

Study of Optimizing Sliding Door Efforts and Package Layout

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ABSTRACT

A sliding door is one of the car door systems, which is generally applied to the vans. Compared with swing doors, a sliding door gives comfort to the passengers when they get in or out the car. With an increasing number of the family-scale activities, there followed a huge demand on the vans, which caused growing interests in the convenience technology of the sliding door system. A typical sliding door system has negative effects on the vehicle interior package and the operating effort. Since the door should move backward without touching the car body, the trajectory of the center rail should be a curve. The curve-shaped center rail infiltrates not only the passenger shoulder room, but also the opening flange curve, which results in the interior package loss. Moreover, as the passenger pulls the door outside handle along the normal direction of the door outer skin, the curved rail causes the opening effort loss. In this study, we discuss not only how the curved center rail causes negative effects on the vehicle interior package and the manual operating effort, but also how to effectively improve and optimize the sliding door system. Moreover, we propose a new design concept of a convenient sliding door system. By applying a straight center rail and a latch with a multi-link structure, we were able to decrease the center rail infiltration. Also, the performance of getting on and off the 3rd row was improved, and the manual operating effort was improved about 60%.

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INTRODUCTION

As customers' life-style changes, automotive industry turns into a way of creating life values from a mere transportation itself. Moreover, people started to come up with the importance of a leisure time in their life and spend it dynamically. These changes caused automobiles to change into the ways of spending their leisure time, and the mini-van needs started to increase. The increase in mini-van needs resulted in a growing interest of a sliding door system which makes senior citizens as well as children easier to enter into or exit from the vehicle. And the automotive companies have been focusing on the sliding door systems.

SLIDING DOOR MECHANISM

A sliding door system consists of 3 rollers (upper, center, and lower roller) on the sliding door and 3 rails (upper, center, and lower rail) on the car body. Compared with a swing door system which rotates by one hinge axis, the sliding door moves along the 3 rail paths by 3-dimensional direction as in [Figure 1](#).

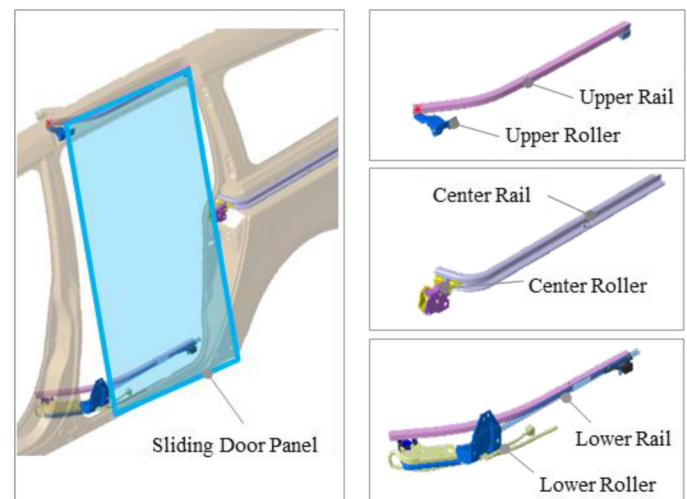


Figure 1. Sliding Door System Overview

STRUCTURAL LIMIT OF SLIDING DOOR MECHANISM

A sliding door should move along the longitudinal direction first so that it can move backward without touching the car body. So the center rail shape should be a curve and it necessarily infiltrates the interior package. This structural characteristic affects not only the interior package layout, but also the sliding door operating effort as in [Figure 2](#). As a sliding door engineering designer, this structural limit always comes to a challenging task.

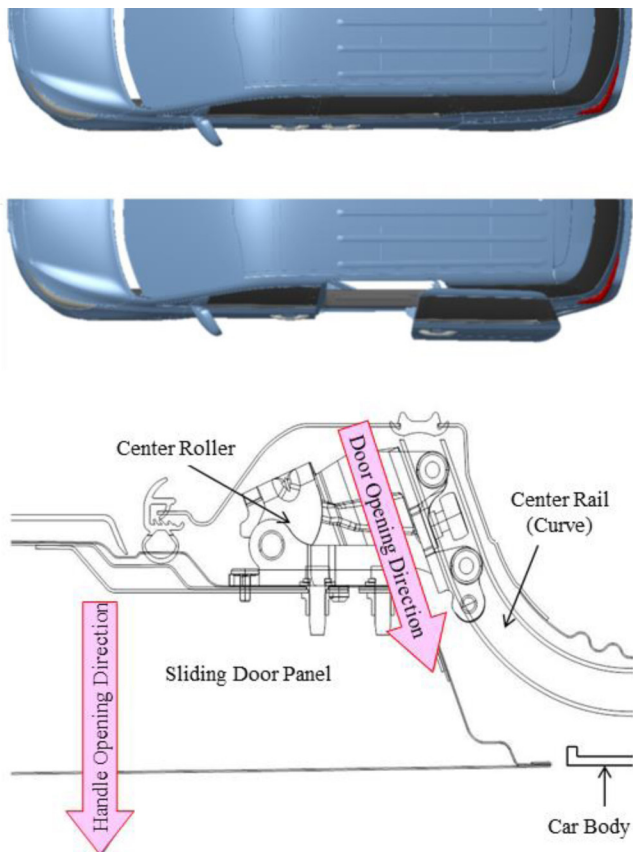


Figure 2. Opening Mechanism Near Center Rail

Interior Package Layout

The curve shaped center rail has no choice but to intrude into a vehicle room([Figure 3](#)), which causes the protrusion from the pillar trim([Figure 4](#)). So the shoulder room gets smaller, which causes a negative effect on the interior package space.

