

Study of Airbag Interference with Out of Position Occupant by the Computer Simulation

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ABSTRACT

In the past few years many cases of serious injury to out of position occupants caused by airbag deployment have been reported in the United States. FMVSS208, which requires equipping automobiles with airbags, was revised to reduce the risk of deployment injury by airbags. The new regulation defines some new test procedures and several performance requirements regarding the out of position tests. The uniform gas pressure analysis has been a general analysis method for airbag deployment with computer simulations up to this point. However the membrane force of the airbag is a major parameter for the interference between the airbag and an out of position occupant, and the gas used for airbag deployment has the characteristics of a compressible fluid which is difficult to model. Therefore the general Euler-Lagrange coupling method will be necessary for the computer simulation of out of position occupant interference. This paper describes the results of the airbag- out of position interference by using computer simulation with the general Euler-Lagrange coupling method in regards to occupant position, bag and inflator characteristics. The results of the simulation are correlated to laboratory out of position testing.

INTRODUCTION

In recent years, the air bag became a standard occupant protection system in vehicles, like the seat belt. It is reported that the air bag has saved more than 3000 lives in the US as the result, and it is thought that it has contributed to the improvement in a vehicle occupant's safety. However, in the United States it is reported, on the other hand, that more than a hundred persons have died from the deployment of an air bag. The result was a demand for an out of position occupant safety requirement to be incorporated in FMVSS208. The importance attached to the problem of deployment injury by the air bag in such a situation resulted in an amendment to FMVSS 208 in May 2000. However, it becomes a very big subject to solve the new demands by trial and error, since very many combination checks are needed and there are very complicated interference of an air bag and an out of position occupant. The use of simulation technology to solve these problems is expected to grow. However since the simulation involves high-speed and hot gas, with very complicated deployment of an air bag, the repeatability and accuracy of the air bag deployment using a simulation by conventional uniform gas method was not so good. In this paper, reproducing deployment of the air bag by simulation with the Euler-Lagrange coupling method is

introduced.

Comparison between Uniform Gas Method and Euler-Lagrange coupling methods

The deployment simulation of the air bag used for evaluation of occupant protection in a crash has been set up with inner pressure of an air bag by the Uniform Gas Method. However, deployment of an actual air bag consists of hot gas fluid generated from an inflator, and the pressure distribution inside an air bag is uneven, also including the thrust of an inflator. Especially, these factors change the vector of force applied to an occupant in interference of an out of position occupant and an air bag during the flying-out mode of the air bag in the early stages of deployment. So, in order to predict an out of position occupant's injury, the accuracy of the simulation in early stages of the deployment is a big subject. Furthermore, the leading force also applied to an occupant in the middle-stage stage of air bag deployment is the membrane force of an air bag. It is thought that the gas flow in an air bag has a big influence on occupant injury values also in this stage. Here, the displacement of the out of position occupant in Uniform Gas Method and Euler-Lagrange coupling Model was compared using the dummy model of MADYMO. Figure 1. shows the interference condition of the air bag and occupant in the 30msec after deployment by the Uniform Gas Method. Figure 2. is the result of using the Euler-Lagrange coupling model in the same timeframe. Since the thrust of the gas from an inflator is reproduced by the Euler-Lagrange coupling model in the early stages of deployment of an air bag, interference of an occupant and an air bag is reproduced. Moreover, as an air bag may deploy by uniform pressure distribution by the

