Optimization Study of the Velocity of a Cargo Moving Stage for Container Inspection System

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1. Introduction

The global market of Container Inspection System (CIS) is worth of a few billions dollar whereas a small number of companies such as Varian, Rapiscan in U.S.A, Nuctech in China, etc. has dominated the CIS market. The prices of CIS equipment are up to 10 millions dollar and also fairly huge amount of maintenance costs are required. Korea customs has fourteen CISs at major ports and borderline in Busan, Incheon, etc. [1]. In order to improve the national competitiveness and reduce outflow of foreign currency, Korea Atomic Energy Research Institute (KAERI) has started to develop localized CIS.

There are many requisites in CIS operation especially in optimization of image quality. Above all, the velocity of a Cargo Moving Stage (CMS) is one of the important issues to acquire clear and accurate images.

2. Methods and Results

2.1 Structures of CIS and CMS

Figure 1 shows overall CIS 3D rendering image and installed CMS. CMS tows a cargo and goes to stop point while the cargo on the CMS is being penetrated using by X-ray. X-ray is irradiated from radiation source and passes through several collimators to eliminate scattered X-ray and to form fan shape. Then it penetrates cargo and reaches to detector cabin. Detectors can produce postprocessing images that show the inside figures of the cargo.

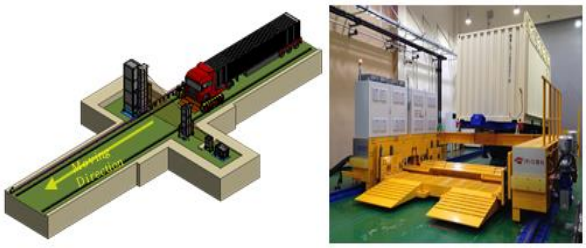

Fig. 1. Overall 3D rendering image of CIS (and) and real CMS with cargo (right).

As shown in Figure 2, the detectors are fixed on the cabin as fan shape to get each X-ray beam with equal distance from radiation source.

Fig. 2. Right-side view of the detector cabin.

2.2 Measurements of actual velocity of CMS

It was suspected that there was an error between the input value of velocity on the control computer and the actual velocity of CMS. Therefore it needs to measure the actual velocity of CMS which was set as 302 mm/s on computer in the constant velocity range without acceleration and deceleration with two methods.

First, it was measured using by tapeline and timer along 6 m cargo rail. Table 1 shows measurement record. The mean velocity was measured as 302.68 mm/s and the mean error was 0.22%.

Table Ⅰ: Record of tapeline and timer method

Classification		1st	2nd	3rd
Section of 0~2 m	**Time [s]**	6.60	6.60	6.67
	Velocity [mm/s]	303.03	303.03	299.85
Section of 0~4 m	**Time [s]**	13.15	13.22	13.2
	Velocity [mm/s]	304.18	302.57	303.03
Section of 0~6 m	**Time [s]**	19.81	19.92	19.74
	Velocity [mm/s]	302.88	301.21	303.95

Second, it was measured using by encoder value that can read from Programmable Logic Controller (PLC). Table 2 shows measurement record. Encoder is mounted inside of the CMS. When the wheel of CMS moved as one turn, the encoder counted to 256. The measured mean velocity was 302.6 mm/s and the mean error was 0.21%. It can be thought that measured actual velocities are reliable because there was less than 1% error compared to set velocity.

Table Ⅱ: Record of encoder method

Classification	1st	2nd	3rd
Start time [s]	3.87	5.78	56.15
Counts of start time	1129	1128	1125
Stop time [s]	34.49	36.40	86.77
Counts of stop time	2809	2806	2804
Displacement [mm]	9272.81	9261.78	9267.29
Interval [s]	30.62	30.62	30.62
Velocity [mm/s]	302.82	302.45	302.62

2.3 Determination of proper velocity of CMS

The cargo projections can be stretched or shrunk by the velocity changes of CMS compared to the size of the actual cargo. Therefore, it is important to find proper CMS velocity.

The determination of the velocity of CMS is related to some parameters such as the traveled distance of CMS during one shot which is define as D that is small width of part of cargo and the X-ray imaging frequency. The proper velocity of CMS is determined by the multiplication of the X-ray imaging frequency and D. The calculation process of D is as follows [2].

As shown in Figure 3 where A is the distance between radiation source and detector, that is, 15100 mm. B is a distance between radiation source and center of cargo, that is, 9899 mm. C is a slit width of cabin, that is, 6.5 mm.

It can be thought using proportional expression

$$A : B = C : D \tag{1}$$

As a result, D is calculated to 4.26 mm. It means that the velocity of CMS must be adjusted based on 4.26 mm which appears as 7 mm on monitor actually. This is due to the distance among the radiation source, CMS, and detectors. In case of 70 Hz operation, CMS moves by 4.26 mm for 0.014 second at 70 Hz and proper velocity of CMS is 298 mm/s.

