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Design of Heavy Weight Door Hinge for Built-in Appliances

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빌트인 가전기기용 고 중량 도어힌지의 설계에 관한 연구

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ABSTRACT

In this study, the hinges of heavy weight doors were designed and analyzed in line with the trend that built-in appliances are becoming larger and the weight of doors is also increasing. The main specification of the heavy weight door hinge is to allow the deflection at the end of the door to be less than 2 mm when opening and closing, including the automatic closing, slow closing, and closing force control functions. The structural analysis of the design mechanism, component design, and methods for improving the deflection are as follows:
1) Mechanism of the automatic closing function should sense automatically using the spring compression force at a specific angle by the contact between the cam and the cam module roller. 2) Through structural analysis, the maximum stress of the door was found in the link pin hole connected to the pin at each link. 3) Consequently, the pin holder was designed and applied, with little variance, but up to 93% of the specification limit.

Key Words : Built-in Appliances(빌트인 가전기기), Hinge Mechanism(힌지장치), Door Hinge(도어힌지), Heavy Weight Door(고중량 도어)

1. Introduction

When purchasing houses and apartments, more and more people are buying houses with home appliances and furniture, and the market for ‘built-in’ appliances, is expanding.

The Buildings with built-in appliances are gaining popularity mainly among single people who pursue a comfortable life as the number of residential complex officetels equipped with all facilities is increasing. However, this industry is still in its infancy, and its potential for growth is unlimited. As domestic conglomerates are busy attempting to preoccupy the market, and consumers who value space design, interiors, and prefer built-in home appliances that can be placed in furniture and spaces are increasing, the number of home

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appliances manufacturers demanding heavy doors is also increasing. This creates a situation in which various functions and durability of doors is required. In this study, mechanism and parts designs for each function were conducted for the hinge design that required an automatic closing function, slow opening and closing functions, and durability of opening and closing 100,000 times according to the demand of home appliances manufacturers for the hinge of the heavy weight (110 kgf) door of the built-in home appliances. Additionally, stress and deformation were reviewed through structural analysis.

2. Hinge Case Study and Design Specifications

2.1 Case study of structural analysis of a hinge

Lee[1)] evaluated the extent of deflection of the door through structural analysis of the lower freezer door of a built-in refrigerator. A factor analysis model was constructed and the deflection of the door evaluated by comparing the analysis results with the experimental measurement results. In this case, door weights of 5 and 10 kgf were used, and the deflection of the door of a general built-in home appliance was evaluated. In the application of the door hinge for large vehicles, Yang[2)] explained the variance between forged and press parts with the optimal design using the DFSS technique. The results of the fatigue life using ANSYS for design improvement to solve the problem of damage to the hinge lever-part of the damping hinge used in the built-in double-door refrigerator were reported by Lee[3)].

2.2 Structural analysis of hinge

Kim[4)] analyzed the characteristics of single- and multi-stage molding using the finite element method for the process of manufacturing **pins** separately from the **brackets** and combining them. The results of this study indicate that wrinkles do not occur owing to a multi-stage molding process rather than because of a single molding phenomenon in which pin buckling occurs. In addition, Jin[5)] et al. studied container door hinge mounting that automatically engages the hinge mounting by designing a common hinge loading gripper with automatic assembly of hinge mounting. There has been extensive research on hinge design and manufacturing processes, but the hinge design of heavy-weight doors employed in built-in home appliances is still a challenge. Therefore, it is necessary to develop a high design concept that provides strength, stiffness, automatic closing function, and damper control function within a small volume range.

2.3 Design specifications for heavy weight door hinges

The design mechanism specifications of door hinges should satisfy the following three specifications: automatic closing function, slow closing function, and deflection limitations after door installation.

1) Automatic closing function – the door automatically closes at a certain angle even if there is no external force when the hinge is closed. Particularly, users should be able to select automatic closing functions according to their application (ON or OFF states). The automatic closing function was designed to be easily installed in the OFF state and switched to the ON state to reduce the risk of automatic closing during installation and increase convenience. Additionally, it was designed to adjust the closing force in a simple manner by providing an automatic closing force regulation function.
2) The slow closing function (damper control function) allows smooth closure at a certain angle to mitigate the impact of the door when

the hinge is automatically closed. Additionally, it was designed to be suitable for installation conditions that require the sealing force of the door. Particularly, depending on the closing angle of the door, it was designed to maintain the closing force in a 3-stage section, with the 1st stage being stage free operation, 2nd stage damping operation, and 3rd stage free operation.

