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Optimization of the strength design for recliner connected structure on the folding headrest in a static load

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Abstract- The main purpose of functional seats in RV is to maximize space within the vehicle. Seat arrangement and types have become diversified for more efficient space utilization, especially in vehicles with higher passenger capacity such as minivans. This study designed an operating mechanism for a new headrest height adjustment device, linked to the recliner mechanism of auxiliary seats, and tested its performance using CAE analysis techniques

Optimal dimensions were obtained from an analysis of factors affecting deformation and stress, and the FMVSS202a standard was satisfied by the proposed recliner-linked headrest. A regression equation was derived in consideration of design factors, and a structural analysis was performed on the link structure of the optimized recliner-linked headrest. The optimal dimensions of the connecting unit were verified through a comparison of maximum deformation and maximum stress before and after optimization.

Keywords: Headrest, Assistance seat, Optimization, Strength design, Recliner connected structure

Introduction

Recently, improved working conditions and higher income have led to an increased demand for recreational vehicles (RV). This consumption trend can be traced to sociocultural changes such as a rapid increase in owner drivers, the transition to nuclear families, and family-oriented leisure activities(1)

The main purpose of functional seats in RV is to maximize space within the vehicle. Seat arrangement and types have become diversified for more efficient space utilization, especially in vehicles with higher passenger capacity such as minivans. Foldable auxiliary seats are usually folded for passengers to easily move between seats, and can be returned to the upright state to be used as extra seats when there are more passengers. Other uses of foldable seats include armrests and seat back tables.

Vehicles are equipped with safety devices such as airbags and pre-crash sensors to minimize injury in case of accidents. The headrest provides protection for the neck, but it is not attached to most auxiliary seats. As such, it is essential to develop headrests to protect the necks of passengers in auxiliary seats.

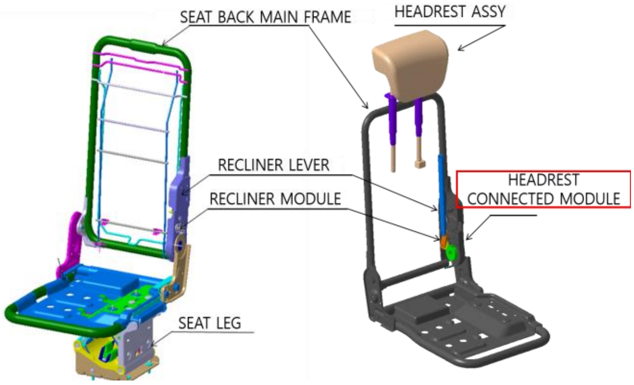
If a headrest is introduced to the existing folding and unfolding mechanism of an auxiliary seat, it may result in interference with the seat in front. The headrest should be connected to the recliner mechanism, so as to enable folding and height adjustment simultaneously with folding of the seat back.

Many studies have been conducted to improve passenger comfort in vehicles. M.K. Shin et al. analyzed the effects of design variables such as seat back stiffness, backset, and contact time on neck injury based on passenger behavior(2), while J.H. Choi et al. proposed a lightweight, shock-resistant Dynamic Locking Tongue (DLT) device by generating a finite element model and performing optimization to minimize weight and stress(3).

This study designed an operating mechanism for a new headrest height adjustment device, linked to the recliner mechanism of auxiliary seats, and tested its performance using CAE analysis techniques(4). Optimal dimensions were obtained from an analysis of factors affecting deformation and stress, and the FMVSS202a standard was satisfied by the proposed recliner-linked headrest. A regression equation was derived in consideration of design factors, and a structural analysis was performed on the link structure of the optimized recliner-linked headrest. The optimal dimensions of the connecting unit were verified through a comparison of maximum deformation and maximum stress before and after optimization.