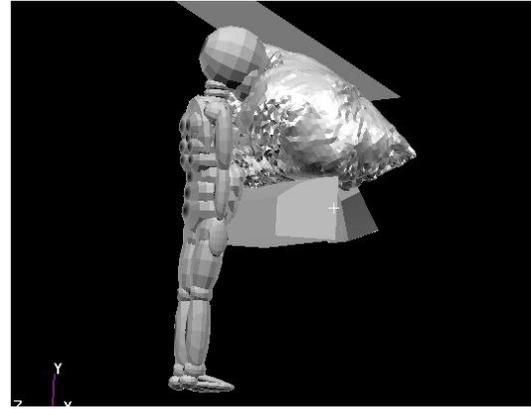


Figure 1. Uniform Gas method at 30 msec

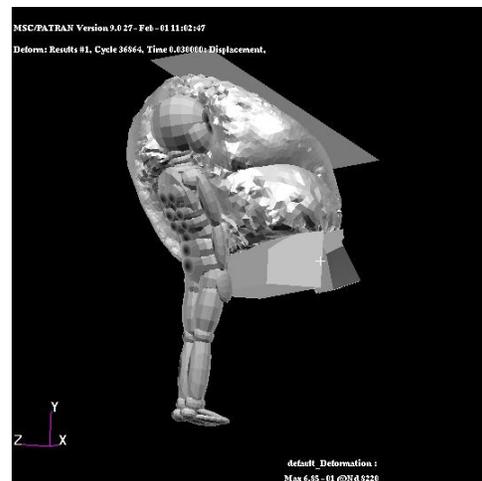


Figure 2. Euler-Lagrange coupling model at 30msec

uniform gas method, there is no deviation of the force, which a dummy receives from an air bag. On the other hand, in order to spread in the direction with smaller resistance in the case of deployment in the Euler-Lagrange coupling model, it deploys in the form where the upper half of the body of the dummy with much low resistance space is wrapped. The air bag force concentrates on the upper half of the body of a dummy as the result. Furthermore, the difference of the Uniform Gas Method and the Euler-Lagrange coupling model is shown in Figure 3., which demonstrates change of the motion of the dummy for each ten milliseconds. The result, in which the white portion

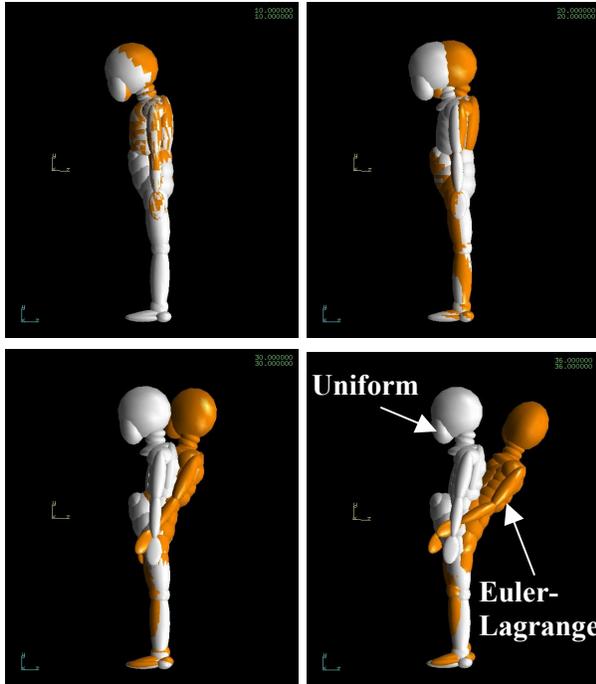


Figure 3. Comparison of Dummy motion between Uniform & Euler-Lagrange

shows the dummy position by the uniform gas model in these figures, and the red portion shows the Euler-Lagrange Model, is shown. Since interference of a dummy and an air bag is reproduced, the Euler-Lagrange model shows that the displacement of a dummy increases.

Evaluation of a friction force effect.

The force which an air bag applies to a occupant in interference of out of position occupant and an air bag consists not only of the force by inner pressure, but also movement of the occupant side of the fabric of an air bag. The friction force between an occupant and an air bag greatly influences an occupant's displacement in that case. For example, when an air bag contacts an out of position occupant's head, during deployment, the air bag does not give an occupant a big force by only grazing the head without friction force. However, the friction force is important in interference with an actual

out of position occupant, and twists its head and neck. Figure 4. and Figure 5. show comparison of the phenomenon using the simulation. The difference caused by existence of the friction force appears as a difference in the twist mode of a head. When there is no friction force, the head of dummy slides on the surface of the deploying bag, and the whole dummy moves back with a bag. However, when friction force works, the head of a dummy is twisted in the movement direction of the bag fabric. Since a neck force and a neck moment are the most important factors to evaluate an injury risk in evaluation of interference of an out of position occupant and an air bag, the high accuracy in the mode of head or neck at the time of this interference is demanded. Figure 6.

