SICK AG WHITE PAPER

MINIMUM DETECTION TIME FOR SAFETY LASER SCANNERS IN VERTICAL APPLICATIONS

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AUTHORS

Otto Görnemann

Manager Machine Safety & Regulations
at SICK AG in Waldkirch, Germany

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CONTENT

Introduction

The current version of the SICK instructions for the use of safety laser scanners states that a maximum of 90 ms response time shall not be surpassed and that the resolution shall not be set to values above 150 mm. This precludes many typical applications for which this limitation of the response time is neither reasonable nor practical. For certain applications, a “minimum detection time” needs to be stated properly. The settings of the safety laser scanner shall be such that the response time adjusts to the detection time, which is the time required for the scanner to detect a specified object and to start the process (switch OSSDs to OFF state) that initiates the required safety function.

Definitions

Scan time: Time required for the safety laser scanner to complete one revolution scan of the detection plane.

Detection time: Time required for the scanner to reliably detect the presence of an object of a specified size. This is typically based on the number of scan cycles programmed into the scanner. By default: detection time = 2 x scan time.

Minimum detection time: Shortest time required for the body or parts of the body which shall be detected by a safety laser scanner according to the detection capability stated to entirely pass through the vertical detection plane.

Response time: Maximum time stated by the supplier for the safety laser scanner to initiate a stop signal (switch OSSDs to OFF state). Response time = detection time (+ internal processing time).

Horizontal projection (TX): Dimension of the portion of the human body detected while passing through a vertical detection plane.

Statement

The response time for vertical safety laser scanner applications can be increased to the following values depending on the approach speed assumed during the risk assessment process:

Horizontal projection of the part of the body to be detected in mm	Minimum detection time in ms according to the application approach speed	
	1.1 m/s	1.6 m/s
200	182	Not applicable
250	227	156
350	318	219

The approach speed shall be selected according to the application. If the distance between the vertical detection plane and parts of the machine is less than 500 mm [1], it can be considered that easy full body access (easy standing or trespassing) is not possible and 1.1 m/s can be assumed. Otherwise 1.6 m/s shall be assumed.

Explanation

The response time is given by the time the object to be detected (body, parts of the body) remains in the vertical detection plane of the safety laser scanner. This time is directly related to the horizontal projection of the human body (or parts of the human body) as long as it is detected in the protective field of the safety laser scanner. The detection should be ensured as long as the object presents a reflective surface with a minimum retroreflectivity and a minimum width (size measured in the plane of the detection field) according to the manufacturer data.

To estimate the response time (which depends on the minimum detection time), the following parameters are to be considered:

1. Dimension of the horizontal projection of a human body while passing through a vertical detection plane
2. Relationship between horizontal projection of a human body and approach speed
3. Approach speed corresponding to application

1. Dimension of horizontal projection of a human body while passing through a vertical detection plane

1.1. Minimum horizontal projection of a human body while walking

As a basis, the commonly accepted physiological model of human walking by Perry (Perry 1992) with 8 phases shall be applied.

A rough assessment of the horizontal projection of the human body according to the abovementioned model shows that the mid swing phase (MSW) shall be applied for the estimation of the human horizontal projection:

- The initial contact phase of Perry's model of human walking (IC – 1st phase) and the initial swing phase (ISW – 6th phase) are not considered since they are initial phases. Therefore, they will only occur outside the detection plane (otherwise the human body would already be detected).
- The phases which follow the possible initial phases (loading response/LR phase – 2nd phase, or mid swing/MSW phase – 7th phase) are the moving phases to be considered for the smallest horizontal projection (TX)
- The MSW phase is considered as the phase with the smallest horizontal projection of a walking human
- The horizontal projection (TX) can be limited to the human body height at which the size of body parts always surpasses a minimum detection capability of 70 mm. This limitation ensures detection of the head, the rump, and the lower limbs above 300 mm from the reference plane (refer to ISO 13855:2010, subclause 6.4, formula 8) [2]

This lowest value of the horizontal human body projection is given at the MSW phase (T_{MSW}). It can be taken as the smallest value during any moving phase.

