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Error Compensation of a Large Scale LCD Glass Transfer Robot

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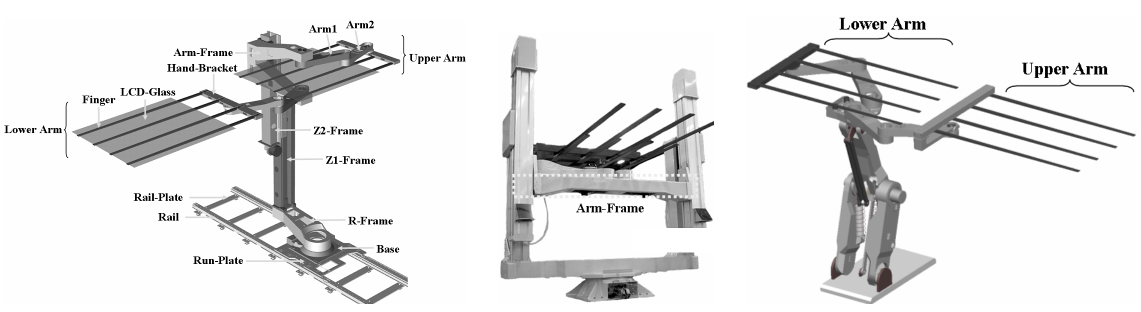
Abstract: A new generation LCD (liquid crystal display) technology requires the bigger size of raw glass in order to supply the demand for a large size TV. Samsung Electronics Company has built the world first 7th generation LCD plant and also recently 8^{th} generation LCD plant. In order to handle bigger and heavier glass, a large scale LCD glass transfer robot is necessary. This robot requires precise path accuracy in order to improve stack efficiency of glass cassette which affects the productivity of LCD plant. But it is difficult to meet the requirement of accuracy because the deflection and deformation of structural components to bear the large dynamic loads deteriorate the accuracy of the robot. This paper presents a method of improving the vertical path accuracy by kinematic compensation for the deflection without any increase of structural stiffness. Firstly, the LCD transfer robot and its requirements are introduced. Next, flexible multi-body dynamic model to simulate the deflection and deformation under dynamic loads is established. Then the idea of improving the path accuracy is presented. Finally its optimization problem is solved using DOE (design of experiment) method.

1. INTRODUCTION

LCD's are widely used in TV, computers, mobile phones, etc. Recently, the size of raw glass has greatly increased in new generation LCD technology because of the demand for a large size TV. Samsung Electronics Company (referred to in this paper as "SEC") has built the world first 7^{th} generation LCD plant and also recently 8^{th} generation LCD plant. The size of 7^{th} and 8^{th} generation raw glass is 1870x2200mm and 2200x2500mm, respectively. In order to handle bigger and heavier glasses, a large scale LTR (LCD glass transfer robot) to support various complicated LCD fabrication processes is necessary. SEC has developed the new robots to be capable of transporting large scale glasses. Fig. 1 shows three types of LTR to handle 7^{th} and 8^{th} glass, e.g. one post type, gate type, and link type. LTR motion can be described with the cylindrical coordinate system that consists of rotational, vertical, and radial axis. Last radial axis consists of one or two horizontal arms that grasp and carry glass. More glasses have to be stacked in a cassette in order to increase the productivity of the plant. This means that the cassette pitch has to be smaller and the robot requires precise path accuracy.

The horizontal arm must carry large bending moment loads while extending the arm and bringing the glass. A vertical deflection of the horizontal arm is necessarily generated. Such deflection brings a deterioration of path accuracy. In an original design, the deflection of the horizontal arm is about 30~40mm. But the deflection has to be smaller than 10mm in order to handle a glass within the given cassette pitch. Thus the robot needs 3~4 times stronger rigidity. Rigidity can be increased by making structure stiffer and using bigger reduction gears. But these methods result in an increase of cost. This paper presents a new method to improve the path accuracy by kinematic error compensation without any increase of structural stiffness and additional cost.

Compensation can be achieved by inserting thin plates, i.e. shims, into rotational joints of horizontal arm. The objective of the present research is to find the thickness of shims to minimize the deflection of horizontal arm. In order to



(a) One post type (b) Gate type (c) Link type

Fig. 1. LCD transfer robots (LTR)

determine shim's thickness, a flexible multi-body dynamic model to simulate the deflection of robot under dynamic loads is established and DOE(design of experiment) method is used for optimization. This paper is organized as follows. A flexible multi-body dynamic model is presented in Section 2. In Section 3, optimization problem is solved by DOE method. Finally, some concluding remarks follow in Section 4.

