Optimum Design of a Cellular Phone Using LS-OPT Considering the Phone Drop Test

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ABSTRACT

The main factor of the cellular phone fracture is the impact due to the phone drop. Two cases of design criteria are assigned to reduce the damage of the phone for the drop test. One is that the main part and the battery should not be separated, being dropped at a height of 30 cm. The other is that they should be separated, being dropped at a height of 150 cm. The separation between them could reduce the damage of the cellular phone. However, it is undesirable for the battery to be frequently separated from the phone at a low height. The purpose of this study is to optimize the locking knob of the cellular phone considering the phone drop test at a height of 30cm. The design variables are the width and the thickness of the locking knob. LS-INGRID is adapted to automate the optimum design process because the shape of the locking knob could be changed in the design process. The optimum design is performed using RSM (response surface method) in the LS-OPT. The optimum design values are determined to optimize the displacement at the certain position of the locking knob of the cellular phone.

INTRODUCTION

The main factor of the cellular phone fracture is the impact due to the phone drop. A lot of cellular phone makers conduct the phone drop test 150 cm for the guarantee of the product reliability. But the regulation for reliability is getting more robust, so we need to have an additional test such as the drop at a height of 30 cm. In the event of a 30 cm drop test, the main part and the battery should not be separated because it is undesirable for the battery to be frequently separated from the phone at a low height. Otherwise, in the case of a 150 cm drop test, it'll probably be beneficial to reduction of the damage of the phone for the battery to be disengaging.

The purpose of this study is to optimize the shape of the battery locking knob during the drop-impact test at a height of 30cm. The design variables are the width and the thickness of the locking knob. These variables are mainly affected the separation between the main part and battery of the phone. The optimum design is performed using RSM (response surface method) in the LS-OPT. To investigate the effectiveness of the RSM model considering the cost and the quality of the solution, the approximate function of the response is used to three types of linear, elliptic and quadratic. LS-INGRID is used to parameterize the design variable. The shape of the locking knob may be changed during the optimization process.

APPROACH

Analysis Model

The analysis model of cellular phone is shown in Figure 1. The cellular phone is composed of front part, back part, battery, PCB, LCD and so on. The connection of parts is constructed using common nodes, rigid beam elements etc. The FE-model is made of two parts that one is the main parts generated from FEMB and the other is the locking knob generated from LS-INGRID. The locking knob is represented in Figure 2. The Battery pop-off is caused by bending deformation of the locking knob. It bends downward due to shock. And then, the locking knob loose contact with the rear part of the phone. We have to prevent the locking knob from separating for the 30cm drop test. The concept of shape optimization and the interface among LS-DYNA, LS-OPT and LS-INGRID is represented in Figure 3. The status of the model is summarized in Table 1.

