Collaborative and Mobile: When Standards Collide – The Confusing Area of Robots and Mobile Platforms

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Applications are growing
Separation between traditional industrial robot applications and mobile is closing
New Sensors, New Mobile Platforms
Collaborative Robot Technology

“Mobile Robots Market worth 10,605.4 Million USD by 2020
According to a new market research report on the “Mobile Robots Market” the mobile robots market is expected to grow at a CAGR of 16.31% between 2015 and 2020, and reach USD10,605.4 Million by 2020”

The Problem

How to Ensure Safety of People Working Next To, With, and Coming in Contact with Robots on Mobile Platforms.

Source: RIA/GE Global Research
Two 1/2 Standards

R15.06
TS15066

Two Areas

B56.5
Current Situation

• How to apply the two standards
• Must be consistent with both standards and yield a safe environment
• New Cases
• New Problems
Case 1 - Mobile Platform + Static Robot During Platform Motion
(Robot Application When Platform is Static)
Case 2 - Mobile Platform + Non-Static Robot During Platform Motion (Robot Application While Platform Moves)
Case 3 - Mobile Platform Integrated With Robot Motion for Resulting Robot Application (6 axis + 2 axis integrated motion control)
## What About the Gaps?

Gray space exists in these 3 cases of which standard to apply and where.

<table>
<thead>
<tr>
<th></th>
<th>Moving AGV + Stationary Robot</th>
<th>Stationary AGV + Moving Robot</th>
<th>Moving AGV + Moving Robot</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Unexpected startup of robot or AGV</td>
<td>A/R</td>
<td>A/R</td>
</tr>
<tr>
<td>b</td>
<td>Robot/AGV hardware safety interlock</td>
<td>A/R</td>
<td>A/R</td>
</tr>
<tr>
<td>c</td>
<td>Human approach angle other than current direction of AGV travel, human is...</td>
<td>A/R, A/R</td>
<td>A/R, A/R, A/R</td>
</tr>
<tr>
<td></td>
<td>...in robot work volume, in AGV path</td>
<td>A, A</td>
<td>A, A</td>
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<tr>
<td></td>
<td>...out of robot work volume, in AGV path</td>
<td>A, A</td>
<td>A, A</td>
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<tr>
<td></td>
<td>...in robot work volume, out of AGV path</td>
<td>A, A</td>
<td>A, A</td>
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<tr>
<td>d</td>
<td>AGV position uncertainty</td>
<td>A₁, A₁</td>
<td>A₁, A₁, A₁</td>
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<tr>
<td>e</td>
<td>Robot position uncertainty</td>
<td>R², R²</td>
<td>R², R²</td>
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<td>f</td>
<td>Conflicting emergency stop situations</td>
<td>A, A</td>
<td>A, A</td>
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<tr>
<td>g</td>
<td>Robot sensing within the restricted space</td>
<td>A, A</td>
<td>A, A</td>
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<tr>
<td>h</td>
<td>Mobile manipulator stability</td>
<td>A₄, A₄</td>
<td>A₄, A₄</td>
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<tr>
<td>i</td>
<td>Overhanging obstacle extends into robot or AGV path</td>
<td>A₅, A₅</td>
<td>A₅, A₅</td>
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<tr>
<td>j</td>
<td>Reporting joint configuration of robot</td>
<td>A/R, A</td>
<td>A/R, A</td>
</tr>
<tr>
<td>k</td>
<td>Robot/AGV inhibiting motion of the other</td>
<td>A/R₆, A</td>
<td>A/R₆, A</td>
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<tr>
<td>l</td>
<td>Planned/automatic restart from pause/stop</td>
<td>A/R, A</td>
<td>A/R, A</td>
</tr>
<tr>
<td>m</td>
<td>Sensing beyond vehicle path</td>
<td>A/R, A</td>
<td>A/R, A</td>
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<tr>
<td>o</td>
<td>Human carrying large load into AGV/robot path and vice versa</td>
<td>--, --</td>
<td>--, --</td>
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<tr>
<td>p</td>
<td>Velocity of any point greater than that of AGV/robot</td>
<td>Not Applicable</td>
<td>R, --</td>
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<tr>
<td>q</td>
<td>Unplanned restart from pause/stop</td>
<td>A/R</td>
<td>--, --</td>
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<tr>
<td>r</td>
<td>Error recovery startup</td>
<td>R, --</td>
<td>R, --</td>
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<tr>
<td>s</td>
<td>AGV/robot software safety interlock</td>
<td>R, --</td>
<td>R, --</td>
</tr>
<tr>
<td>u</td>
<td>AGV/robot assumes master control during a pause event</td>
<td>A₇, A₇</td>
<td>A₇, A₇</td>
</tr>
</tbody>
</table>

Source: Bostelman, Marvel / NIST

“Test Methods for the Evaluation of Manufacturing Mobile Manipulator Safety”
Practical Issues with Applying TS15066 with Other Than PFL Robot in a Mobile Environment

1. Contact With Moving Platform

Source: Bostelman, Marvel / NIST
“Test Methods for the Evaluation of Manufacturing Mobile Manipulator Safety”
Practical Issues with Applying TS15066 with Other Than PFL Robot in a Mobile Environment

2. Maintaining Speed and Separation Distance with Moving Platform

Source: Bostelman, Marvel / NIST
“Test Methods for the Evaluation of Manufacturing Mobile Manipulator Safety”
Practical Issues with Applying TS15066 with Other Than PFL Robot in a Mobile Environment

3. Non-Collaborative Robot Can Present a Hazard Even if Not Moving

Source: Bostelman, Marvel / NIST
“Test Methods for the Evaluation of Manufacturing Mobile Manipulator Safety”
Integration between the mobile platform and the robot controller needs to meet the overall control/stopping performance requirements.

What happens if you need to stop both the robot and the platform?

Graphics Source: Aethon, FANUC
AGV/Robot Software Safety Interlock(s)

Per Marvel, Bostelman Paper:

• Both the AGV and industrial robot safety standards require onboard equipment to be interlocked with the controller to reduce the risk of injury. These interlocks prevent the accidental activation of components. The AGV safety standards mandate that all such interlocks be implemented in hardware. In contrast, industrial robot safety standards allow for both hardware- and software-based interlocks (e.g., dynamic axis limiting or safety rated monitored stops). Example behaviors could include:

  • While the manipulator is moving or stopped in a non-stowed position, communication between the AGV and manipulator could be interpreted as the AGV is allowed to move which causes a manipulator collision-potential with objects in the environment.

  • Similarly, while the AGV is stopped, the manipulator could be commanded to move and without interlock AGV/manipulator communication, the AGV could begin moving causing a manipulator collision-potential with objects in the environment.

Source: Bostelman, Marvel / NIST
“Test Methods for the Evaluation of Manufacturing Mobile Manipulator Safety”
Being clear about which guidance to apply when will be a challenge until R15.08 group can help "standardize" the handling of all the cases.
Next Steps

Applying

– Flexible Collaborative (PFL) Robots
– Standard Robots in Collaborative Use
Following TS15066
– Non-Collaborative Robots on Mobile Platforms will be more complex until work is done to clarify common requirements.

If you are applying industrial robots on mobile platforms thorough risk assessment is a must.
Where to Go for More Information


This is a good place to start to review many of the key issues of integrating industrial robots to mobile platforms.

https://www.fujipress.jp/jrm/rb/robot002800020199/
Questions?
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