MADYMO USED FOR COMPUTER AIDED DESIGN OF A DYNAMIC ACTING CHILD RESTRAINT SEAT

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ABSTRACT

A child restraint system based on a new concept was computer designed and optimized. This unique child restraint system is based on a moving impact shield. The shield is horizontal during normal use, so the child can have good forward visibility, but during a frontal collision the shield pivots upward to restrict the forward motion of the child's head and thorax. The first stage of this study was to design and optimize the actuating mechanism of the dynamic shield. In the second stage, the performance of the restraint system was optimized for the TNO-P3, 3-year-old child Dummy. The optimization of the design was carried out in both stages by varying the geometry, padding, and inertial properties, using the MADYMO Crash Victim Simulator. The final stage of the study was to perform sled tests to validate and refine the design of the system.

INTRODUCTION

Mathematical simulation of the gross motion of the human body in a dynamic impact environment has become a very active researche objective in the last fifteen years. The development of these crash victim models has been primarily concentrated on the adult male. The only previous available data for dynamic impact child models were reported in a freefall study by Snyder et al. [1] In the modelling work carried out at IW-TNO a family of 2-dimensional mathematical models (cadaver, part 572 3-year-old, TNO-P3 3-year-old) have been developed and validated for the use in studies relating to the restrained child in a frontal impact. Wismans et al. [2] These mathematical models have been formulated, using MADYMO, which is a compact general purpose computer program package for two- or three-dimensional Crash Victim Simulations. Maltha et al. [3]

Child restraint system design exhibits widely varying configurations with restraint concepts ranging from belt harnesses to padded shields (fig.1)

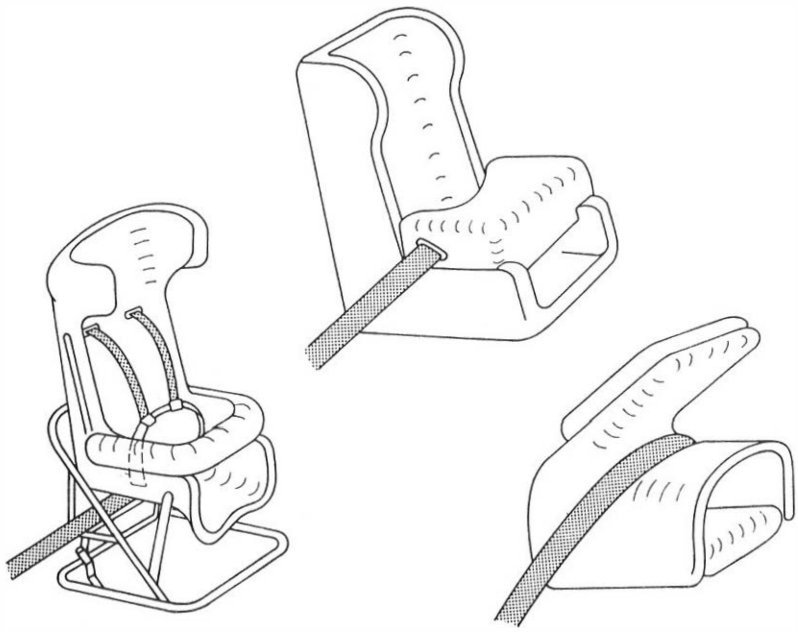

Fig. 1. Child Restraint Systems

Each one of these systems has its own advantages and disadvantages.
A properly adjusted harness restaint system offers the advantage of good impact protection while allowing the child to sit up high with good forward visibility. The major disadvantage of this type of system is however, that the harness is difficult to adjust and is often miss used, leading to poor crash protection. The major advantage of a shield device is that it gives very good load distribution over the childs body during a crash. Another strong advantage is, that it does not need any adjustments to provide this good crash protection, so therefore it is seldom miss used. The major disadvantage is that the child has to sit behind a shield and has very poor visibility.

The sponsor of this work wanted to combine the best feature of the harness system, good visibility for the child and the best features of the shield system, good load distribution and ease of use, into one new child restraint. Their concept of this new system was a child restraint device with the shield in the horizontal position for normal use, but that would pivot upwards in crash to the conventional shield system position.

IW-TNO was contracted to use the MADYMO Crash Victim Simulator to aid in the design and optimization of this new concept. The study presented here relates to this cooperation resulting in a new child restraint system.

SYSTEM CONCEPT

This new restraint system is based on a polystyrene shell with a table in front of the child which will tip-up into the shield position during a crash. The polystyrene shell will have wings on the sides for lateral protection and acts as a support for the table assembly. The table assembly will provide: a pivot support for the table-shield, housing for the table-shield actuating mechanism, a pelvis support during an impact, and anchorage points for the car lap belts.