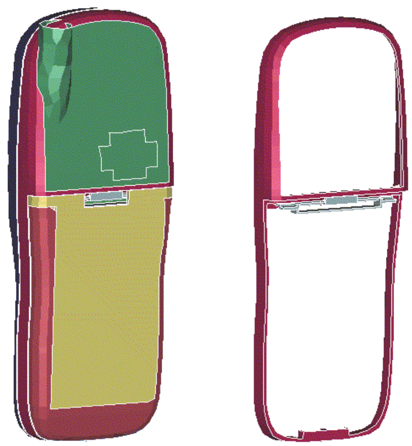

Figure 1 Cellular Phone Model

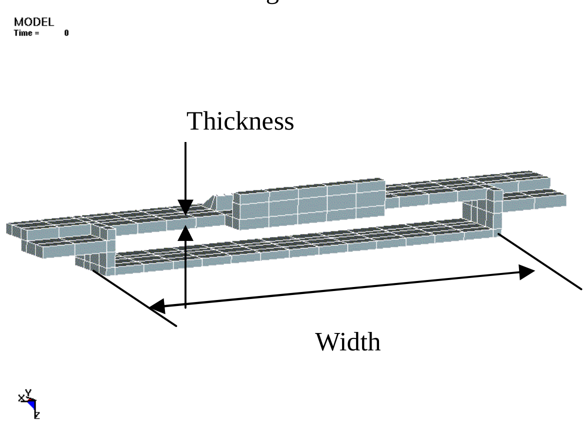

Figure 2 Locking Knob Model

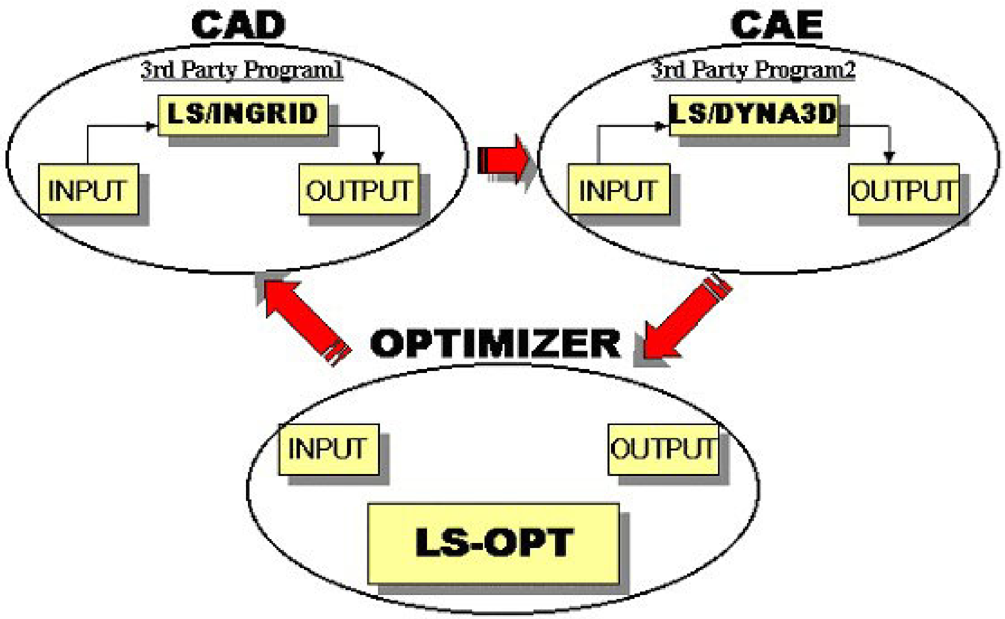

Figure 3 Shape Optimization Using LS-DYNA, LS-OPT and LS-INGRID

Table 1Summary of the Analysis Model

Item	LS-INGRID Model	Full Model
Block	192	3165
Node	470	6794
Part	1	29
Material Property	1	13

Initial Condition

The drop test of the cellular phone is performed in the free fall condition at the 30 ㎝ height. The initial condition is calculated as Equation (1).

$$v_0 = \sqrt{2gh} = 2.426mm/ms \qquad (1)$$

DISCUSSION OF ANALYSIS AND OPTIMUM DESIGN

Analysis Results of Initial Design

The result of the drop simulation at a height of 30cm before optimization is illustrated in Figure 4. The battery of the phone was separated from the main parts.

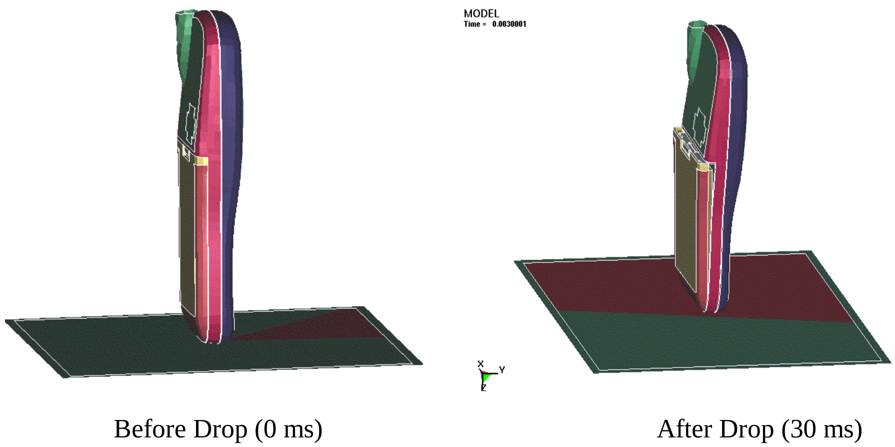

Figure 4 Free Fall Behavior of Phone before optimization

As we see the reason of separation in detail, Locking knob is moved backward depended on the elasticity of the material during drop-impact. Battery is separated when locking knob translates over the end of the rear case hook.