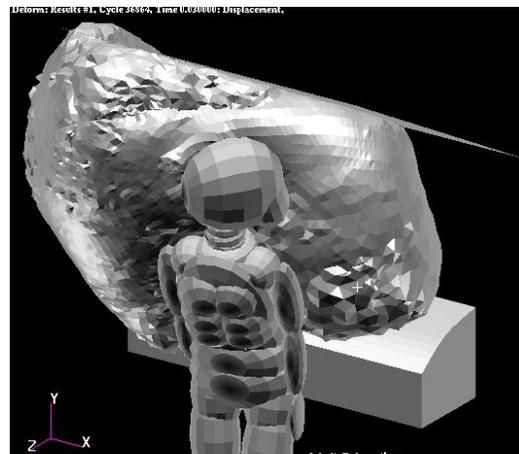


Figure 4. Interference mode without friction

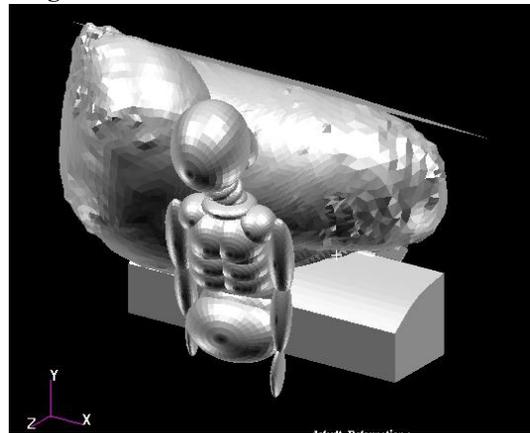


Figure 5. Interference mode with friction

compares the dummy mode for every 10msecs by friction force existence. The remarkable difference: the head is being twisted in the transverse direction when there is no friction and it appears to be twisted in the direction of bag fabric movement when there is friction. The moment generated on the neck of a dummy, as the result, appears quite different. (Figure 7.)

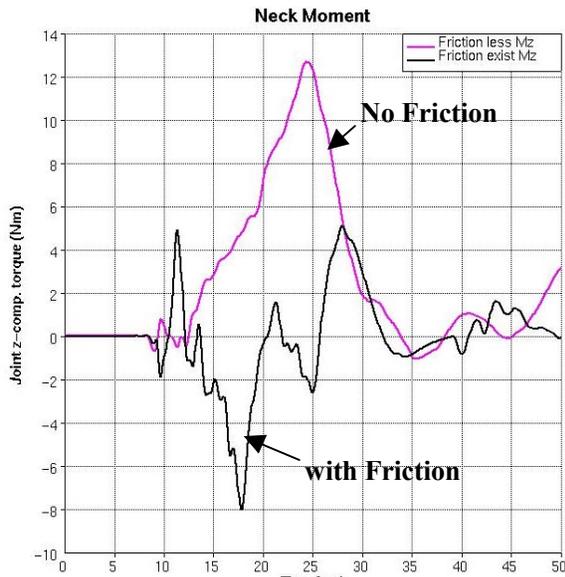


Figure 7. Comparison of neck moment effected by friction

Co-relation between the simulation and the actual testing for out-of position

The situation of the Out of Position test in the position 1 using the C3Y dummy of FMVSS208 is shown in Figure 8. It is the test mode, which places a dummy as close to an instrument Panel as possible, maintaining clearance of the head and Windshield at 5mm in this Position 1, and deploys an air bag. The air bag deploys towards the head and the neck of the dummy in this mode for the Top Dash Mount, and the injury value of the neck is mainly evaluated. The injury value of the neck, which occurs in that case, is shown in Figure 9,

