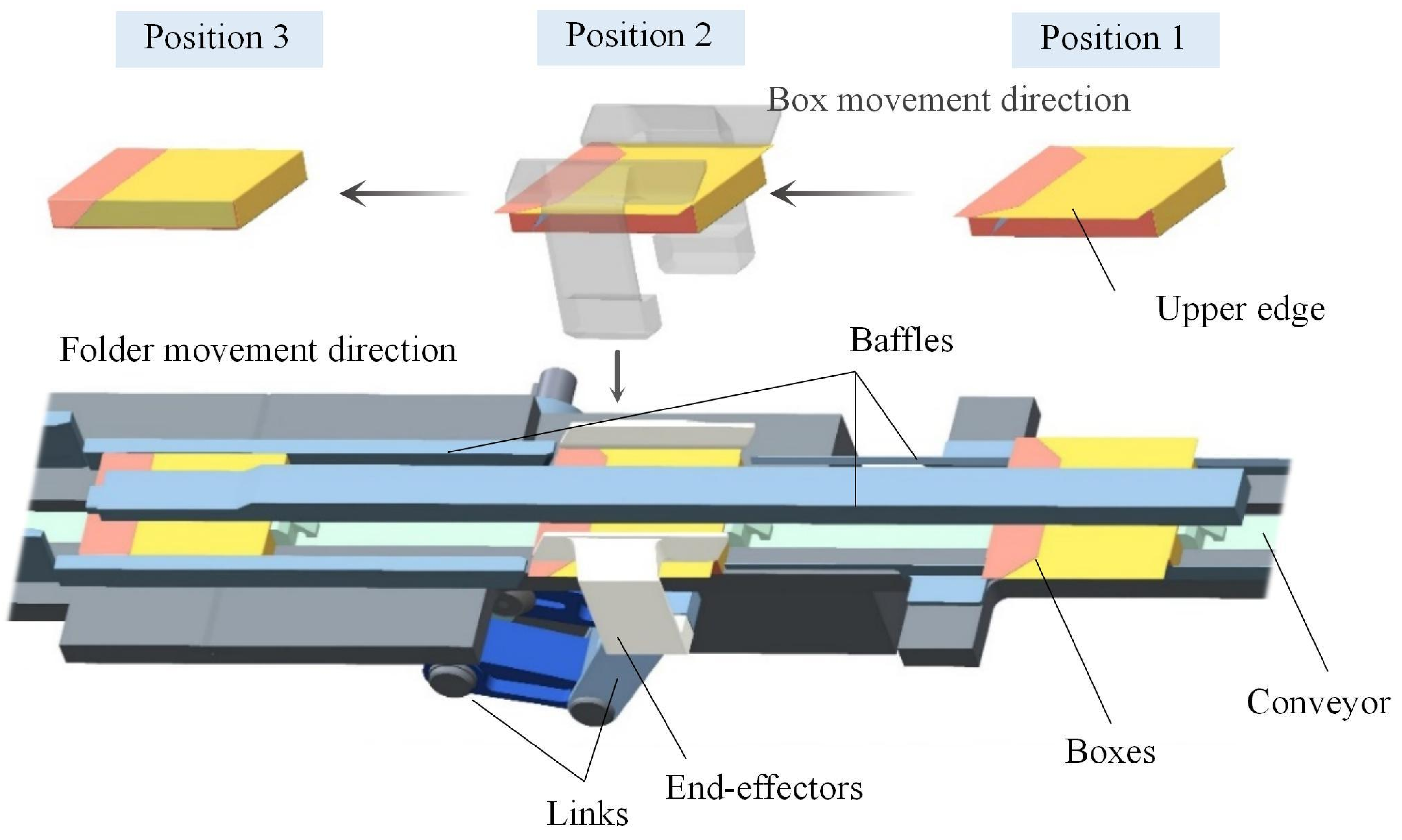
Paper ID: CS763 The 4th International Conference on Applied Mathematics, Modeling and Computer Simulation (AMMCS 2024)

Numerical simulation study on folding behavior of paper and structural optimization of end-effector

Jie HONG[a], Xuanli ZHOU[a*], Gang WANG[a], Kui ZHOU[a], Ziwen REN[a]
[a] Shanghai Tobacco Machinery Co.,Ltd., Shanghai, China
*Corresponding author's email: xlzhou007@163.com