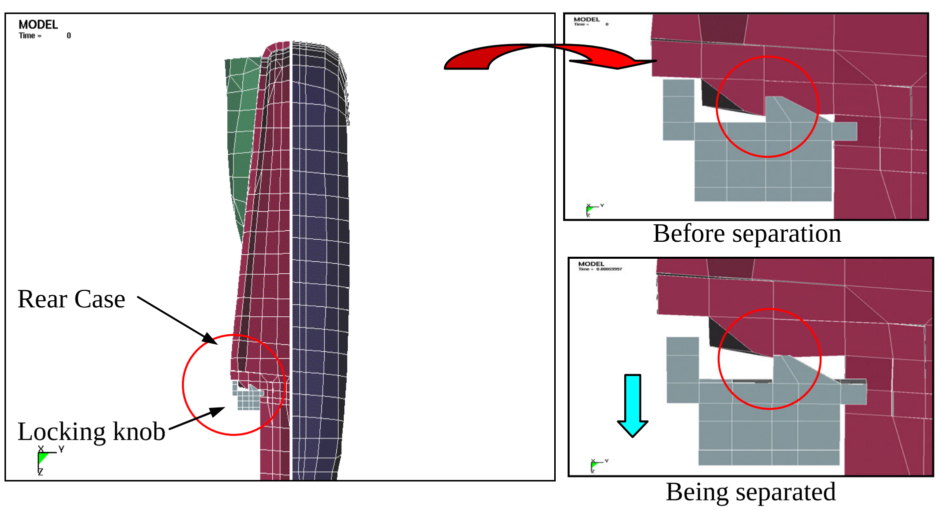

Figure 5 Description for separation

According to the simulation results, the separation occurs when the displacement of the node number 247 which is one of nodes of the locking knob is over 1.31 ㎜. There are several nodes at A area of the locking knob in figure 6. But their behaviors seem to be almost same like that of a rigid body. So, we decided to take node 247 as the representative node and only consider the displacement of that node. The position of the node 247 at the locking knob is in Figure 5. The time history of the node 247 is shown in Figure 6. And the maximum value of this graph is at 6ms.

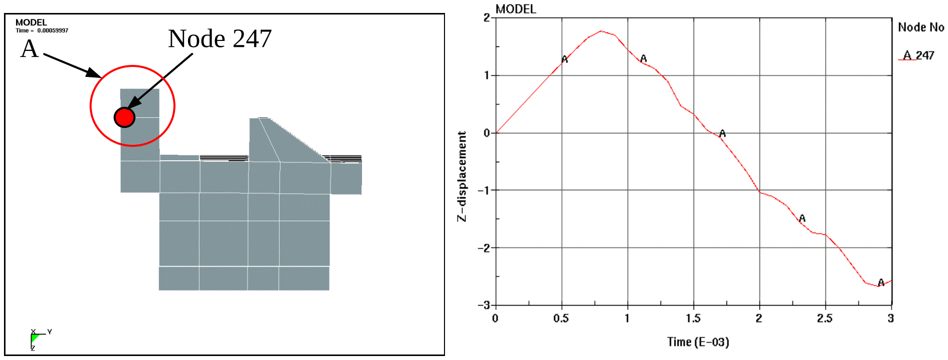

Figure 6 Time History of the Node 247 Displacement

Formulation of Optimum Design

The shape of the locking knob should be optimized considering the battery not to be disengaged from the cellular phone during drop-impact at the 30 ㎝ high. So, we have to keep the maximum of the displacement of 247 holding under the 1.31mm between 5.5995 ms and 7.1199 ms. We don't have to run this problem during the whole time because the maximum value occurs at 6ms. The formulation of the optimum design is described as Equation (2). Design variables are the thickness and the width of the locking knob. The design space of variables is summarized in Table 2 considered the range of product design.