2. Design of recliner-linked mechanism

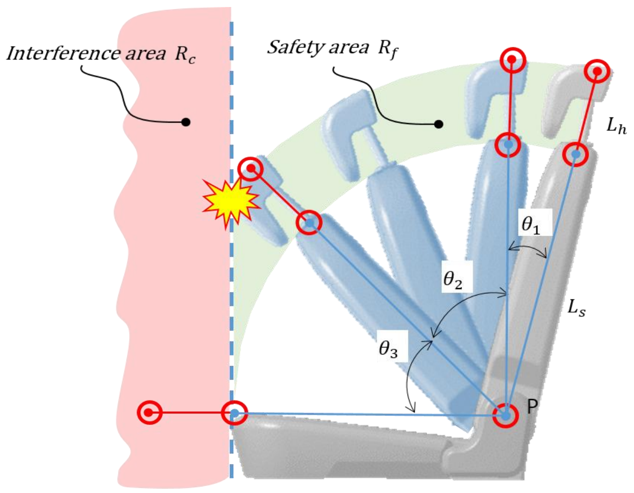
2.1 Kinematics modeling



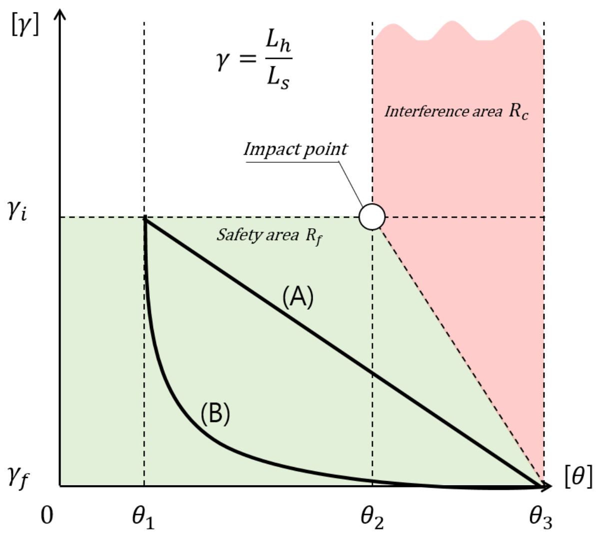
(a) Conventional seat (b) Development seat

Fig. 1 Seat frame structure

When attaching a headrest to an auxiliary seat, there should be a mechanism that determines the permitted folding angle of the headrest and enables folding within that range



(a) Interference pheonomenon in folding



(b) The length ratio of seatback and headrest

Fig. 2 Interference pheonomenon on the seat design parameters

Fig. 2 shows the seat of withdrawal and containment procedures. As shown in (a) in consideration of the interference region, such as front-seat requires a design mechanism. Fig.2 (b), it shows the design safety sector and the interference region according to the ratio of the length of the seat back and headrest length. Wherein the L_s, L_h and θ_1, θ_2, θ_3 seat back length, respectively, headrest length, rotation arbitrarily set for the convenience of passengers each, the headrest stored in the ideal angle range indicates a rotation angle at which the problem occurred it is not stored in the headrest

Fig.2 (b) shows the method for converting the rotational motion of the reclining liner, as shown in A in linear motion of the headrest, by using the rack and pinion gear, the method of changing the direction of the force , as in the B, using the wire , there is a method to draw the reclining liner rotation at the headrest .

This methods, since the size of the reclining liner gear is relatively large, there are space constraints, because the seat is required additional equipment, such as a spring for restoring the position of the drawer when the headrest design there is a problem that is complicated.

There are respective mechanisms Kinematic advantages and disadvantages, ease of manufacture , in consideration of the simplification of parts , in the present study , This study have proposed a height adjustment mechanism using links and recline liner gears.

2.2 Headrest height adjustment mechanism

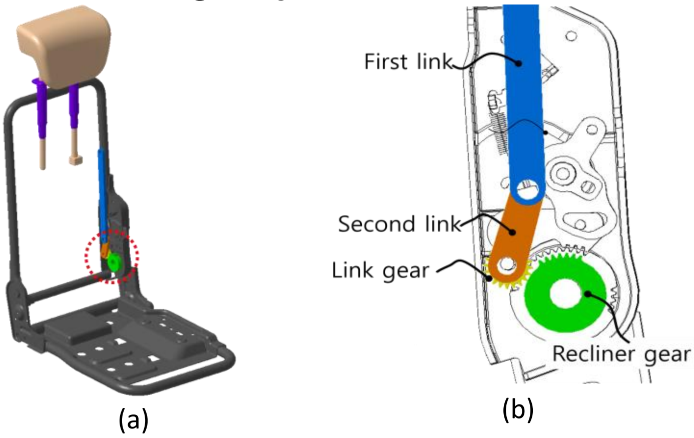


Fig. 3 Modeling of height adjustment mechanism

Fig.3 shows the headrest height adjustment mechanism integrated with the link mechanism. Fig. 3(a) gives the position at which the height adjustment mechanism is applied, and (b) shows the names of components in the connecting unit. The link rotates according to the rotating angle of the seat back, and the headrest-connecting link engages in up-and-down motion.

