Study of Injury Risk Assessment Methods for Pediatric Crashes to the Floor -Estimation of Acceleration and Load Subjected to Human Body Using Multibody Dynamics-

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Abstract

In this study, we proposed a method for evaluating the risk of injury to a child in a collision with a floor using multi-body dynamics analysis. In addition, the accuracy of the analysis was verified by comparing the acceleration during the collision between the experiment and the analysis.

In this study, we proposed a method to evaluate the injury risk of a child's head impact on a floor using multi-body dynamics analysis.
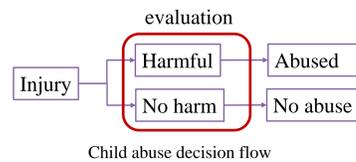
It was shown that the parameters created by the experiment using the head impactor could be applied to the whole body dummy to evaluate the risk of injury in children.

Comparison of the experimental and analytical results showed the accuracy of the analysis and the usefulness of the injury risk assessment method.

Introduction

- In Japan, the number of cases of abuse consultation [1] and the number of cases cleared for abuse [2] are on the rise.
- It is difficult to declare the victim of abuse.
- There may be more potential victims of abuse.

✓ Need a simple and quantitative method of determining abuse

evaluation

Injury → Harmful → Abused
Injury → No harm → No abuse

Child abuse decision flow

Child abuse

Injury risk assessment method
- Behavior analysis using a dummy model
Reproduce the behavior at the time of injury and identify the injured area
- Calculation of parameters related to injury
Evaluation of the possibility of injury based on HIC, load, etc.

Assessment of Harmfulness

Objectives of this study
- Contact setting by floor type
- Accuracy verification by comparison with experimental results

Multibody dynamics analysis software

Software:
MADYMO Over2020.1

Siemens Corporation
https://www.plm.automation.siemens.com/global/ja/products/simcenter/madymo.html

- Motion mechanism analysis software using rigid body models

Example of use:
Behavior analysis of automobile accidents
Falling behavior analysis

How to use
- Model creation and adjustment
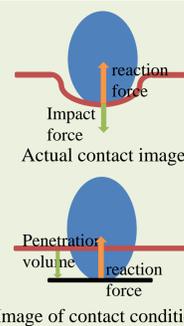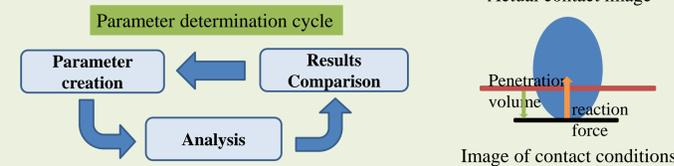- Parameter setting and adjustment

Analysis example

Setting analysis parameters

Contact parameter setting method

✓ The contact condition of MADYMO is determined by the graph of penetration vs. reaction force and various parameters.
✓ Parameters can be set to adjust the reaction force of contact.
✓ The parameters are adjusted to be the same as as the experimental results.
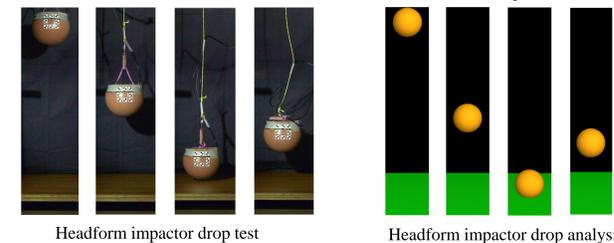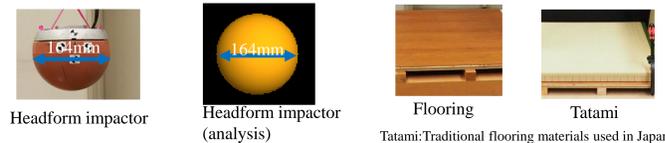
Parameters
① LOAD CURVE ② UNLOADING CURVE
③ HYS_SLOPE ④ DAMP_COEF
⑤ FRIC_COEF ⑥ EVA_TYPE

Parameter determination cycle

Parameter creation → Analysis → Results Comparison → (cycle)

reaction force
Impact force
Actual contact image

Penetration volume ← reaction force
Image of contact conditions

Headform impactor drop test and analysis

Experimental and analytical conditions

	Weight [kg]	Radius of curvature [mm]	Falling status	Drop location	Measured value
Experiment	3.5	82	Free fall	Flooring, Tatami	Acceleration
Analysis	3.5	82	Free fall	Flooring, Tatami	Acceleration

Headform impactor

Headform impactor (analysis)

Flooring

Tatami
Tatami:Traditional flooring materials used in Japan

Headform impactor drop test

Headform impactor drop analysis

✓ The parameters were set to obtain the same maximum acceleration and HIC as the experimental results.
✓ The acceleration waveforms were also close to the experimental and analytical waveforms.
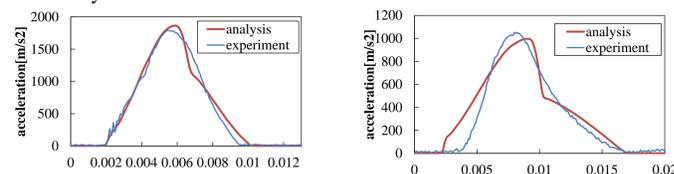
(a) Flooring