3) As shown in Fig. 1, the limit of deflection after door installation is the most significant specification of a heavy-duty door. In the hinge design of a door weight of 110 kgf, the deflection of the door end was designed to be less than 2 mm. Additionally, the design limits the extent of deflection of the door end to within 2 mm after 100,000 times of opening/closing durability tests. The door opening angle was designed to be 115°. It was also designed as a multi-link type during installation to prevent finger pinching and press processes. Table 1 lists the hinge design specifications for heavy-weight doors.

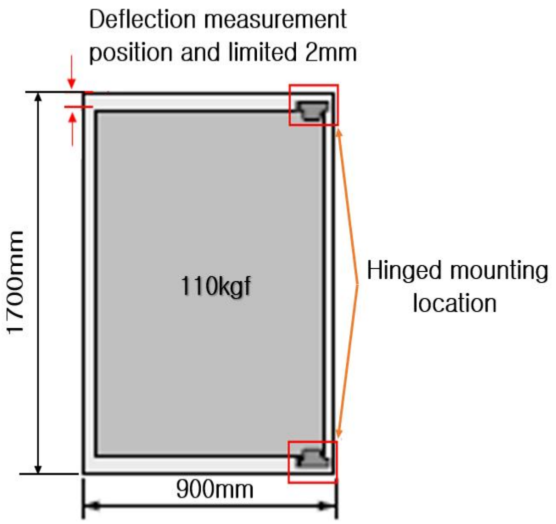


Fig. 1 Positions of hinge mounting and deflection measurement

Table 1 Specification for hinge design of heavy weight door

Contents	Specification
Door weight	110kgf
Door Deflection	2mm under at end point of door
Open angle	115°
Structure	Multi links of press process
Special functions	Auto closing
	Auto closing ON/OFF
	Soft closing
	Closing force adjustment
	Prevent finger entrapment

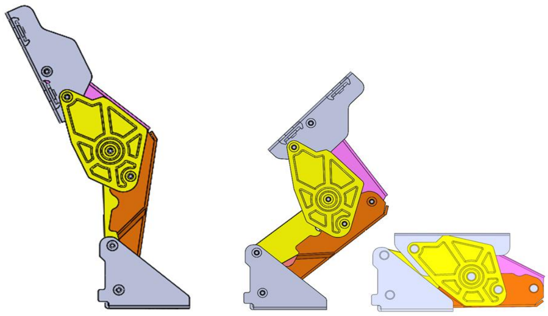
3. Hinge Design and Structural Analysis Results

3.1 Hinge mechanism design of a heavy-weight door

A mechanism for multi-links was designed using two sets of four-link systems, as shown in Figure 2 (a) shows the hinge operation state when the door is opened at 115^{o} Figure 2 (a) shows the hinge operation state when the door is opened at 115^{o}.

1) Implementing an auto-closing mechanism

As shown in Fig. 3, the automatic closing mechanism of the door was implemented using Cam. A cam roller was installed at the end of a spring module that implements the force required for automatic closing at the link in the door, and a cam was attached to the middle link to adjust the force of the cam roller and cam contact until they reached a certain angle. Figure 4 shows an assembly diagram of the automatic closing module. The door closing force can be adjusted such that it does not close at all. Rotating the regulator changes the force exerted on the roller according to the compressive force of the spring, thereby allowing the adjustment of the door closing force. Additionally, automatic closing does not work because the compressive force of the spring is not transmitted when released to the maximum