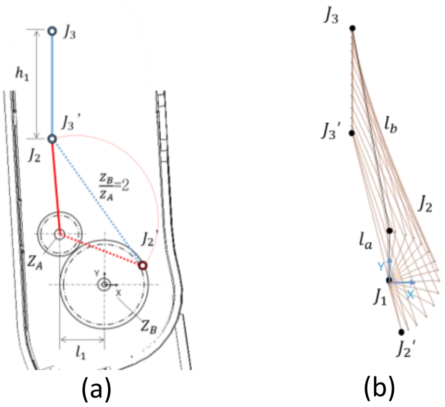


Fig. 4 Simulation of link motion in a recliner case

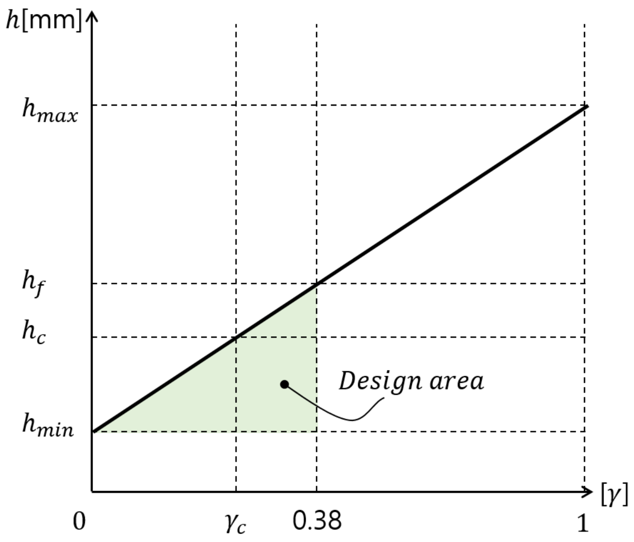


Fig. 5 The length ratio of link mechanism

Fig.4 shows the trajectory when the link mechanism is applied for height adjustment of the headrest. The method in Fig. 4(a) widens the rotating angle using a gear ratio of 2:1, while Fig. 4(b) reviews interference with other components based on the trajectory analysis. J_1, J_2, and J_3 respectively represent the center of rotation of the recliner and connecting gear, the center of rotation of the link, and the edge of the headrest pole.
In Fig. 4, the headrest becomes completely folded as J_3 moves to J_2' while J_2 rotates to J_2'.

Fig. 5 is a graph of the relationship between the two links and the headrest length variation ratio designed. Height adjustable headrests are standard on the FMVSS202a because it is 800mm from 750mm H-point can be defined based on the design area

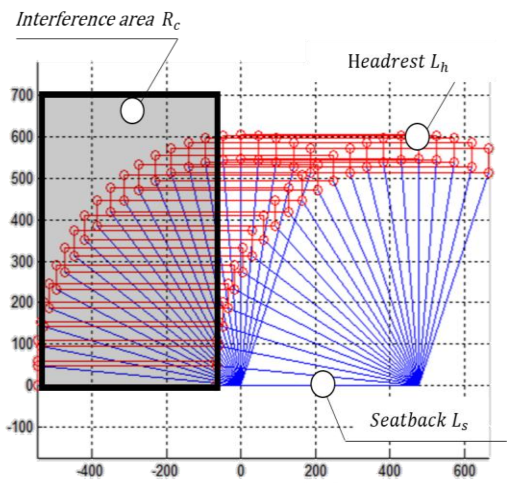


Fig. 6 Simulation of mechanism

Fig.6 is a simulation of a wire frame of seatback and headrest height adjustment mechanism to apply the seat, and represents the cumulative moving distance of the rotation. Set the collision area and examined the intersection with the headrest. If the intersection is generated and the impact point, deriving a ratio of the length of seatback and headrest collision does not occur. In addition, it is possible to derive the ratio of the length of the connecting link. Recliner interlocking headrest through the simulation showed that the interference is not Occurs.

3. Structural design and analysis of link mechanism

3.1 Finite element modeling

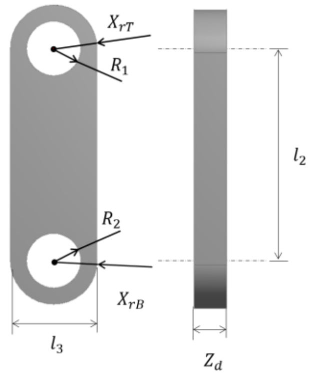


Fig. 7 Link design parameters

Fig.7 is a link connection. In the previous section, prior to the initial design was used to derive the value of the length (l_2) of the link. To prevent damage and malfunctioning from repeated up-and-down motion of the headrest, a finite element analysis was performed on the connecting unit. Each variable was designed with reference to maximum values associated with recliner components