(b) Tatami

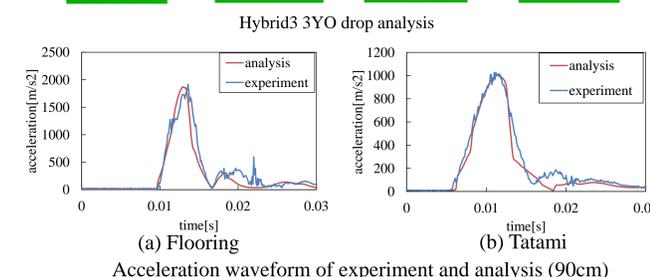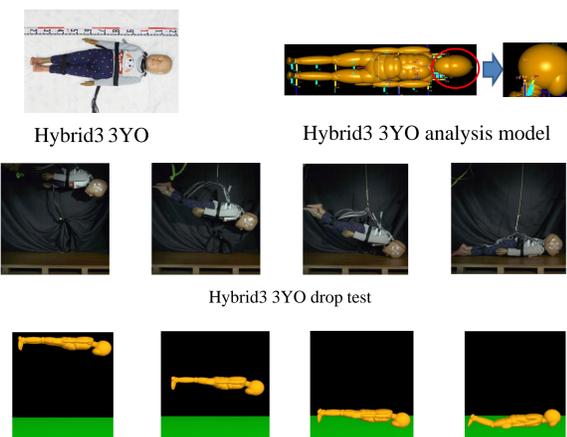Acceleration waveform of experiment and analysis (90cm)

Flooring contact setting

Tatami contact setting
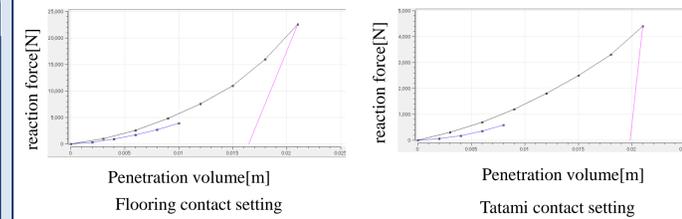
Headform impactor drop test and analysis results (Threshold: HIC 570)

	Flooring				Tatami			
	Experiment		Analysis		Experiment		Analysis	
Drop Height [cm]	Max. acceleration [m/s²]	HIC	Max. acceleration [m/s²]	HIC	Max. acceleration [m/s²]	HIC	Max. acceleration [m/s²]	HIC
15	611	80	607	73	346	32	329	28
30	880	216	931	199	531	82	499	73
60	1404	576	1425	547	816	209	766	191
90	1790	1021	1865	1003	1053	367	996	339
120	2183	1528	2229	1524	1251	531	1233	532

Dummy drop experiment and analysis

Experimental and analytical conditions

	Dummy doll	Weight [kg]	Falling status	Drop location	Falling posture	Measured value
Experiment	Hybrid3 3YO[3]	16.8	Free fall	Flooring, Tatami	Lying on one's face	Acceleration
Analysis	Hybrid3 3YO	16.8	Free fall	Flooring, Tatami	Lying on one's face	Acceleration

Hybrid3 3YO

Hybrid3 3YO analysis model

Hybrid3 3YO drop test

Hybrid3 3YO drop analysis

(a) Flooring

(b) Tatami

Acceleration waveform of experiment and analysis (90cm)

Hybrid3 3YO drop test and analysis results

	Flooring				Tatami			
	Experiment		Analysis		Experiment		Analysis	
Drop Height [cm]	Max. acceleration [m/s²]	HIC	Max. acceleration [m/s²]	HIC	Max. acceleration [m/s²]	HIC	Max. acceleration [m/s²]	HIC
15	483	50	408	29	300	20	202	10
30	821	155	720	116	603	75	433	47
60	1386	483	1346	409	819	201	748	169
90	1918	968	1871	848	1027	345	1002	329

✓ It was shown that the maximum acceleration and HIC of the head can be measured by using the contact parameters of the head impactor as a whole body dummy.
✓ As a result of comparing the experimental and analytical results, it was shown that the accuracy of the maximum acceleration and HIC was better when the drop height was higher.
✓ In the case of a fall from 90cm to the flooring, the HIC may exceed 570.

$$Percentage[\%] = \frac{Analysis\ results}{Experimental\ results}$$

Hybrid3 3YO comparison of drop test and analysis results

Drop Height [cm]	Flooring		Tatami	
	Max. acceleration [%]	HIC[%]	Max. acceleration [%]	HIC[%]
15	84.5	59.3	67.5	50.6
30	87.7	74.8	71.8	62.0
60	97.1	84.7	91.3	83.9
90	97.6	87.7	97.6	95.4

Conclusion

✓ The maximum acceleration and HIC were lower in the experiment with the dummy than in the experiment with the head impactor. The same results were obtained in the analysis.
✓ It was shown that the injury risk assessment method using MADYMO can be used by setting the contact conditions.
✓ The contact conditions can be created by determining the experimental results to match the analytical results.
✓ The contact settings for each floor for head injury can be determined from the experiments using the head impactor, and can be used for the analysis of whole-body dummies.

References

1) Ministry of Health, Labour and Welfare." Number of cases of child abuse consulted by child guidance centers in FY2020". Ministry of Health, Labour and Welfare . https://www.mhlw.go.jp/content/11900000/000824239.pdf.(2021-12-19)
2) National Police Agency."Juvenile delinquency, child abuse, and child sexual abuse in 2020 and Sexual Abuse of Children in 2020". National Police Agency.https://www.npa.go.jp/publications/statistics/safetylife/R2.pdf(2021-12-19)
3) NHTSA."HYBRID III 3-Year Old Physical Date".NHTSA.https://one.nhtsa.gov/Research/HYBRID-III-3%E2%80%93Year-Old-Physical-Data,(2021-12-19)