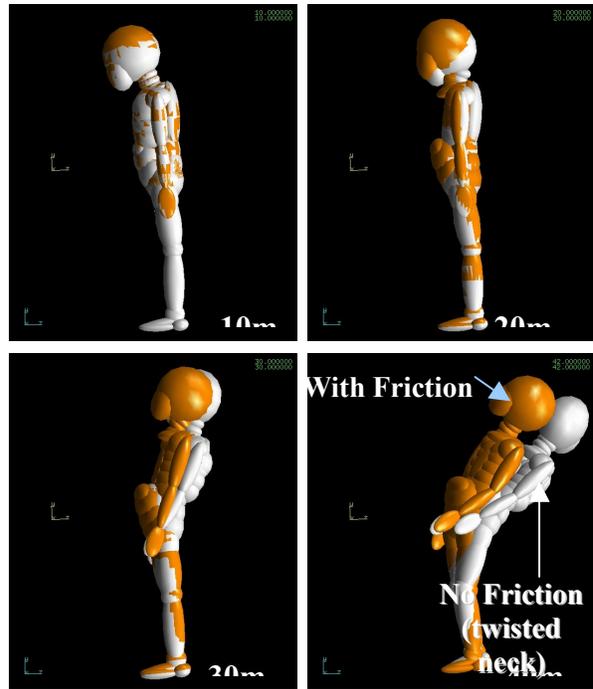


Figure 6. Comparison of displacement mode effected friction

Figure 10, and Figure 11. A Dual Stage Inflator, which had a bag of 110 liter and a total output 480kpa at 60 liter tank volume is used in this test, operated with an ignition Delay Time of 40 milliseconds. In the Flexion/Extension Moment generated on the neck, coincidence of waveforms is obtained mostly. Moreover, in Neck Shear Force, a small difference is seen in the case of a deployment of 1st Stage of Dual Stage Inflator. When the air bag immediately after the deployment pushes the whole head in an actual test, the

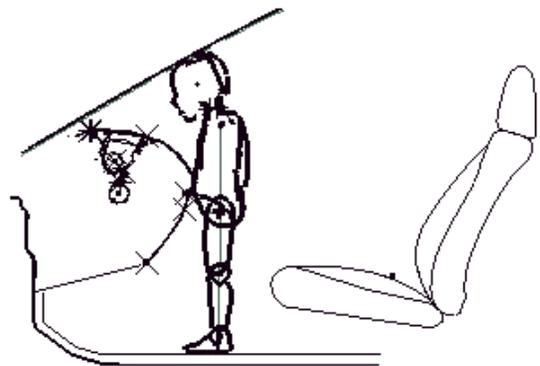


Figure 8. C3Y Dummy set for Position 1

backward shear force is generated. The forward shear force is generated after that, when a bag fabric covers the neck portion. Since the cover of an air bag is not modeled in the simulation, from the early stages of deployment, a bag deploys in the direction of the head