DESIGN AND OPTIMIZATION OF TABLE ACTUATING MECHANISM

The table actuating mechanism basically consists of a leverarm on the moving table connected to a rod with a heavy mass at the other end. During the car crash the table moves into its upright position by the decelleration forces acting on the mass. (fig.2)

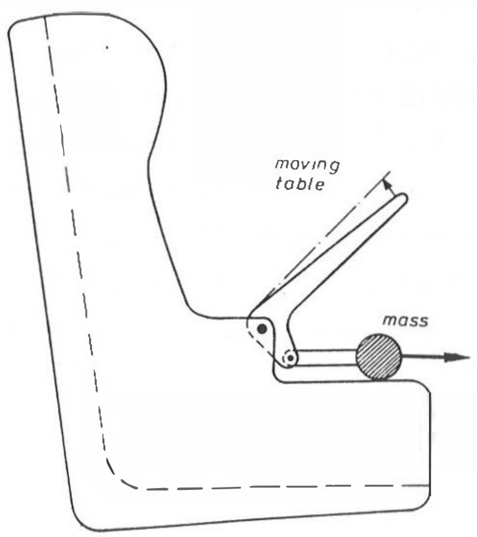

Fig.2.The table actuating mechanism

The downward motion of the table due to loadings from head or chest is prevented by a locking device.
A number of provisional system parameter values are selected, which are based on global calculations and engineering experience for this actuating mechanism. The behaviour of this system in a 50 kmh frontal crash is than simulated by using the MADYMO CVS program package.

This computermodel of the seat with the mechanism consists of a linkage of three rigid elements. The first element represents the seat polystyrene shell and includes the housing for the table actuating mechanism. This element has a total mass of 4 kg and a rotational moment of inertia of 0.145 kgm^2. The second element is the moving table with a pivot connection to the mechanism housing on the first element. The mass is 0.8 kg and the moment of inertia 0.001 kgm^2. The third element represents the actuating concentrated mass and connecting rod which pivots on a leverarm on the moving table. This element has a total mass of 1.5 kg and the moment of inertia is neglected because of the translational motion.

For realistic modelling of this mechanism the interactions of the Child restraint with the car seat and lap belt are also taken into account. The measured force-penetration characteristics of the child restraint into the car seat and the beltforce-elongation characteristic together with the sled deceleration curve are given as input for this model. The first modelruns showed that the basic concept could work and a prototype of the seat was built and tested on the deceleration sled.

After that a number of computerruns with this model were necessary for the validation process. This validation is done by comparing some model results like kinematics, beltforce and relative table angle with the results of the experiment on the prototype. These comparisons showed the need to establish some system parameters more accurately, for instance the penetration function and friction coefficient of the soft car seat. After these model improvements good agreement between model and experiment was found (fig.3).

In this stage of the study the optimization aims only at obtaining maximum table angle in the shortest possible time. Based on the validated model the system optimization was carried out by a number of modelruns with succesive parameter changes. These parameter changes were within reasonable limits so that unacceptable deviations from the validated model behaviour were avoided.

The following parameters were varied: the actuating mass was made heavier and lighter; the lever arm on the table was shortened and lengthened; the mass and the moment of inertia of the table were varied; the belt attachment point on the seat was moved to other positions; etc. The effects of these changes were studied and finally lead to an optimal combination of values to give maximum table angle (fig.3).

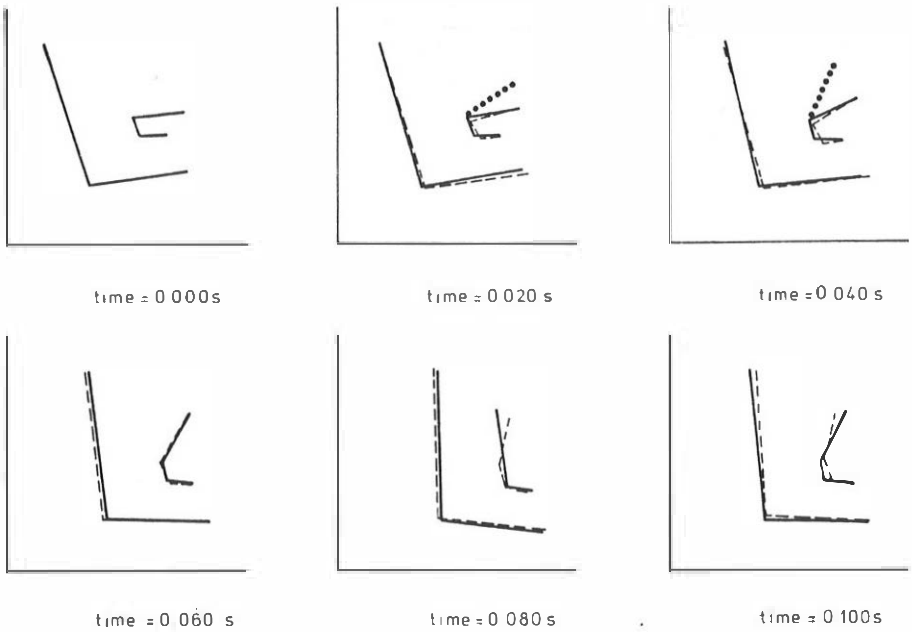

Fig. 3. Validation and optimization results.