(a) Open (b) Auto closing start (c) Closed

Fig. 2 Hinge mechanism for high weight door of builtin home appliance

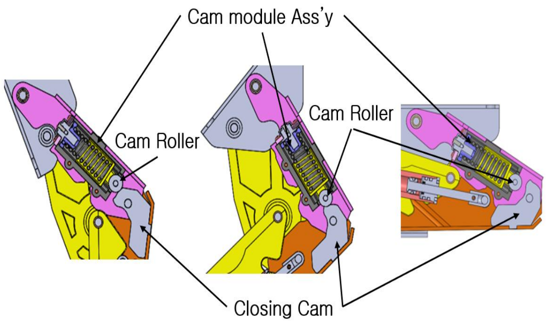


Fig. 3 Auto closing mechanism

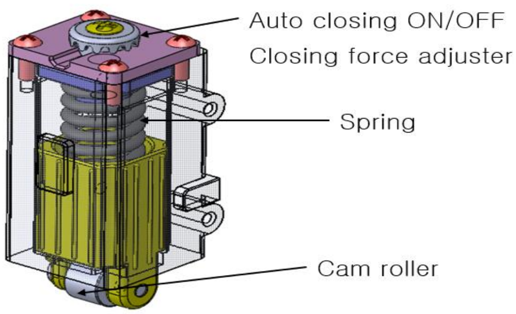


Fig. 4 Auto closing module assembly

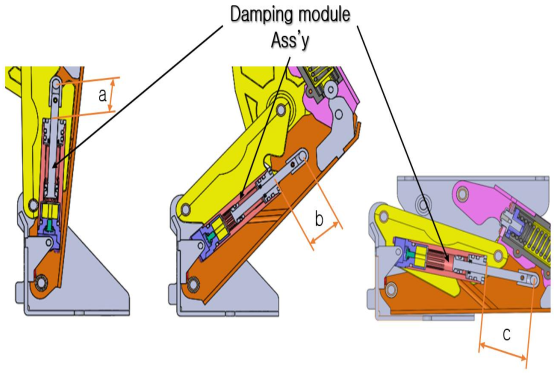


Fig. 5 Damper mechanism for soft closing

2) Design of the slow closing function

Typical methods for the design of the slow closing function of hinges are the buffering effect induced by the spring and the damping effect induced by the orifice. In this study, we applied a method to utilize the damping effect using the orifice pass resistance of the latter fluid. As shown in Fig. 5, a damping module was constructed, which passed through the fluid with an orifice using cylinders and pistons. In the open state, the damping resistance is zero because the piston is located on the lowest side, and at a certain angle as closure begins, the piston rises, resulting in orifice movement of the fluid from top to bottom. At this point, damping resistance occurs, causing the door to close smoothly and slowly. Fig. 5, (a) for opening, (b) automatic closing, and (c) closing, indicate the position of the damping piston rod for each position, respectively.

3) Hinge design to reduce door deflection

The built-in, heavy-weight door hinges consist of a body-mounted bracket, two four-link systems, and a door-mounted bracket. A damping module is attached to the body part link, and an automatically closed module is attached to the link close to the door part. Seven pins are connected to each link, and pins are connected to the link in the hinge

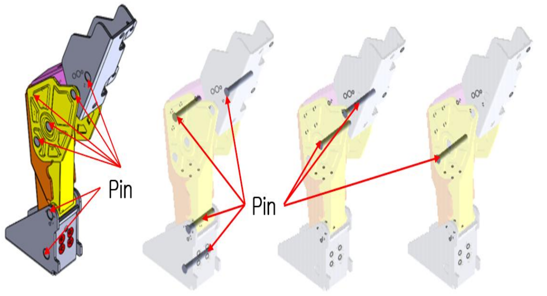
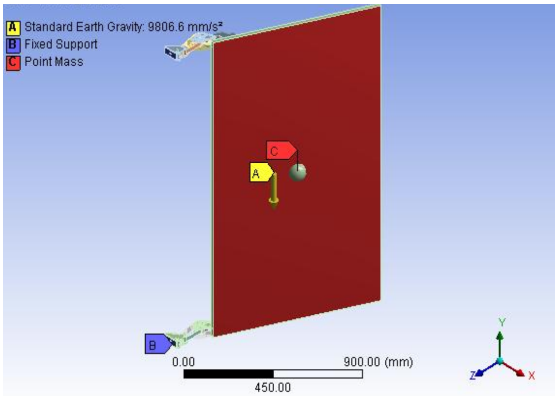


Fig. 6 Position of pins in hinge assembly

assembly, as shown in Fig. 6. As a design method for door deflection, the gap between the pin and link connection was expected to be more effective than the effect of door deflection due to the mechanical properties of the material. Therefore, structural analysis was performed using ANSYS.
As shown in Fig. 7, a width and length of 900 and 1700 mm, respectively, with a weight of 110 kgf was employed for the door specification, and a boundary condition to hold the base of the bracket fixed to the body was evaluated as 284,519 mesh elements and 546,318 mesh nodes. Structural analysis revealed the maximum stress of each link and the displacement of the door end.