2. SIMULATION MODEL

2.1 Flexible Multi-Body Dynamic Model

One post type LTR of Fig.1 (a) is reconstructed by a flexible multi-body simulation model. This can be modelled with 86 rigid bodies, 30 flexible bodies, kinematic joints, and force elements. Major components such as arms and link frames are made of cast iron or cast aluminium. Those structural components can be assumed to be linear elastic during normal operation. This model was embodied by IDEAS and ADAMS, which are commercial software. Time history of deflection, vibration, stress during specific operation can be predicted through simulation. In particular, vertical deflection of the end-effector is obtained while the horizontal arm moves.

2.2 Path Accuracy and Compensation

As shown in Fig.3, dynamic simulation shows that the vertical deflection of the end-effector is 42mm which exceeds the design requirement 10mm.

The vertical path accuracy can be improved by inserting thin-tapered plates called shims into three rotational joints of horizontal arm as shown in Fig.2. This compensates the error kinematically while structural stiffness doesn't have to be increased.

3. OPTIMIZATION

The combination of three shims' thickness determines compensation of deflection. Thus, their thickness to minimize deflection has to be found. The objective function is to minimize the differences of the vertical z-displacement of 4 points in the Fig.4. The DOE method of 3 levels and 3 factors

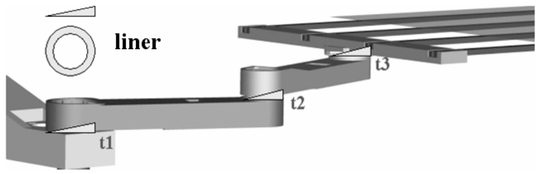


Fig. 2. Compensation of deflection by shims

is used to find optimal thickness of three shims. The optimized thicknesses found by DOE are t1=0.5mm, t2=0.48mm, and t3=0.78mm. The error by deflection is reduced to 5.8mm as shown in Fig.4. Experimental result to verify a validity of the simulation shows that the deflection is about 6.1mm.

4. CONCLUSION

This paper has introduced a large scale LCD transfer robot that is capable of carrying 7^{th} and 8^{th} generation LCD glass. LTR needs a precise path accuracy to improve stack efficiency of glass cassettes which affects the productivity of the LCD plant. The specification of vertical path accuracy due to static deflections has to be limited to 10mm in order to meet the customer requirement while the original robot has the vertical deflection of 42mm. This paper presents a method of improving the path accuracy by a kinematic compensation without any increase of material cost. The horizontal arm of the robot has three revolute joints. Shims are inserted into the three joints so that the error is compensated. The robot's flexible multi-body dynamic model is established to simulate the deflection and deformation. The thickness of shims to minimize deflection is found by dynamic model and DOE. Simulation result shows that the path accuracy can be reduced by 5.8mm while test result is 6.1mm. The result of the present research has been applied to the horizontal arms of the robots installed in T7 and T8 lines of Tangjeong plant.

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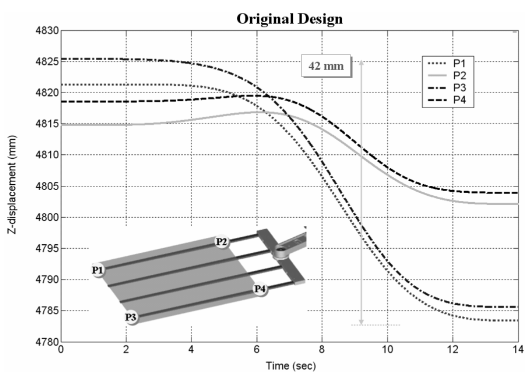

Fig. 3. Vertical defection of end-effector

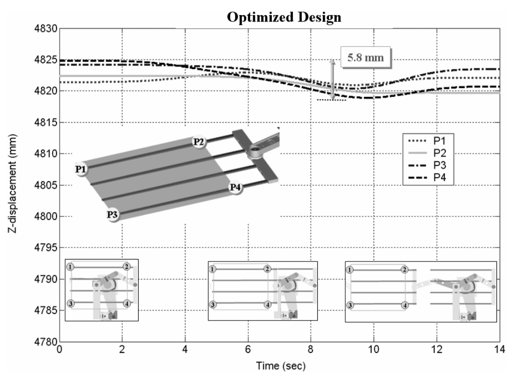

Fig. 4. Optimization result