———— : validated model
-------- : experiment
.... : optimized model

DESIGN AND OPTIMIZATION OF THE COMPLETE RESTRAINT SYSTEM WITH DUMMY

A prototype of the child seat based on design recommendations of the previous section was built and tested on the sled with the 3-year-old dummy (fig.4).

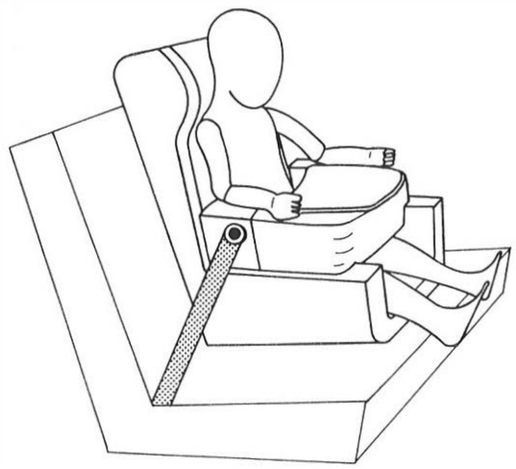

Fig.4.Restraint System with Dummy

This test showed an interference of the dummy chest with the moving table preventing further upward motion of it, so further optimization of the system was required.

The existing three element computer model of the child restraint was completed with the standard nine element model of the TNO-P3 three-year-old child dummy. A detailed description of the dummy model is contained in reference [4] . The locking mechanism of the moving table to prevent the downward motion under loads is simulated by adding a very simple force interaction model to the programpackage. A drawing defining the geometry of the complete system as used in the optimization is shown in fig.5.

Comparison of the results of the first runs of this extended model with the test showed that accurate and detailed modelling of pelvis and chest contacts with table and mechanism housing was necessary for realistic performance. After incorporating more detailed contacts, the model was globally validated to the experiment.

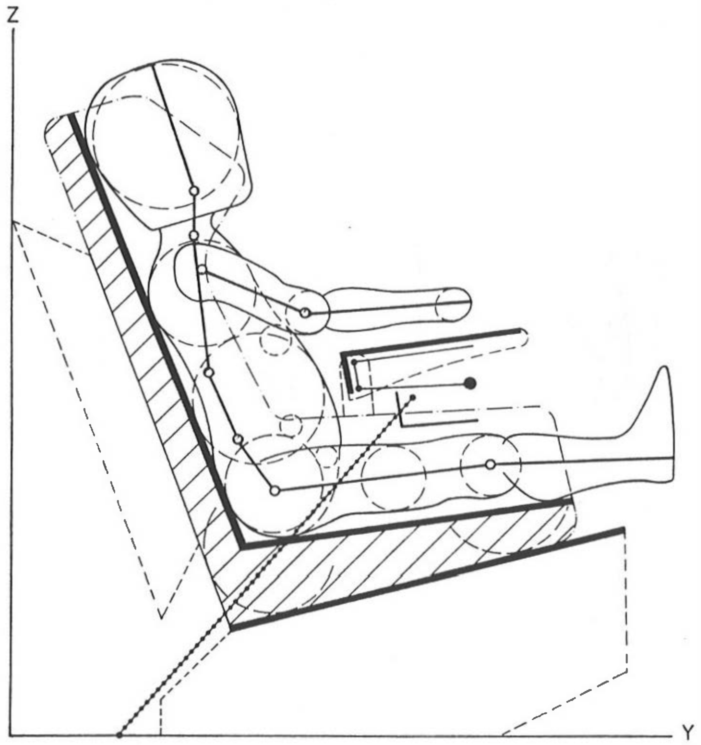

Fig.5. Geometry and contacts of complete system.

The model was then run several times with succesive systemparameter changes: the belt attachment point locations were moved; the geometry of pelvis, abdomen and chest contacts were changed; the table maximum angle was varied; the table length was changed; and etc. These performance optimizations were done based on the results of the overall kinematics, maximum head excursion and resultant head- and chest accelerations.
The kinematical results of one of these runs are shown in fig.6.

