Design of Butt-Joint Gap Transfer Tooling for One Subway Seat Mask

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Abstract. Aiming at the phenomenon of clothing pinching on the seat cover of a certain type of subway vehicle, the cause of clothing pinching on the seat is analyzed, and a tooling for permanently transferring the butt-joint gap is designed. Firstly, the structure of the seam of the seat cover is analyzed. Secondly, two types of transfer tooling are designed, namely, a connector and a coupling structure. Finally, the coupling structure tooling is selected based on the principle of permanent transfer. The application results show that the coupling structure tooling permanently transfers the butt-joint gap of the seat mask, effectively solving the problem of the seat clamping passenger clothing.

Keywords: seat mask; butt-joint gap; coupling structure; permanently transfer; tooling

1 Introduction

In modern society, subways are widely used due to their convenience, comfortable environments, and ability to alleviate traffic congestion[1-3]. Passengers vary across different age groups, including the elderly, children, middle-aged individuals, young adults, and infants[4-6]. Consequently, optimizing the design of subway seat reliability and comfort has become a crucial aspect of subway seat development[7-13].

This investigation focuses on a subway seat from a project initiated in 2012. The seat, designed for eight passengers as illustrated in Figure 1, features a cover made of stamped stainless steel. Due to production technology and cost considerations, a four-person seat splicing method was chosen. The specific splicing configuration is depicted in Figure 2. The four-person seat covers are aligned with a 2mm gap, which is sealed with a rubber strip between the seat cover and the seat frame.

However, because the rubber strip possesses significant elasticity, misalignment can occur when the two covers experience different forces, potentially leading to clothing being caught. Additionally, as the rubber strip ages during subway operation, the reduction in support at the seam can widen the gap, further increasing the risk of clothing entrapment. To enhance passenger comfort and fully resolve the issue of clothing getting caught in the seams, it is essential to optimize the seat structure design.

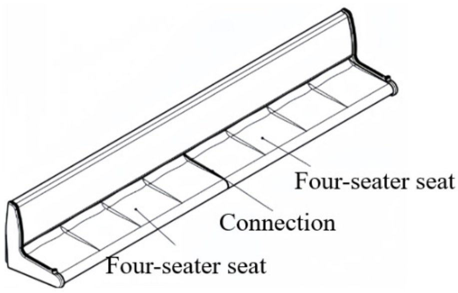


Fig. 1. Eight-person seat in a subway.

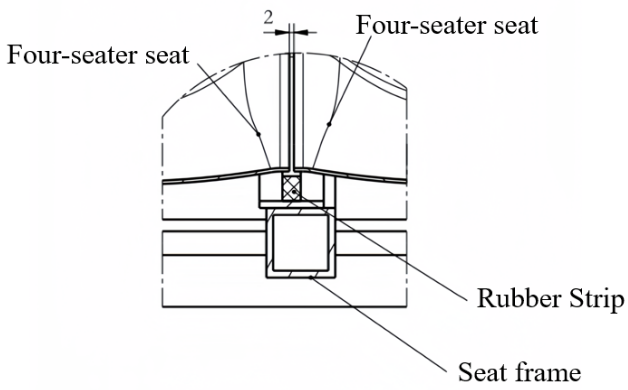


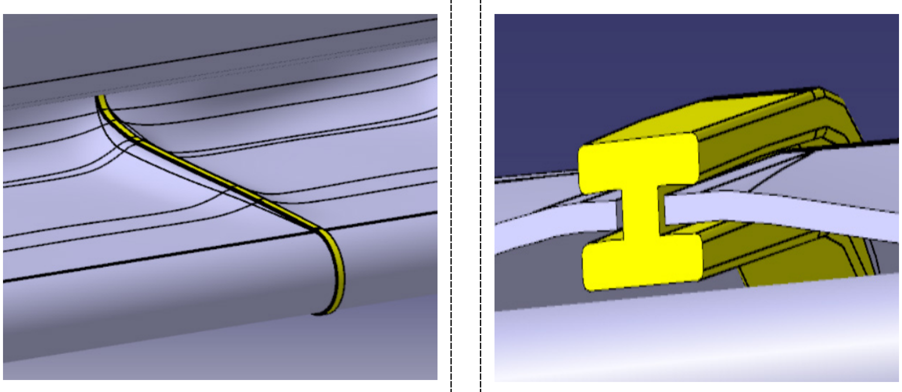
Fig. 2. Four-person seat splicing scheme.