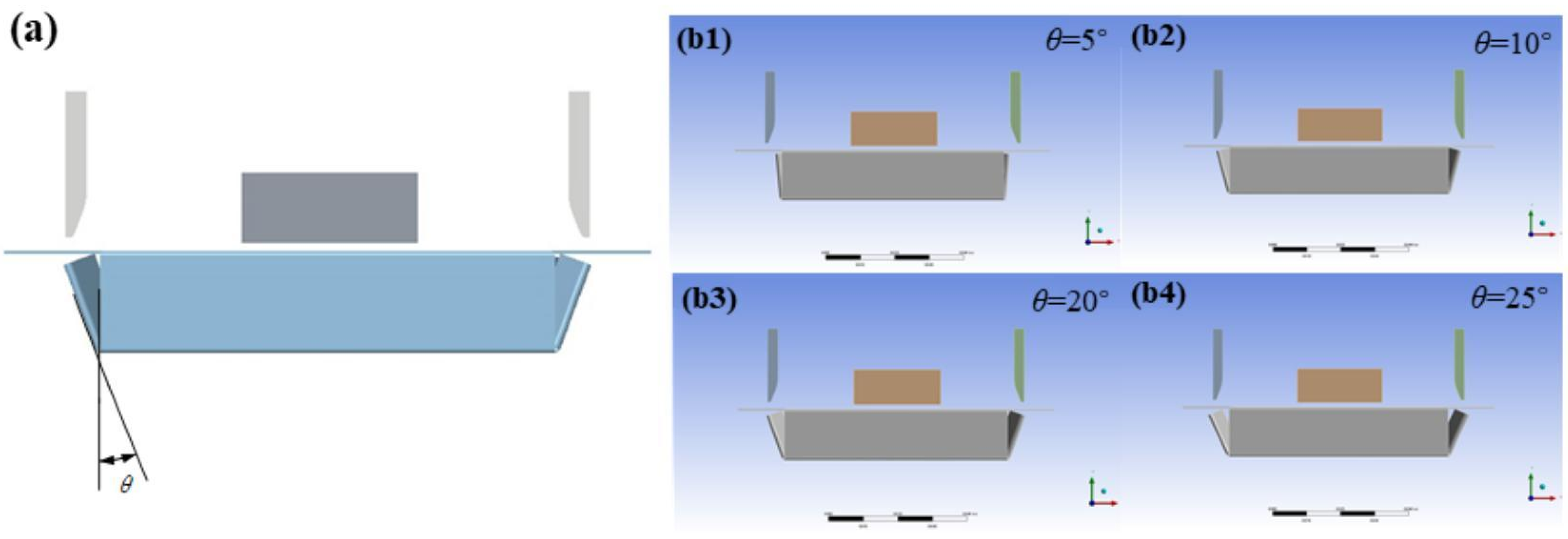
Theory basis

Paper folding principle



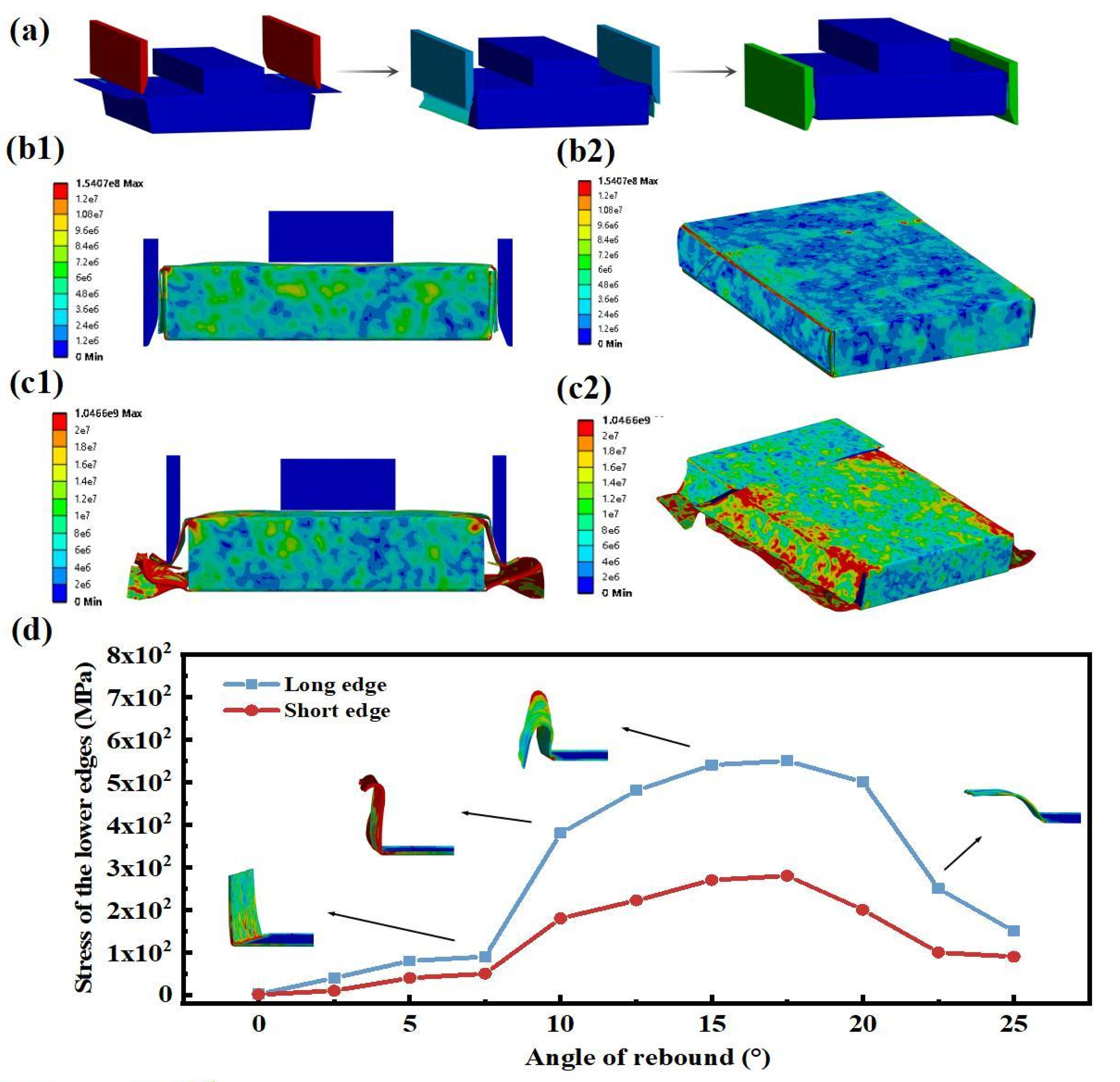
FE modeling

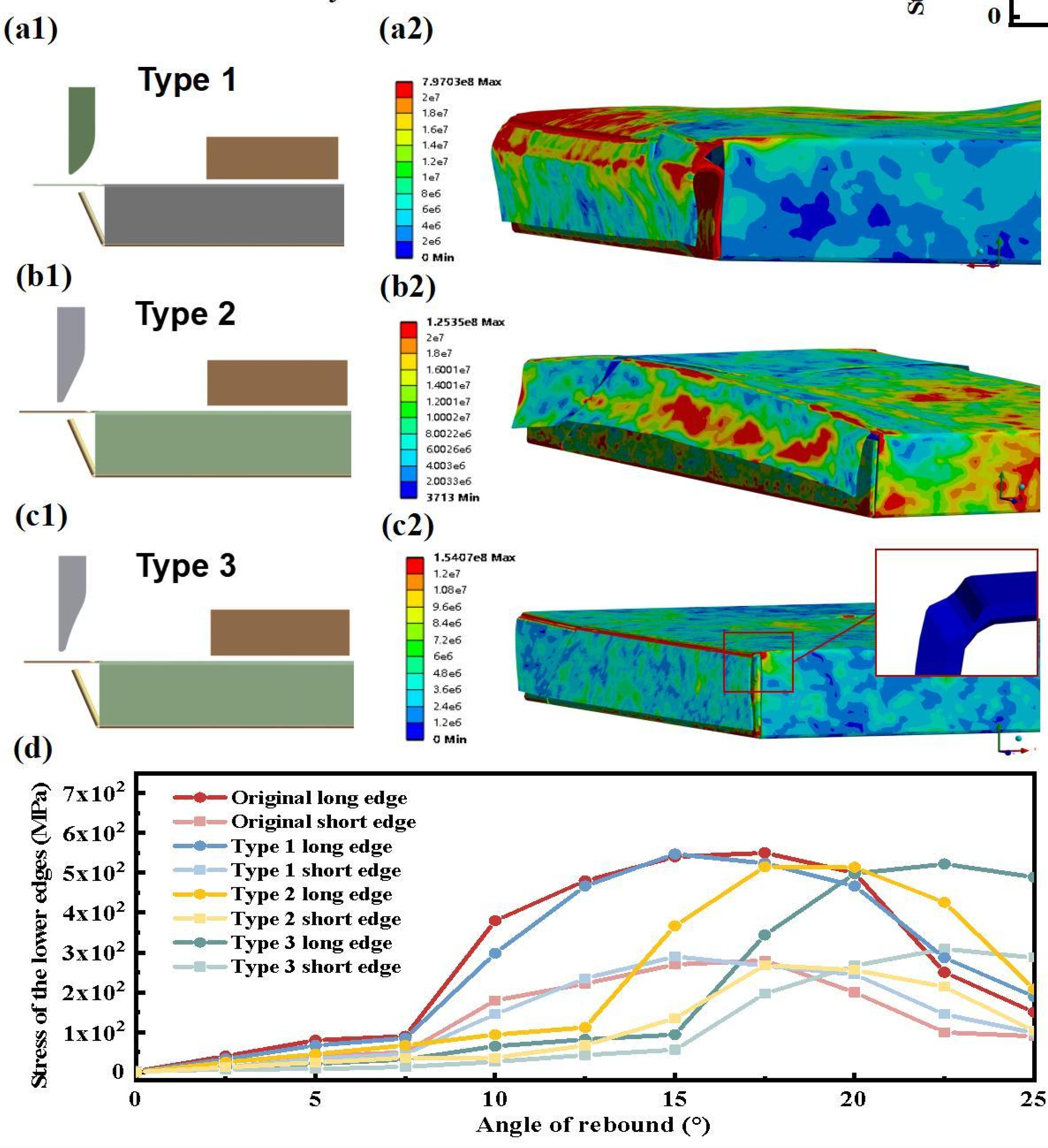
The rebound angle also changes due to differences in material and restraint time. The rebound angle will directly affect whether the folding of the upper edge is successful and the overall folding effect. So we model boxes with different rebound angles.



Results and discussion

- As the end-effector moves downward, the paper is folded along the creases.
- When the rebound angle is between 0 and 7.5°, the stress and rebound angle are linearly related. This shows that the box was successfully folded and the paper material at the lower edges was elastically deformed.
- The stress suddenly increases when the rebound angle reaches 10°, and continues to rise between 10° and 17.5°. This shows that when the rebound angle increases to 10°, the lower edges are crushed and the box cannot be folded successfully.
