plexiglas is mounted into the fence panels near the place position to prevent reach through.
Case Study – Body Transfer System
Movie of Actual Similar System

* www.youtube.com
  M-2000iA Car Body Transfer Robot & M-20iA Sealer Robot
* http://www.youtube.com/watch?v=xoJ_L-KgdhY

Case Study – Safeguarding
Suggestions for Users and Integrators

- Users should partner with robot integrators that have the experience, tools, and talent to properly apply safeguarding techniques & technologies.
- Need to know and understand the prevailing applicable robot & system safety standards.
- Need application and verification experience related to safeguarding technologies...especially robot Soft-Axis & Space Limiting functions.
- Need Risk Assessment expertise.
Contact Information
“Thank You for Attending!”

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