2 Design of Tooling

The subway seat utilizes a mature four-person seat mask panel docking system, employing stainless steel calendaring molding technology. This process results in significant deformation and rebound, making it challenging to uniformly manage the seam along the arc of the seat surface. To address the joint gap without investing in the eight-person seat mold, it is necessary to design specialized tooling for this purpose.

2.1 Plug-in Tooling Design

A plug-in will be added to the original seat joint, which will be inserted into the mask (as shown in Figure 3) to transfer the joint gap from the passenger contact surface to the non-contact surface.



a) Overall view	b) Partial view

Fig. 3. Connector tooling.

This connector can be fabricated using four common methods: aluminum die-casting, aluminum profile bending, rubber, and plastic. The advantages and disadvantages of each method are outlined below. (All methods require increasing the gap between the two seat masks; it is recommended to expand the gap from 2mm to 4mm to enhance the connector's strength.)

Aluminum Die-Casting: This method offers good size control, with a required front thickness of more than 2.5mm to ensure part strength. A 0.5mm gap must be reserved at the insertion point to prevent assembly interference. Surface spray painting allows for color selection. The final product possesses significant strength and is essentially indestructible to passengers once assembled. However, aluminum die-casting cannot accommodate large deformations, which may lead to size deviations in the mask arc, poor fitting, and an increased risk of connector cracking. This method requires a pair of aluminum die-casting molds, which incurs a certain mold cost.

Aluminum Profile Bending: This method is low-cost, requiring only one profile mold and one bending mold. However, controlling the relative bending size is challenging, and the arc section may not match the mask well. Additionally, bending can easily deform the plug interface, which complicates the mask connection.

Rubber: This is the most economical option, needing only one rubber extrusion mold. The softness of rubber reduces assembly difficulty. However, its pliability makes it prone to buckling by passengers and increases the likelihood of damage.

Plastic: Similar to aluminum die-casting, plastic can be colored, offering better wear resistance than spray painting. Plastic exhibits certain toughness; local deformation does not lead to damage, and wall thickness can be reduced to minimize bulges. However, like rubber, plastic is more susceptible to human damage compared to metal.

In summary, the recommended order for plug-in materials for adding connectors is: plastic, aluminum die-casting, rubber, and aluminum profile bending. Notably, the original four-person seat mold can be reused at a low cost. However, the seat mask employs a plug-in to transfer the gap, resulting in a bulge between seats that affects aesthetics, complicates assembly, and poses a risk of damage. This approach does not fundamentally resolve the issue of splicing gaps and necessitates a mold opening cycle.

2.2 Design of Joint Structure Tooling

To prevent cracking of the joint tooling, ensure a proper fit, and avoid buckling by passengers while achieving the permanent transfer of gaps, a joint structure tooling design has been developed. A flanging forming structure is introduced between the two four-person seat mask panels (this structure requires a dedicated flanging mold, necessitating the creation of a new mold), as shown in Figure 4. A sealing plate made from 06Cr19Ni10 is placed between the two mask panels, with edges designed to match the curvature of the seat panel, and is welded to the mask panel. This solution demands a high degree of fit between the side curves after welding, as well as high flatness for the components on both sides, resulting in stringent process requirements. The two sealing plates are directly connected by fasteners, as shown in Figure 5. Due to the strong mechanical connection, the impact of gap changes when the mask is subjected to uneven forces can be effectively disregarded.

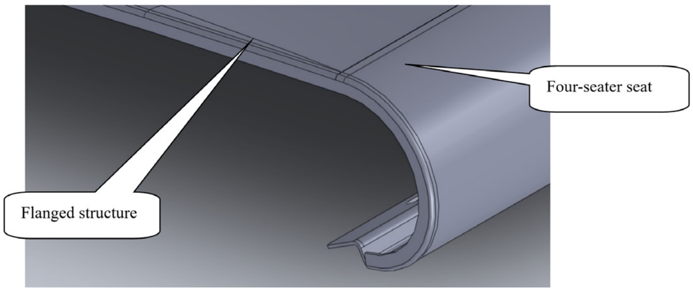


Fig. 4. Flanged structure of a four-person seat.