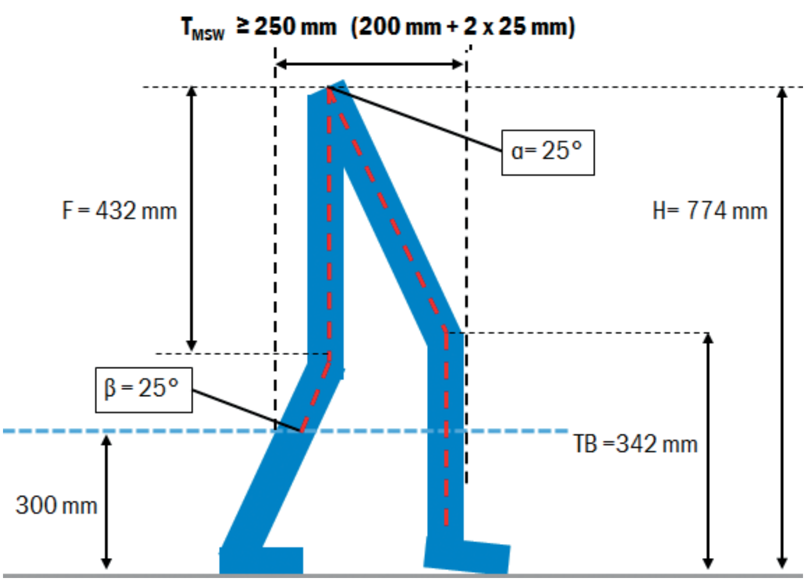
Note: Standing phases are obviously excluded since they will inevitably lead to prior detection.

1.2. Estimation of the minimum value of T_{MSW}

The minimum value of T_{MSW} can be estimated considering the following:

- The flexion values given by Perry during the MSW phase for the hip (α = 25°), knee (β = 25°), and ankle joints (flexion 0°)
- Worst case dimensions (5th percentile) of human bodies as given in ISO 7250-3:2015-08 – Basic human body measurements for technological design – Part 3: Worldwide and regional design ranges for use in product standards [3]
- The femoral length (F) is defined as the difference between the spina iliaca height and the tibial height stated in ISO 7250-3:2018-08 and is calculated with 432 mm.

The following figure shows that as a result of this approach the value of T_{MSW} is always larger than 250 mm since the since the thickness of body soft tissue needs to be added to the geometrical values of the pure bone structure:



ISO 7250 measurement	P5 value	Source
Spina iliaca height (H)	774 mm	ISO 7250; §4.1.6
Tibial height (TB)	342 mm	ISO 7250; §4.1.8
Femoral length (F)	432 mm	ISO 7250; §4.1.6 – §4.1.8

Figure 1: Geometrical estimation of the horizontal projection of the bone structure of a human lower extremities based on Perry's model and the 5th percentile values of ISO 7250-3. © SICK AG 2016.

2. Relationship between horizontal projection of a human body and approach speed

2.1. Minimum horizontal projection of a human body while walking

The minimum horizontal projection of a human body is given when a person is in a standing position, with the upper limbs resting adjoined to the body as shown at the left side of Figure 2 (Source: ISO 7250-1, Figure 9). In this position, the horizontal projection equals the chest depth value. This value is stated in ISO 7250, §4.1.10 – P5 as equal to 185 mm. Nevertheless, this value can be ignored since it does not allow any movement other than hopping or skipping. Such a movement cannot be reasonably foreseen and it will presumably lead to a significantly lower approach speed.

Figure 2 (middle) shows a person walking with the upper limbs resting adjoined at the body – the situation assumed in the previous section of this document. Persons walking in this way cannot reach the walking and grasping speed stated in ISO 13855:2010 or ANSI B11.19-2010 [4]. There are several studies about walking speeds but none of them take into consideration this kind of movement. Consultations with physicians and physiotherapists lead to the assumption that due to the lack of balance which results from the movement of the arms, the maximum reasonably assumed approach speed will not surpass 1.1 m/s, which is in accordance with the average walking speed of 4 km/h.

Figure 2 (right) shows a person walking normally, with arms alternately balancing back and forth. This movement allows an approach speed of 1.6 m/s as stated in ISO 13855:2010 and ANSI B11.19-2010 and it is in accordance with an average "jogging speed" of 6 km/h. In such a movement, the smallest horizontal projection value is then the sum of the horizontal projection described in section 1 and the projection of the protruding upper limbs, which can be assumed as an additional 100 mm.

As a result, the horizontal projection may vary between 200 and 250 mm for speeds below 1.1 m/s (4 km/h) and 250 to 350 mm for the approach speed of 1.6 m/s (6 km/h) as stated in ISO 13855:2010 and ANSI B11.19-2010.