Moreover, the center roller should be located along the center rail path, which causes not only the step deviation of the 2nd row seat opening flange line([Figure 5](#)), but also the opening width decrease. So the ingress and egress performance of the 3rd row seat deteriorates.

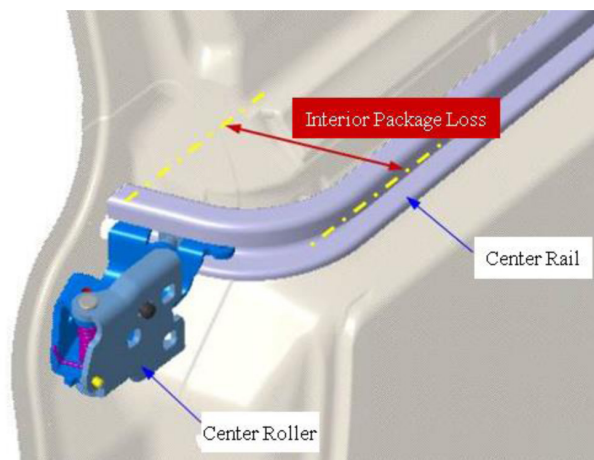


Figure 3. Package Loss; Interior Trim Protrusion Near Center Rail due to Curved Center Rail

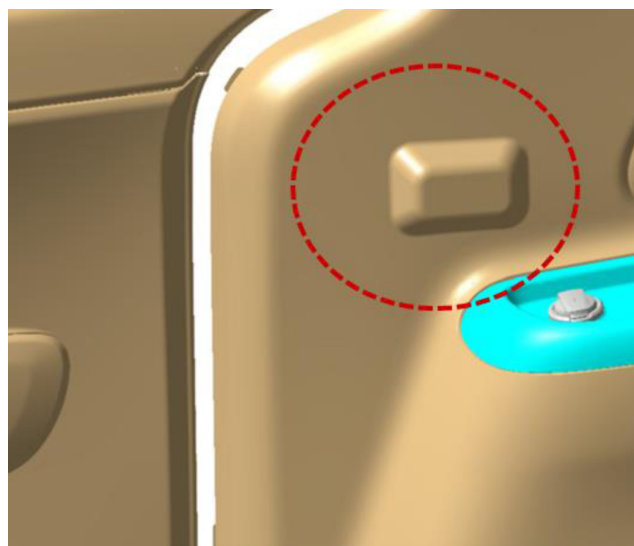


Figure 4. Pillar Trim Protrusion Case (While Developing KIA all-new Sedona)

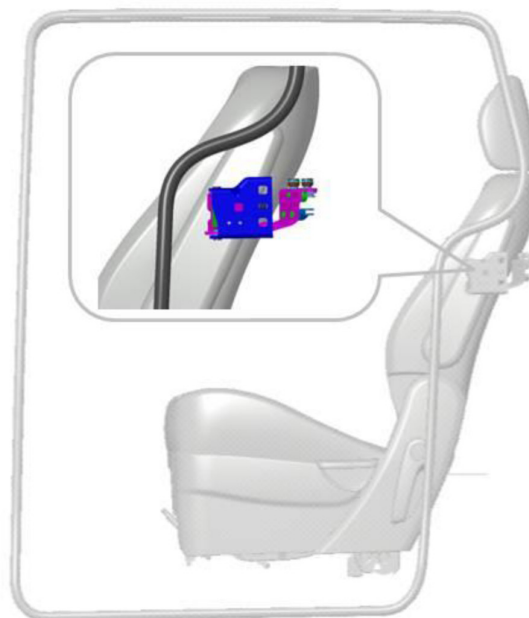


Figure 5. Step Deviation of the Sliding Door Opening Flange due to Curved Center Rail

Sliding Door Operating Effort

To investigate how much the center rail infiltration into the interior space negatively affects the sliding door operating effort, we mathematically analyzed the force engaged to the center roller. Figure 6 shows us the FBD(Free Body Diagram) of the sliding door system. Since the sliding door weight is sustained by center roller/rail and lower roller/rail, we did not consider the upper roller/rail in the FBD.