3.2 Structural analysis results

Structural analysis of the hinge was performed for maximum stress and displacement. It was observed that all pin holes in each link exhibited maximum stress, which might be ultimately associated with the deflection of the door. Thus, the deflection of the door was believed to be determined at the connection interval between the pin and link, indicating the consequence of the deflection of the door in relation to the pin and link hole. Figure 8 shows the greatest stress in the pin hole of the reinforcement link located at the center. The other links similarly exhibited the greatest stress in the pin hole. Figure 9 shows the results of the structural analysis of door deflection. The result was a 0.02 mm gap between the pin and pin hole of the link, with a maximum deflection of 1.789 mm. In general tolerances, the gap between the pin hole of the link and pin hole of the pin is 0.08 mm, and in the present study, the stress and deflection were determined 0.02–0.08 mm spacing. Additionally, Fig. 10 showed the maximum stress acting on each link based on the pinhole gap of the pin and link. The maximum stress has a lower value as it is insignificant to the relationship between the pin and link pinhole spacing. However, as it was valued between 60 and 65 MPa, it can be observed that the gap is safe in terms of strength (yield strength of material 180 MPa) even within the range of general tolerances.



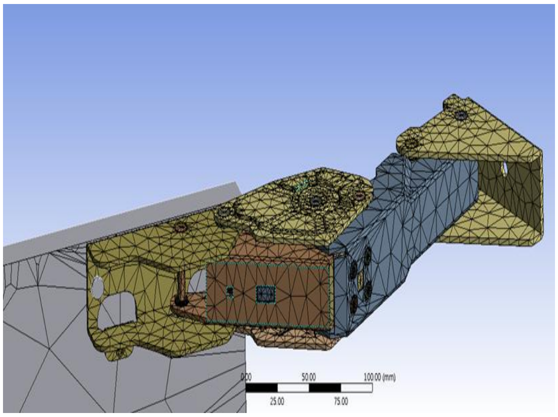


Fig. 7 Structure analysis of door hinge ass'y

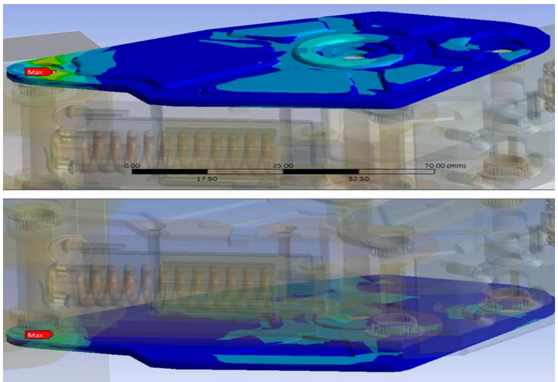


Fig. 8 Results of maximum stress by structure analysis

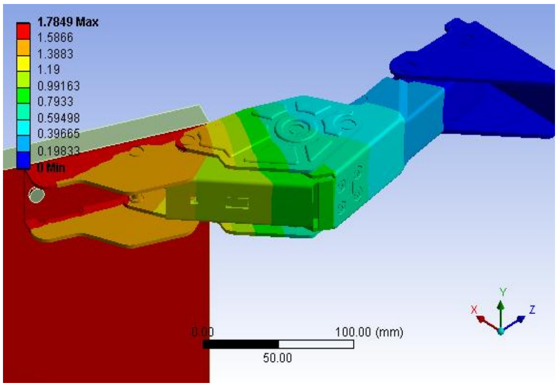


Fig. 9 Results of maximum deflection by structure analysis

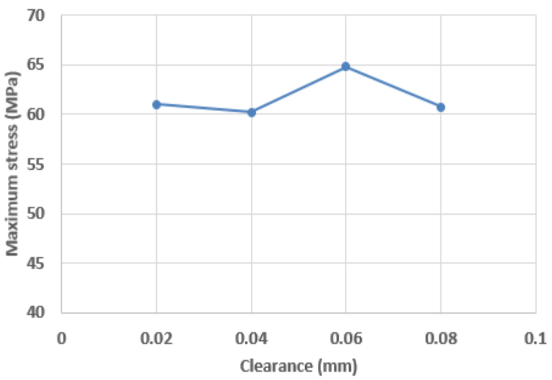


Fig. 10 Relationship between pin and link pin hole clearance and maximum stress

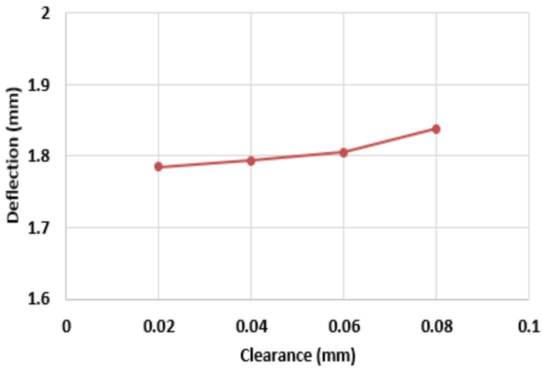


Fig. 11 Relationship between pin and link pin hole clearance and door deflection

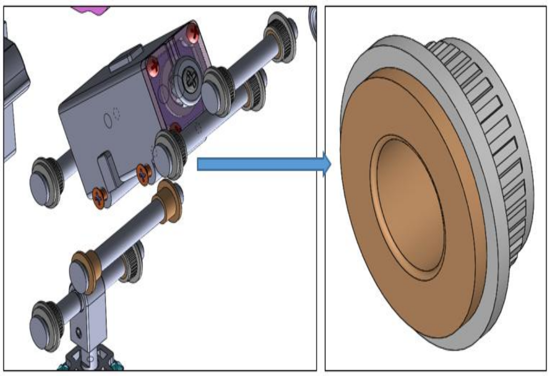


Fig. 12 Pin busing for small deflection

Figure 11 shows the pin hole gap between the pin and link and the maximum deflection of the door. The larger the gap, the greater the extent of deflection. However, even in the range of general tolerance, the deflection was observed to be less than 2 mm, which is the limit value of the door opening. The analysis results exhibited up to 93% of the deflection limit of 2 mm; thus, a new method is necessary. Therefore, a novel concept was applied to the hole of the pin and link.