- When the rebound angle exceeds 17.5°, the stress shows a downward trend. This is because the rebound angle of the lower edges is too large, causing the upper edges to stress the inside of the lower edges during the folding process. At this time, the lower edges are unfolded outwards, and the box cannot be successfully formed.





- In order to optimize the folding performance of the mechanism, we proposed three structural optimization methods for the end folder.
- For type 1, the lower edge of the box is bent during the folding process, so the folding effect is not ideal.
- For type 2, the deformation of the lower edge of the box is relatively small. But under the action of friction, the upper edge is not aligned with the lower edge. This folding effect is also substandard.
- For type 3, the lower edge is completely retracted and the folding effect is very good.
- The simulation analysis model established in this paper can effectively present the deformation and mechanical characteristics of paper packaging boxes under different conditions. This model can be used to analyse the deformation mechanism of paper during the folding process and predict the folding effect of paper under different working conditions.

Conclusions

- A folding prediction model for creased paper was established. The simulation results show that for the original end effector, when the rebound angle of the lower edge of the box is within 7.5°, the upper edge can be folded smoothly. When the rebound angle is greater than 7.5°, the lower edge will be crushed, causing folding failure.
- Three new end effector structures are proposed and simulated. The simulation results show that the second and third structures can adapt to a wider range of rebound angles, and the maximum angles they can adapt to are 12.5° and 15° respectively. This greatly improves the adaptability of the packaging mechanism. This paper simulation analysis method can help predict paper folding effects under different working conditions and guide the design of packaging mechanical structures. The shape of the crease after folding the paper is consistent with the actual crease.