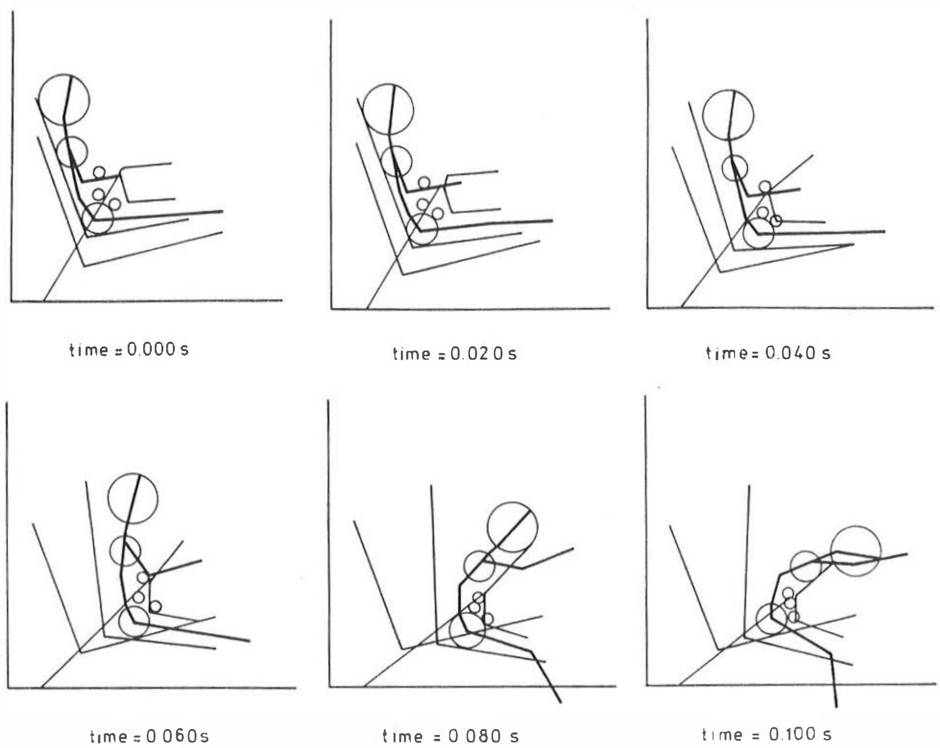

Fig.6. Kinematics of Restraint System with Dummy for one of the Optimization Simulations.

During this optimization process intermediate modifications to the prototype were made. The new prototype was tested on the sled and the results were compared to the model. This process was repeated until the desired performance was obtained. These final design parameters obtained from the computermodel together with engineering experience based on the prototype sled tests, form the basis for the design recommendations for a productionmodel.

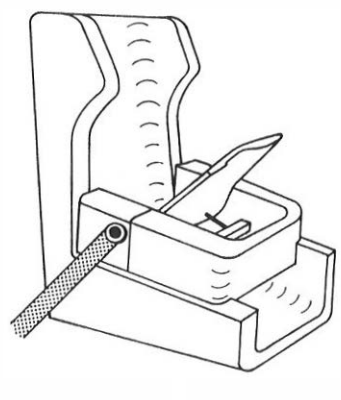

Fig.7. Production Model.

SUMMARY AND CONCLUSIONS

The use of the MADYMO simulation program in this study was found to be invaluable for looking into the basic parameters that are influencing the performance, like the following:

- Table pivot point, driving mass, and inertial properties
- Restraint seat inertial properties
- Lap belt attachment point locations
- Car seat load-deflection and friction characteristics
- Relationship between pelvis contact with the mechanism housing and chest contact with the table
- Sled pluse and velocity
- Table length and maximum angle.

This design approach allows the most important performance parameters (table inertial properties, lap belt anchorage point locations, etc.) to be separated from the lesser important parameters (restraint seat inertial properties, belt properties, etc.), so that the final design could be obtained in a far shorter time than by previous methods of design -sled tested; redesign - resled tested, etc.

Not only the new restraint system design was better understood, but a greater insight into the sled and dummy performance was also obtained. That is for example the influence of the sled free run distance on the restraint loading forces, or the shape and stiffness of the dummy body segments on the dynamic loading of the restraint system.

The conclusions of this study are:

- A child restraint system can be efficiently designed by the aid of a computer
- Computersimulation gives a valuable insight into the relative importance of the basic parameters that are influencing the performance
- The MADYMO CVS program package proved to be an easy to use tool for this design optimization due to its compactness and the standard option for multiple force interacting linkages of elements
- The locking mechanism of the table could easily be simulated by adding a very simple submodel to the program package.

ACKNOWLEDGEMENTS

This research is financed by Römer-Britax, Ulm, West-Germany and the authors appreciate the support and interest shown by the contractor. Special thanks should go to Mr. W.Czernakowski and his colleagues for their invaluable help on this study.

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