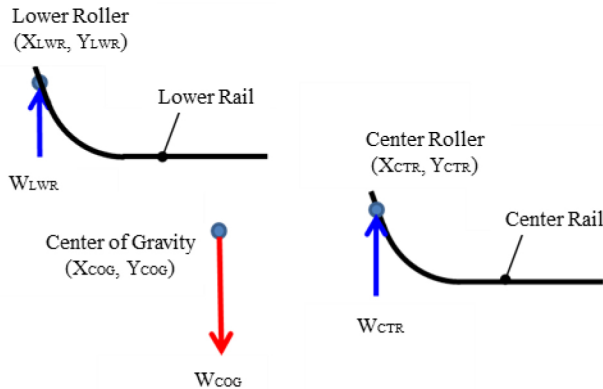


Figure 6. FBD(Free Body Diagram) of Loads on the Center Roller

$$0 = W_{CTR} \times (X_{CTR} - X_{LWR}) - W_{COG} \times (X_{COG} - X_{LWR})$$

$$W_{CTR} = \frac{W_{COG} \times (X_{COG} - X_{LWR})}{(X_{CTR} - X_{LWR})}$$

(1)

If we take W_{COG} as the sliding door weight engaged to the center point of the gravity, W_{LWR} as the weight engaged to the lower roller, and W_{CTR} as the weight engaged to the center roller, W_{CTR} could be defined as (1). Using W_{CTR} , we can calculate the friction force of the center roller bearing like (2).

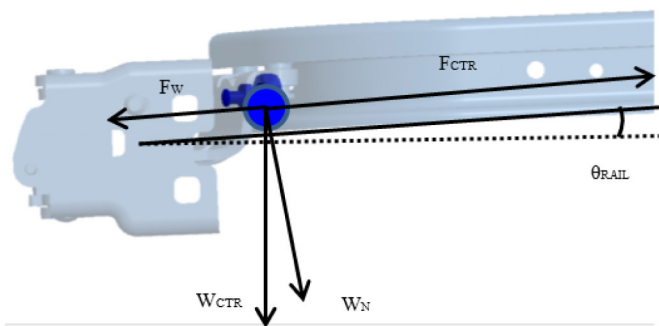


Figure 7. Friction Force on the Center Roller

$$F_{friction} = \mu W_{CTR} \cos \theta_{RAIL}$$

(2)

$$F_W = W_{CTR} \sin \theta_{RAIL}$$

$$F_{CTR} = F_{friction} + F_W$$

$$F_{CTR} = \mu W_{CTR} \cos \theta_{RAIL} + W_{CTR} \sin \theta_{RAIL}$$

(3)

So the minimum force to move the center roller attached to the sliding door could be defined as (3). θ_{RAIL} refers to the center rail slope on the side view, and μ refers to the static friction coefficient of the center roller bearing. If we apply F_{CTR} to the FBD, we can calculate the operating force like (4).

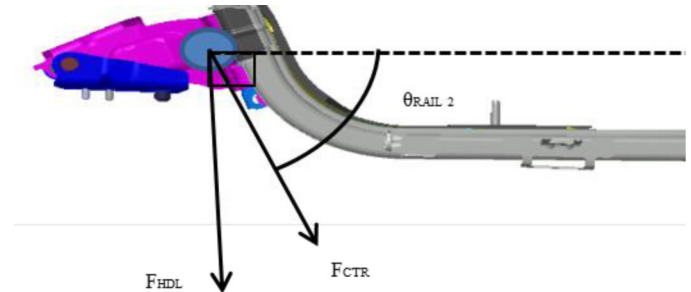


Figure 8. A Force to Open the Sliding Door (F_{HDL})

$$F_{HDL} = F_{CTR} / \cos(90^\circ - \theta_{RAIL2})$$

$$F_{HDL} = (\mu W_{CTR} \cos \theta_{RAIL} + W_{CTR} \sin \theta_{RAIL}) / \cos(90^\circ - \theta_{RAIL2})$$

(4)

Let μ and W_{CTR} as intrinsic values of the car(constant), and F_{HDL} as the force engaged on the outside handle when we open the sliding door. Then, F_{HDL} could be affected by θ_{RAIL} (the center rail angle on the side view) and θ_{RAIL2} (the center rail angle on the top view). However, we excluded θ_{RAIL} from the sliding door operating effort factors, because the decrease of θ_{RAIL} could result in the increase of the door closing force, even if the door opening force could get smaller. If we take a real case, we applied θ_{RAIL2} as 60deg to KIA All new Sedona. Then, F_{HDL} could be calculated as (5).

$$F_{CTR} = F_{HDL} \times \cos 30^\circ = F_{HDL} \times 0.866$$

(5)

So, if we open the KIA All new Carnival sliding door, F_{HDL} (the force on the outside handle when we open the sliding door) would be decreased about 13% compared to F_{CTR} (the minimum force on the center roller to open the sliding door). Here, we supposed F_{CTR} as an intrinsic coefficient of the sliding door itself. Therefore, the curved center rail always results in the sliding door manual operating effort loss.