3.2 Analysis condition and result

According to provisions for height maintenance under the FMVSS202a standard, an adjustable headrest with a locking mechanism must pass a height test, which permits a maximum deformation of 13 mm when subject to a moment of 500 Nm for 5 seconds.[5] When a vertical load is applied at the topmost position of the headrest, the recliner is subject to a maximum moment of 500 Nm. Since the length of the link modeled for the FEM analysis was 38 mm, the load was 13,158N. The maximum deformation was kept within 13 mm

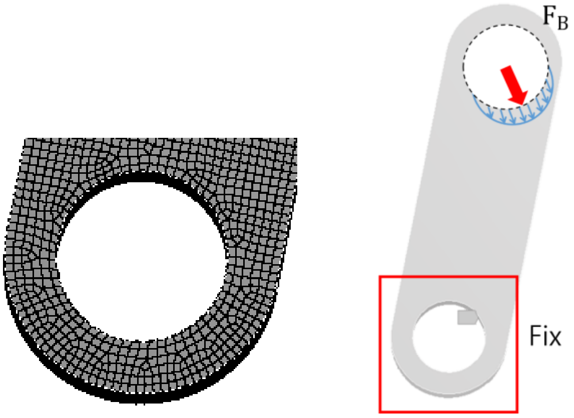


Fig. 8 Mesh and force condition

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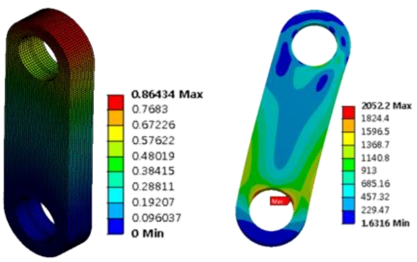
Table 1 Model data and input force

name		unit	value
mesh	nodes	EA	96,412
	elements	EA	19,352
	size	mm	0.5
	type	hexahedral	
load		N	13,158
young's modulus		MPa	200,000

Fig.8 shows the analysis conditions of the finite element analysis. The analysis was performed in accordance with the FMVSS202a standard. Table 1 presents details of the conditions used in the analysis



(a) Deformation (b) Bending Stress

Fig. 9 Analysis result

Fig.9 Shows the stress value as shown in the initial 2,052 [MPa], the deformation was confirmed to 0.86 [mm]. Analysis deformation design goals, but interpret less than 13 [mm] of a safety factor (S = 3) taking into account the 4.3 [mm], because the stress value is relatively high dimensional optimization of the parameters that is needed

4. Optimization

4.1 Optimization of Dimensions

Using general full factorial design, this study designed an optimal shape for the connecting unit of the link mechanism of the adjustable headrest to minimize deformation and stress in relation to the load proposed in the FMVSS202a standard. Fig.7 shows the design parameters. The maximum thickness (l2) of the recliner was set as 12mm. The range of optimization was determined by considering the interference with other recliner components when the width of the link (X_{rT}, X_{rB}) is greater than 17mm. The optimization problem is thus defined by Eq. 1

(Second Link Length) $l_2<39$
(Top and Bottom Diameter) X_{rT}, X_{rB}, <16
Subject to
Minimize Total Deformation (D_t)
Minimize Equivalent Stress (1)

In the formula (1), Interference with other parts inside the recliner occurs when the length of the link is greater than 39 mm, the width of the link, even if it exceeds 16mm interference occurs.

Among the design factors shown in Table 2, levels were set for three design parameters and three design variables that were regarded to be of higher importance. The full factorial experiment was performed a total of 27 times for three factors and three levels. After normalizing the maximum deformation and maximum stress, the regression model function D_t was derived as given in Eq. 2

$$D_t = 2.097 + 0.06485 l_2 - 0.1338 X_{rT} - 0.1026 X_{rB} \quad (2)$$

Table 2 Design variables and values at each level

parameter	level		
	1	2	3
link length l_2(mm)	31	35	39
link top diameter X_{rT}(mm)	12	14	16
link bottom diameter X_{rB}(mm)	12	14	16