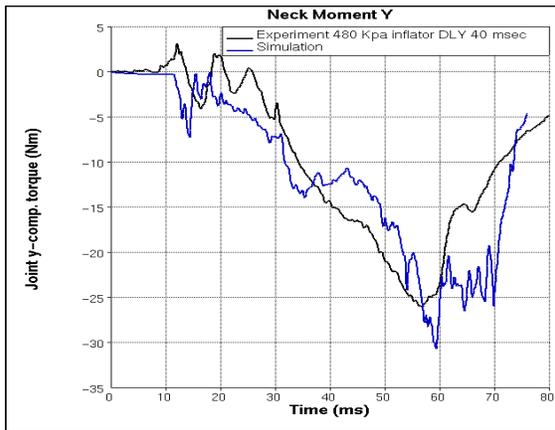


Figure 9. Comparison of Neck Moment Y

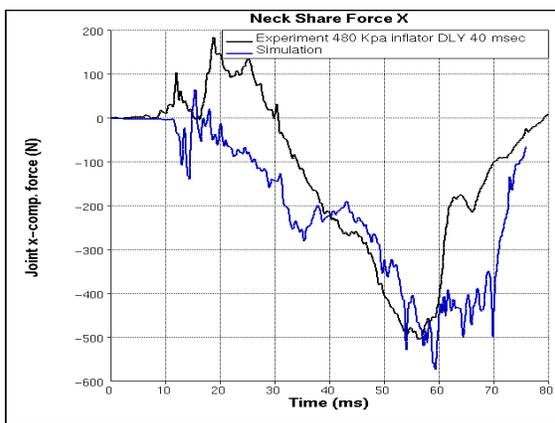


Figure 10. Comparison of neck share force

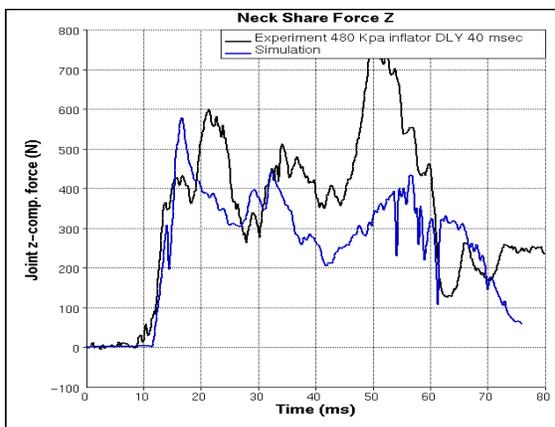


Figure 11. Comparison of neck axis force

of the dummy. The membrane force is generated as the inflator gas tends to spread the bag fabric, since both of the cases have already covered the neck portion in the stage where 2nd Stage deploys on dummy neck, and the shear force can be reproducing the bag mostly in Simulation. However, although it can approximate mostly about Neck Axis Force in the case of deployment of 1st Stage deployment, to the timing of 2nd Stage deployment, the result lower than an actual test result is brought. It is thought that membrane force generated in case it spreads, while a bag wraps in neck portion in this timing is acting. Since the load vector which works with a dummy with the contact surface form of the dummy with the bag fabric at the time of the Membrane force acting on a dummy is determined, the accuracy of the form by the model is also considered to be an important element

Analysis about the influence of a membrane force to injury

The example of analysis about how the membrane force affects it to an occupant's head injury in the

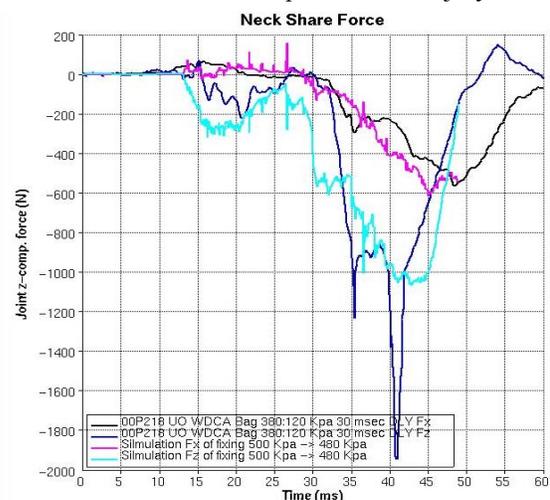


Figure 12. Comparison of neck axis force

deployment process of an air bag is introduced. Also in this example, the test position of a dummy is the position 1 specified by FMVSS208. Figure 12. shows the result of Neck Axis force in the above-mentioned conditions. In this, the small peak generates the compression force of a head around 20 millisecond first, and a big peak is generated around 40milliseconds. Figure 13., Figure 14., Figure 15., and Figure 16. show the contact situation of the dummy and bag, a distribution of the tension generated in fabric in the timing of these two peaks, respectively. This tension means the membrane force by the bag in the portion to which the bag contacts the dummy. In the first peak, as for these showing, in the process, which a bag deploys

while interfering with the head of a dummy, the inertia force of a bag tends to move a head. The resistance force generated in fabric of a bag in that case is making the dummy generate load as membrane force. Moreover, the head of a dummy exists in the process in which a bag becomes regular shape in the peak of 40milliseconds. The membrane force generated in that case depresses the head of a dummy, and makes a neck generate a compression force. In this timing, the interference area of a bag and a head is large and the pressure of a bag is also rising. The load which high membrane force generates in the large area on the fabric of a bag for the reason, and is generated in the neck shows big value. Thus, the interference force