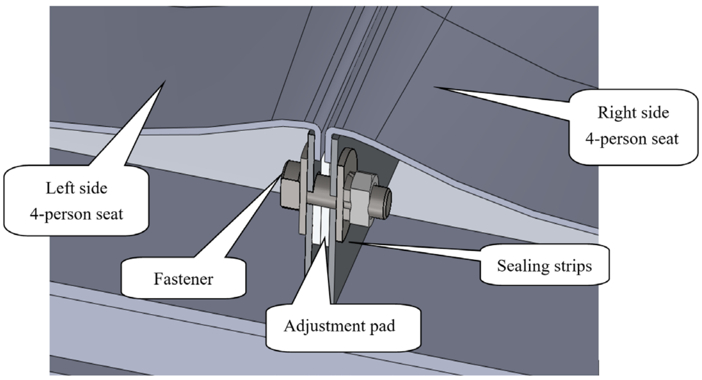


Fig. 5. Connection structure tooling.

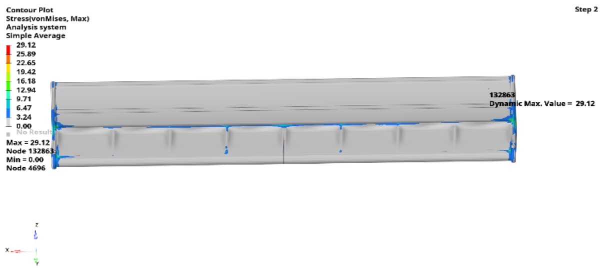
It is evident that the tooling does not require mold opening, features a short cycle time, and allows for the reuse of the original four-seat mold. This solution is low-cost, provides a uniform and aesthetically pleasing appearance, and effectively resolves the issue of splicing gaps. The use of connecting structure tooling can prevent problems such as passenger buckling, cracking, and poor fit, while ensuring the permanent transfer of the seat mask joint gap, thereby addressing the issue of passengers' clothing being caught in the seat. This tooling solution has significant application potential in future urban rail vehicle projects. It fully utilizes the existing mature four-seat mold, significantly reducing the need for investment in an eight-seat mold, and contributes to cost reduction and improved efficiency.

3 Seat Force Analysis

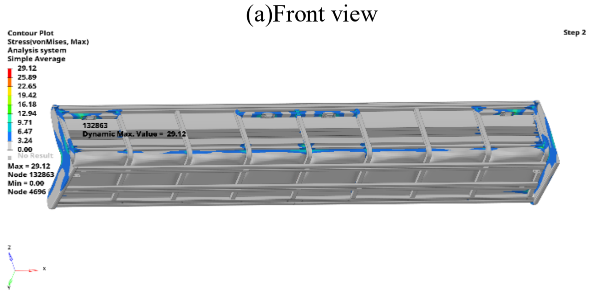
To test the stress of the seats, two working conditions are selected. Working condition 1 is to apply 1000N to all eight seats; working condition 2 is to apply 1000N to the two adjacent seats in the middle.

3.1 Seat Force for 2 People

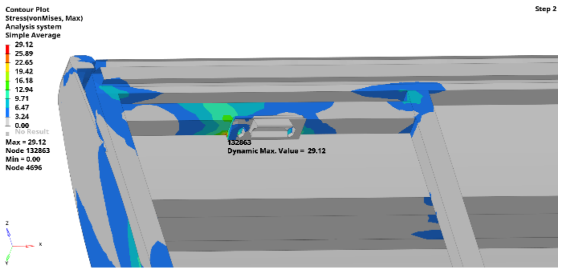
From the force diagram of two people riding (as shown in Figure 6), we can see that the maximum value of dynamic stress is 29.12 MPa, the stress is concentrated below 16.18 MPa, the maximum stress is located at the mask joint gap and the inner side of the top of the seat mask, and gradually decreases to both sides. Although the 8 seat masks are unevenly stressed when two people are riding, the mechanical connection strength of each connecting tooling is high, so the impact of the gap change under the uneven stress of the mask can be completely ignored.



(a)Front view



(b)Back view

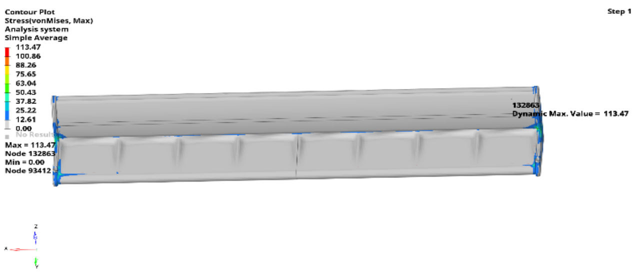


c) Partial view

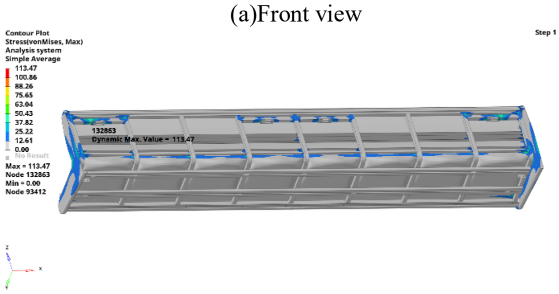
Fig. 6. Seat force analysis when 2 people are sitting.