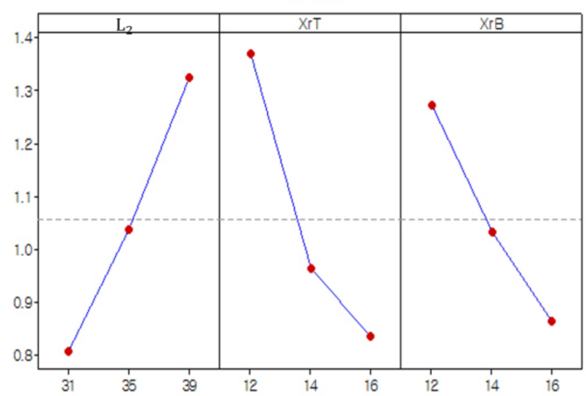


Fig. 10 Main effects plots for deflection

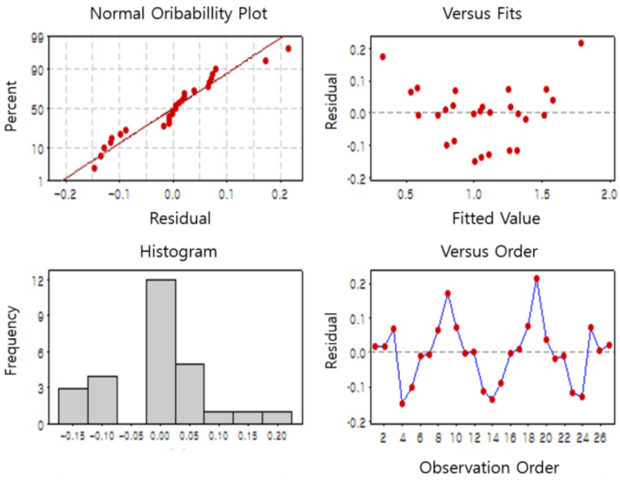


Fig. 11 Residual plots for deflection

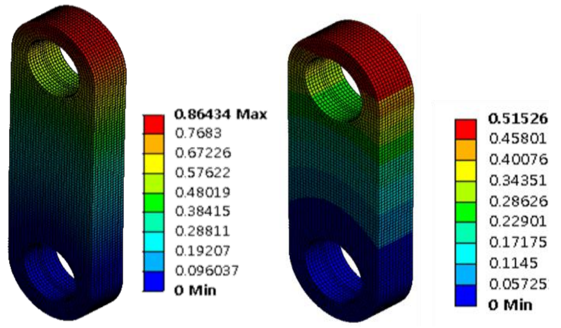
From the main effect analysis for maximum deformation in Fig.10, can identify the factors having a more significant influence. Fig.11 is the residual graph used to assess the accuracy of simulations. A distribution analysis table was drawn as shown in Table 3 to test the reliability of the regression model function. The derived model function was found to be significant with a p-value of 0.000 for l_2 and 0.063 for X_{rT}. This implies that the model functions can be used as objective functions for optimization within a confidence interval of 94.07%

Table 3 ANOVA table for the link

source	SS	MS	F	P
L_2	1.211	1.211	135.6	0.00
X_{rT}	1.289	1.289	144.4	0.00
X_{rB}	0.757	0.757	84.85	0.00
error	0.205	0.008		
total	3.462			
S=0.0945	R-Sq=94.07%		R-Sq(adj)=93.30%	

4.2 Results and Discussion

General full factorial design of the design of experiments was used to identify optimal design variables that minimize the objective function. Fig.12 shows the values before (Fig.12(a)) and after optimization (Fig.12(b)). As given in Table 4, the maximum stress dropped by 31% from 2052 MPa to 1601 MPa, and the maximum deformation by 32% from 0.86 mm to 0.51 mm.



(a) Initial (b) Optimization
Fig. 12 Compare initial with optimization

Table 4 Results of the design optimization

parameter	initial	optimum
l_2 (mm)	39	31
X_{rT} (mm)	16	16
X_{rB} (mm)	16	16
total deformation (mm)	0.86	0.51
equivalent stress (MPa)	2,052	1,558

4. Conclusion

This study proposed a recliner-linked headrest mechanism with height adjustment for auxiliary seats in vehicles. Using the link structure so that the headrest can be interlocked with the operation of the recliner and finite element analysis was performed in accordance with the FMVSS202a standard to assess the validity of the design. Residual analysis and model function is derived from the variance analysis table was determined that significant In addition, optimized the link structure of the general geometric dimensions value through full factorial design

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Conclusion

In this paper we introduced the framework for recharging the sensor nodes by sensors. This approach increases the longevity of the network. Simulation are performed to evaluate the performance of the proposed system in large scale network, and it shows the significant performance gains with respect to various metrics such as average response time, delay and network lifetime. The energy information of sensor nodes can be received by sensors in faster manner, and thus nodes are recharge soon. Thus the lifetime of the wireless sensor network has been prolonged.

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