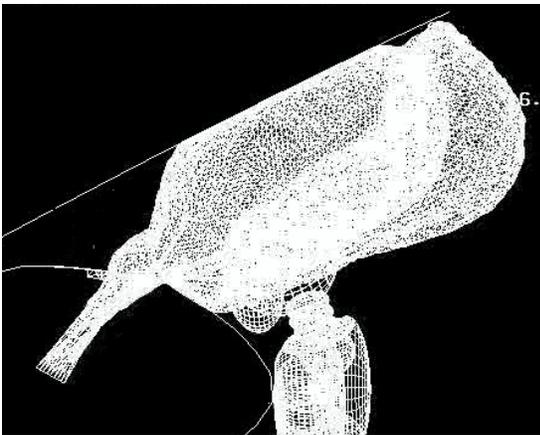


Figure 13. Interference at 20 msec

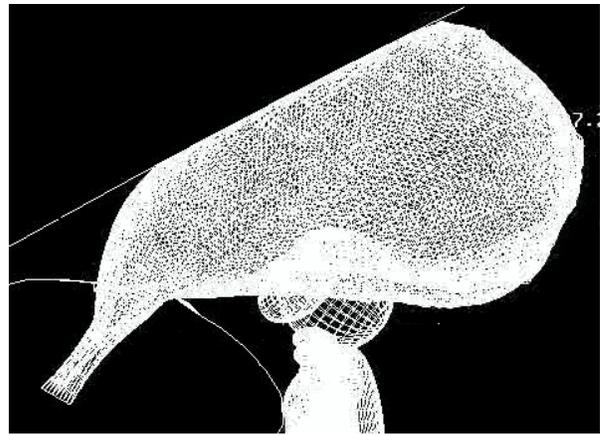


Figure 14. Interference at 40 msec

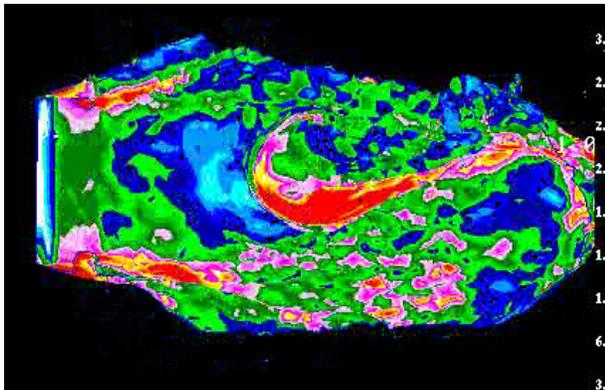


Figure 15. Distribution of tension generated in fabric at 20 msec

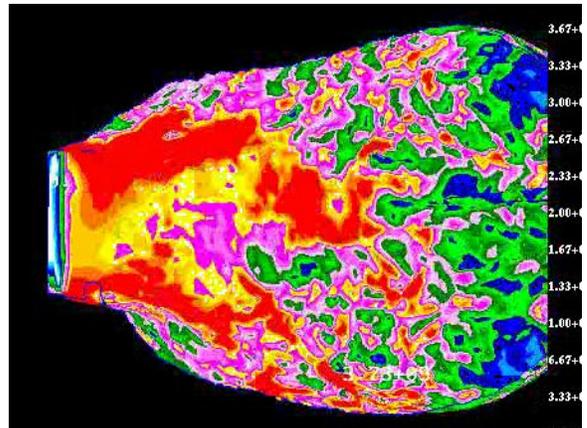


Figure 16. Distribution of tension generated in fabric at 40 msec

generated at the time of interference with a dummy can be predicted by analyzing membrane force on fabric of a bag. Moreover, this analysis technique is applicable to optimization of the shape of a bag, or the output of an inflator in order to reduce membrane force.

CONCLUSION

It became possible to reproduce deployment of an air bag roughly by using the Euler-Lagrange coupling method, as stated above. However, some problems still exist in analyzing the deployment phenomenon of a complicated air bag with sufficient accuracy. The following problems exist as a present subject.

1. How to fold up an air bag in the case of a passenger seat air bag is comparatively complicated -- it becomes for the reason, by setup of a model, a penetration phenomenon may arise between fabric of a bag in the midst of calculation. In this case, since the force which is different in it being actual in a penetration portion works, deployment process of a bag may be unable to reappear correctly. Since the capacity of the bag on calculation decreases owing to the penetration phenomenon between fabrics, the injury value generated at the time of interference with a dummy will become high. The know-how and a new tool in the creation process of a simulation model are needed for this solution.

2. In the calculation model of friction problem present, the friction coefficient is not correctly applicable. Since the model of an air bag is still complicated, when the actual value of a friction coefficient is applied as a reason, it is to become easy to generate penetration of fabric surface of a bag in the midst of calculation of deployment process. However, it turns out that the friction force between an occupant and a bag affects the

injury value to OOP occupant not a little in OOP analysis. Moreover, since the model itself becomes complicated further when this technology will be applied to the occupant protection performance prediction in a crash in the future, it is predicted that the influence of friction force becomes large. Many labors are needed as it is necessary to change a definition of friction characteristics and it becomes a complicated model by the portion of a bag, in order to solve those problems. It is the subject, which must be solved in case of utilization of this technology from now on also including an improvement of a model

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