3.3 Combination of pins and links

Generally, a hole is machined in a link made by a press, and a pin is used to connect with other links. In this study, the connecting part of the pin was designed, as shown in Fig. 12. Because only the thickness of the material of the link is to be connected to the pin, parts similar to bushings are connected to widen the contact area of the pin tube. It may be possible to machine the gap precisely with the pin. Both end supports were designed to reduce the amount of deflection as a fixed beam type, not a simply supported beam type, and to make vertical contact up to the pin head.

4. Conclusion

As built-in home appliances become larger, it is critical to design hinges for heavy-weight doors in line with the trend of heavy doors. The main specifications of a heavy-weight door hinge are to ensure that the deflection is less than 2 mm when opening and closing at the end of the door, including automatic closing, slow closing, and closing force control. The following are the conclusions of the structural interpretation of the design mechanisms, parts design, and methods for improving deflection:

1. The mechanism of the automatic closing function is automatically closed using spring compression at a certain angle by contacting the cam and cam module rollers, but after a specific angle, the cam and cam module rollers do not come into contact with each other and recover to the original closing. The manual rotor that can adjust the automatic closing force performs the function by adjusting the compressive force of the spring mounted inside the cam module.
2. The slow closing function was applied with a damper using an orifice pass resistance. The damper was attached to a link close to the body, and the length of the orifice configuration of the piston was designed to allow the door to exhibit a damper function from a specific angle.
3. Through structural analysis, the maximum stress of the door was exerted in the hole of the link pin that connects to the pin at each link.
4. The deflection of the door was analyzed based on the general tolerances of the pin and link pin hole, and the pin holder was designed and applied, with insignificant variance, but up to 93% of the specification limit.

Acknowledgment

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