3.2 Seat Force for 8 People

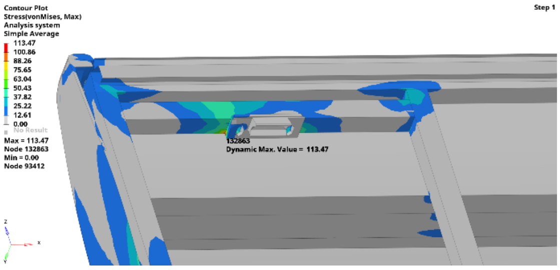
From the force diagram analysis of 8 people (as shown in Figure 7), it can be seen that the maximum value of dynamic stress is 113.47 MPa, the stress is concentrated below 63.04 MPa, and the stress distribution is uniform. The design of the plug-in tooling has been optimized. The seat mask joint seam uses a plug-in method to transfer the gap, which cannot fundamentally solve the problem of splicing gap. It can be seen that the design of the connector tooling can realize the permanent transfer of the seat mask joint gap from the root, ensure uniform stress distribution, and prevent deformation rebound and joint gap, thereby solving the problem of passengers' clothes being clamped by the seat.



(a)Front view



(b)Back view



c) Partial view

Fig. 7. Seat force analysis when 8 people are sitting.

4 Conclusion

Following the completion of the connection structure tooling design, the tooling has been successfully implemented in a subway line project (as shown in Figure 8), effectively resolving the issue of clothing being caught in the seats. The connection structure tooling ensures product quality, enhances riding comfort, and embodies a "people-oriented" approach. This innovation holds significant practical and promotional value for the structural optimization of future projects.

Fig. 8. Finished seat.

References

1. Li Y, Jiao Y, Cao F R, Hou Z K 2021 Design study of subway vehicle horizontal double seats under the synergy of reliability and comfort *Technology and Economic Guide*,29(17):87-88.
2. Li G J, Qian J L, Wang R J, Li W Q 2022 Design of subway double seat and its finite element experiment analysis *Journal of Jiangsu University of Technology*,28(2):102-109.

3. Zheng X Q, Wang S B, Du Y P 2022 Simulation Study on Crack Analysis and Improvement Measures of Railway Vehicle Seat *Railway Vehicle*,60(1):12-15.
4. Luo X Y 2014 Research on subway seat design based on passengers' perceived needs (Chengdu: Southwest Jiaotong University)
5. Jiang T R 2013 Research on subway car interior decoration design based on riding experience (Chengdu: Southwest Jiaotong University)
6. Wang L G 2010 Research on key technologies of subway vehicle interior design (Dalian: Dalian Jiaotong University)
7. Sun L P and Wang L G 2010 Design engineering analysis of subway vehicle interior designers *Journal of Dalian Jiaotong University*, 31(2): 15-19.
8. Chen Q 2012 Design of Metro Vehicle's Saloon Seat for Longitudinal Direction Layout *Technology and Market*, 19(6):128-131.
9. Pan X Y 2014 *Optimization design and experimental study of subway seat structure based on finite element analysis* (Wuhan: Wuhan University of Technology)
10. Wang W B, Su C, Chen G R, Zhou H C 2024 Research on End Structure of Subway Train Seat and Occupant Collision Safety *Machinery Design & Manufacture*, (10):209-214220.
11. Fan Q H, Jiang X C, Wu X L, Nie M, Xin Y S, Li H L, Jia X Y 2022 Experimental Research on Optimization Design and Comfort of Locomotive Seat Based on Ideal Pressure *Journal of Mechanical Engineering*, 58(10):383-394.
12. Xu J H, Qiu J Y 2021 Design and Research on Comfort of Economy Class Seat Based on Ergonomics *Packaging Engineering*, 42(18):403-409,422.
13. Ni W Y, Zhang H, Yao S W 2021 Lightweight design of automobile seat frame based on multiple working conditions *Chinese Journal of Engineering Design*, 28(6):729-736.