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Design Optimization of Robot Arm for Transferring Glass Using Strength Analysis

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Abstract**:** *By strength analysis for structure, design optimization of robot arm for transferring glass was performed. We did analysis of strength for basic model. And after analysis of effect parameter impact, we conducted Taguchi experiments design for analysis. We optimized the thick and width of robot arm.*

Keywords: *DFSS(Design For Six Sigma), CTQ(Critical To Quality), Taguchi Method, Vibration reduction*

1. Introduction

We intend to develop the cantilevered robot with 2,700mm arm in the first year and 3,000mm in the second year using extended system. The use of robots is for transfer and carrying of 5th generation thin glass. We need the robot for long transfer of the glass. The existing robot needs additional equipment and the LM guide of the same length as the stroke becomes longer and the price increases exponentially. In the entire process of cutting glass, the pre-align and pick-up unit robot will be replaced by the long axis robot developed through Interlocked extension. The robot with 1,500mm arm has been developed and used in the field. The robot that is developed has 2,700mm arm and is made of 2-step slide.

In order to make up for the disadvantage, we intend to develop the alternative robotic systems. We will optimize design for deflection of the robot arm by self-weight using structure analysis of in this paper. When it is big, the residual vibration become big by the weak stiffness. And it can cause problems for assembly and transport. If it is too small on the contrary, It is heavier than necessary. And then over design. Therefore, the target for deflection will be 1mm.

Design optimization for stiffness is carried out using Design of Experiments with tool of the structural analysis.

This paper shows design optimization for 2-step long robot arm using Design of Experiments. First of all, we find key factor to have effect on target. And the level of factor is determined. Using DOE, we carry out optimization of design.

2. Main Subject

We do correlation for structure stiffness with the strength analysis of existing robot. The measured deflection is 3.8mm. The deflection calculated with FEM analysis for the robot structure is 3.88mm. The difference is in 1% as 0.01mm. It is evaluated to be correlated each other

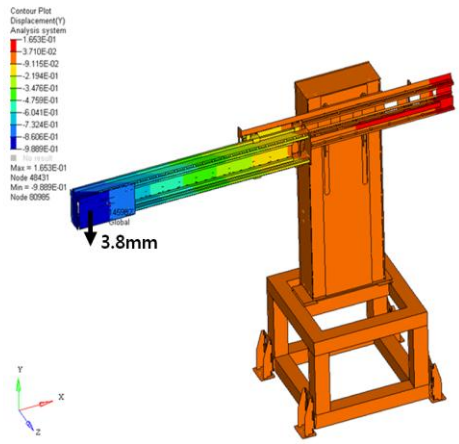

Fig. 1 The Robot with 1500mm Arm

We need a more accurate robot for transfer 5th generation thin glass. So, the target for deflection of robot arm is 1mm.

In order to fulfill the target 1mm, the design factor will be optimized using analysis tool. With sensitivity analysis for the facts, the thickness and width of robot arm were determined as the design factor. The level of the design factors is up to the change of the design possible. As like this, we will determine the number of factors and the level of factors and make a table of orthogonal arrays. And the facts will be optimized by DOE

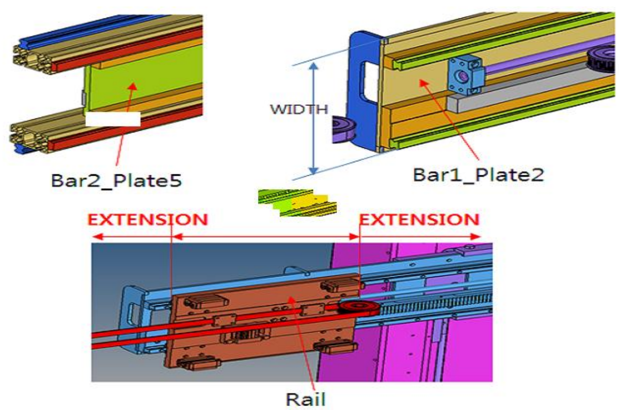

Fig. 2 The key facts of design

The key factors are width and thickness of bar1 and thickness of bar2, and the slide joint length of bar1 and bar2. The width of bar2 is excluded because it is limited to bar1. As shown in Table 1, the number of the factors is 4 and the level is 2.

TABLE I The key factor and level

Factors	Factors	Level1	Level2
A	Bar1 Thickness	30	40
B	Bar1 Width	150	200
C	Joint Rail Extension	100	150
D	Bar2 Width	50	100

TABLE II is a table of orthogonal arrays for $L_8(2^4)$

No.	A	B	C	D	Result
1	1	1	1	1	1.4
2	1	1	2	2	1.12
3	1	2	1	2	1.1
4	1	2	2	1	0.98
5	2	1	1	2	1
6	2	1	2	1	0.89
7	2	2	1	1	0.85
8	2	2	2	2	0.64

As shown in Table 2, the deflection of robot arm was calculated with commercial software in the condition. There are a dispersion control factor and a mean adjustment factor in factors. Because it is calculated using FEM analysis, there is no noise factor and dispersion control factor in the result. So, we consider all the factors as a mean adjustment factor.

Table 3 shows the P-value for the result of Table 2.

TABLE III P-vlaue

	A	B	C	D
P-Value	0.000	0.001	0.001	0.025

As shown in Table 3, the significance for factors was tested. Because the P-values for all the factors are smaller than 0.05, the factors make an effect on the deflection.

TABLE IV Level s for 4 factors

factor		A	B	C	D	
The sum of the levels	1	1.15	1.10	1.09	1.03	Total Sum
	2	0.85	0.89	0.91	0.97	7.98
The mean of the levels	1	1.15	1.10	1.09	1.03	The mean
	2	0.85	0.89	0.91	0.97	0.9975

The prediction value of $A_{i,}$ $B_{j,}$ $C_{k,}$ D_l is calculated by equation(1). We should find the combination closest to the target 1mm in the combinations of all levels for 4 factors.

Prediction Value = $A_i + B_j + C_k + D_l - 3T$
A_i : The mean value for i level of A factor
B_j : The mean value for j level of B factor
C_k : The mean value for k level of C factor
D_l : The mean value for l level of D factor
T : Total mean value
i=1,2 , j=1,2 , k=1,2 , l=1,2

The optimum combination closest to target 1mm are the level 2 of A factor, level 1 of B factor, level 1 of C, level 2 of D. the prediction value of $A_2B_1C_1D_2$ combination is the 1.006. The design value for the thickness and width of Bar1, the width of Bar2 and joint rail should be increased as much as 40mm, 150mm, 100mm and 100mm as optimum design. But those were increased as much as 43mm, 170mm, 110mm and 100mm as the design consideration. We manufactured transfer robot arm as shown Fig. And the deflection was measured. it was 0.91mm . The error was in 10%. We estimated that error was generated because of the modeling error and the difference of design value.

3. Conclusion

In this paper, we optimized design factor for transfer robot system using FEM analysis. At first we heighten the reliability of the analysis by comparing the analysis result and measured deflection of existing robot.

The design factor was selected as to sensitivity priority. We have a real robot was created with the design value optimization using Design of Experiments and we measured the value of deflection. Analysis result and value of deflection are almost same. Thus Optimized design by analysis during development robot can reduce the development cost and time.

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