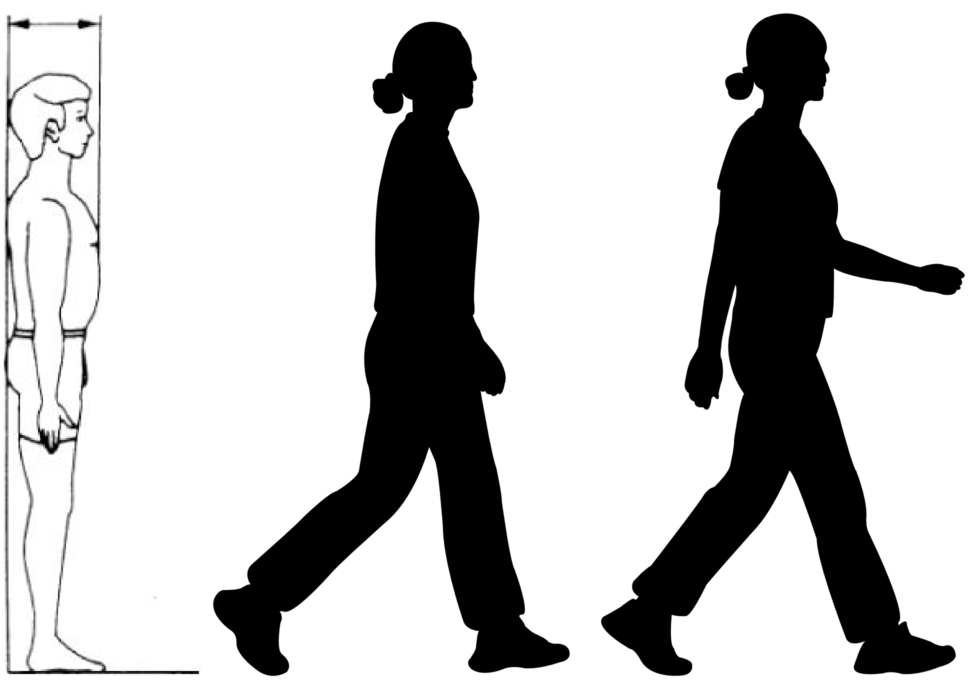


Figure 2: Different positions while walking.

2.2. Application-related approach speed

ISO 13855:2010 and ANSI B11.19 address the approach speed of humans while trying to gain access to hazard zones of a machine. Both standards require the positioning of the detection planes of sensitive protective equipment according to the overall stopping performance of the hazardous machine functions, the approach speed, and the length of a possible undetected intrusion. The standard does not consider approach speeds resulting from other movements than walking, such as jumping etc.

Note 1: ISO 13855:2010: "*The values for approach speeds (walking speed and upper limb movement) in this standard are time tested and proven in practical experience. This standard gives guidance for typical approaches. Other types of approach, for example running, jumping or falling, are not considered in this standard. Other types of approach can result in approach speeds that are higher or lower than those defined in this International Standard.*"

The current draft revision of product standard (IEC/CD 61496-3:2016, [5]) defines a test method using a test piece of 200 mm in diameter and 200 mm in length moving at 1.6 m/s. Although the standard addresses only the manufacturers of such products, the test procedure described refers to their application, which results in unknown and unrealistic additional requirements for machine manufacturers, integrators, and users.

- If a test piece length of 200 mm is selected, an approach speed of 1.6 m/s is unrealistic since the test piece length simulates a person walking with adjoined upper limbs and therefore the maximum achievable speed is 1.1 m/s.
- If 1.6 m/s is assumed as the approach speed, a horizontal projection T_{MSW} of 250 mm and a minimal additional protruding of the upper limbs of 100 mm shall be considered.

In addition, some machine characteristics may preclude the approach of an operator with 1.6 m/s [1)] because of the obvious hazards derived from unavoidable collisions with fixed machine parts.

- If the distance between the horizontal detection plane and parts of the machine is less then 500 mm, it can be considered that easy full body access (standing or trespassing) is not possible and an approach speed of 1.1 m/s can be assumed. Otherwise, 1.6 m/s shall be assumed.

Note 2: This stated value of 500 mm is taken from ISO 13854:1996 and describes the minimum distance which is necessary to avoid crushing of the rump. The distance is NOT the one to distinguish between the approach speeds of 2.0 m/s and 1.6 m/s, described in ISO 13855:2010

1) Approx. 6 km/h, which is the average human speed while jogging or running briskly.

REFERENCES

[1] ISO 13854:1996-12 Safety of machinery – Minimum gaps to avoid crushing of parts of the human body

[2] ISO 13855:2010-05 Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body

[3] ISO 7250-3:2015-08 Basic human body measurements for technological design – Part 3: Worldwide and regional design ranges for use in product standards

[4] ANSI B11.19-2010 – Performance Criteria for Safeguarding

[5] IEC/CD 61496-3:2016-03 Safety of machinery – Electro-sensitive protective equipment – Part 3: Particular requirements for Active Opto-electronic Protective Devices responsive to Diffuse Reflection (AOPDDR)

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