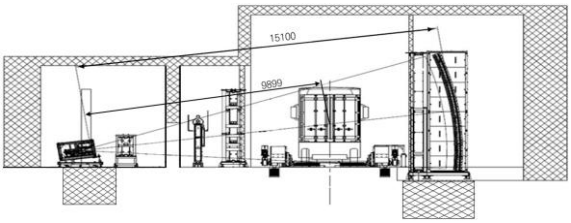

Fig. 3. Overall layout of CIS components.

Table 3 shows specification of an image. Their values are fixed. Detector pixel pitch is 4.6 mm whereas real active area is 4 mm.

Table Ⅲ: Specification of image.

Classification	Value [mm]
image width	2400
image height	1192
Detector Pixel pitch	4.6
Detector Pixel width	4.0
Detector Pixel height	7.0

It is needed to confirm the differences between actual figures in the real cargo and figures of X-ray image with respect to CMS velocity. Therefore the height to length ratio of metal plates with a length and height of 60 cm in the cargo became a standard and they were measured to compare actual figures and X-ray imaging figures. Figure 4 shows several cargo inspection images with different CMS velocity. Three images in the figure 4 have same height whereas length is different. It clearly shows the stretchiness and shrinkage with respect to CMS velocity. And each height to length ratios of metal plate are 1 : 0.47, 1 : 1, 1 : 2.58. Image (a) and (c) show severe image distortion while image (b) with the velocity of 298 mm/s has the ratio of 1 : 1 exactly and shows proper result for use.

3. Conclusion

In this study the relationship between CMS velocity and image optimization was experimentally confirmed. Images are acquired at 70 Hz currently, but optimized parameters which include CMS velocity will be derived through further experiments with different frequency to get the best image qualities in the future.

REFERENCES

[1] Homeland Security Research Corporation, X-ray Security Screening: Technologies, Industry and Global Market, 2014
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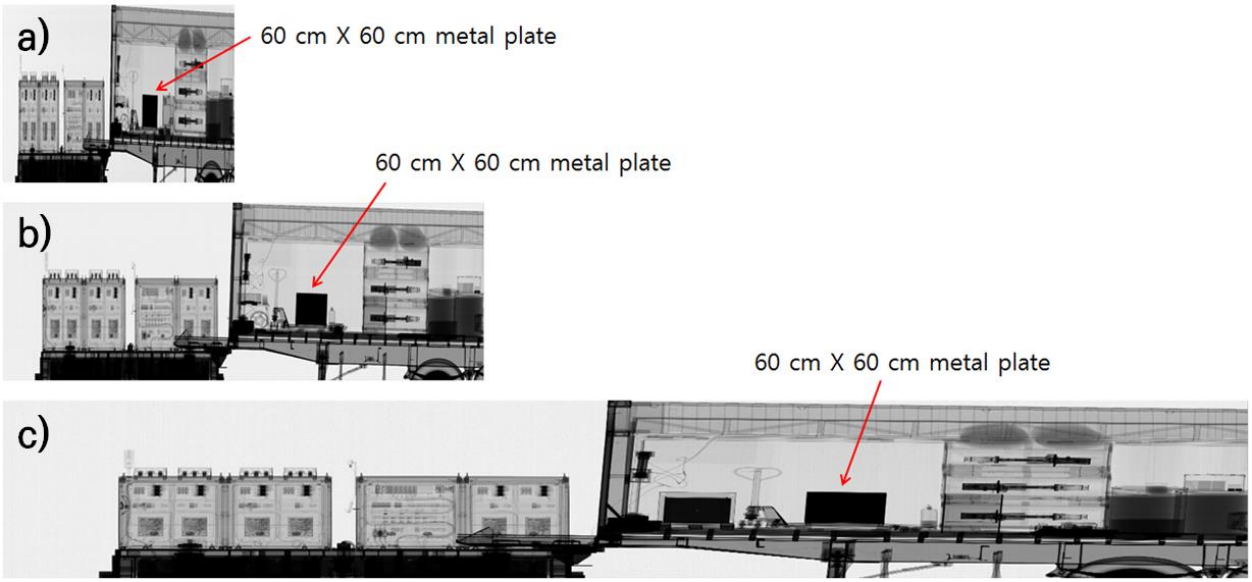

Fig. 4. Cargo inspection images with respect to CMS velocity. They are images (a) when CMS velocity is above 400 mm/s, (b) when CMS velocity is 300 mm/s, and (c) when CMS velocity is 204 mm/s.