$$Objective: \ Min\left[Max\left\{sqrt\left(Position247-1.31\right)^2\right\}\right] \qquad (2)$$

$$at \quad 5.5995\ ms \le t \le 7.1199\ ms$$

Table 2 Design Space

Description	Lower Limit (mm)	Upper Limit (mm)	Baseline (mm)
Locking Knob Width	9.5	15.5	13.5
Locking Knob Thickness	0.45	1.15	0.65

Results of Optimum Design

The approximation for the response surface model is composed of three cases such as the linear, the elliptic and the quadratic function. The results are listed in Table 3 through Table 8. As shown in Tables, the results seem to be same but the quality of the quadratic function is superior to others. The quality of the response model is obtained from the coefficient of determination, i.e., R^2. It is the value dividing the sum of squares due to regression into the total sum of squares due to variation. The coefficient of determination is described in Equation (3). Where, S_R is the sum of squares due to regression and TSS is the total sum of squares due to variation. As you know, the more the R^2 will be close to 1, the more the quality of the approximation of the response model will be increased. Compromising between the quality and the cost of the solution, the linear approximation function for the response model is available in this case.

$$R^2 = \frac{S_R}{TSS} \quad , 0 \le R^2 \le 1 \tag{3}$$

Table 3 Response Surface Approximation Using Linear Function

Mean Response Value	1.2825
RMS Error	0.0048(0.37%)
Maximum Residual	0.0058(0.45%)
Average Error	0.0046(0.36%)
R^2	0.9918
R^2(Adjusted)	1.0000
R^2(Prediction)	0.9147

Table 4 Results from Linear Function

Design Point				
Design Variable	Lower Bound	Value		Upper Bound
Thick	0.65	0.65		1.05
Width	10.5	11.92		13.5
Response Functions				
Response	Scaled		Unscaled	
	Computed	Predicted	Computed	Predicted
Pos247	1.313	1.31	1.311	1.31
Objective Function				
Objective	Computed	Predicted	WT.	
Displacement	0.0008	5.124e-05	1.0	

Table 5 Response Surface Approximation Using Elliptic Function

Mean Response Value	1.2805
RMS Error	0.0029(0.22%)
Maximum Residual	0.0049(0.38%)
Average Error	0.0026(0.20%)
R^2	0.9967
R^2(Adjusted)	1.0000
R^2(Prediction)	0.9764

Table 6 Results from Elliptic Function

Design Point				
Design Variable	Lower Bound	Value		Upper Bound
Thick	0.65	0.65		1.05
Width	10.5	11.92		13.5
Response Functions				
Response	Scaled		Unscaled	
	Computed	Predicted	Computed	Predicted
Pos247	1.311	1.31	1.311	1.31
Objective Functions				
Objective	Computed	Predicted	WT.	
Displacement	0.0008	5.59e-05	1.0	

Table 7 Response Surface Approximation Using Quadratic Function

Mean Response Value	1.2854
RMS Error	0.0008(0.07%)
Maximum Residual	0.0018(0.14%)
Average Error	0.0007(0.05%)
R^2	0.9997
R^2(Adjusted)	1.0000
R^2(Prediction)	0.9973

Table 8 Results from Quadratic Function

Design Point				
Design Variable	Lower Bound	Value		Upper Bound
Thick	0.65	0.65		1.05
Width	10.5	11.92		13.5
Response Functions				
Response	Scaled		Unscaled	
	Computed	Predicted	Computed	Predicted
Pos247	1.311	1.31	1.311	1.31
Objective Functions				
Objective	Computed	Predicted	WT.	
Displacement	0.0008	5.59e-05	1.0	

CONCLUSIONS

The optimum design using RSM (Response Surface Methodology) in LS-OPT has been adapted to obtain the optimum shape of a part of cellular phone during the phone drop. It is successful to apply the combination of LS-DYNA and LS-OPT for the phone drop-impact problem. This approach can be helpful for providing the opportunity to effectively design the phone.

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