Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Bastian Keding [1], Uli Franz [2], Sebastian Stahlschmidt [1], Jens Zschieschack [1]

[1] DYNAmore GmbH, Stuttgart, Germany

[2] DYNAmore GmbH, Langlingen, Germany

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

-

Simple Considerations with the ES-2 Model

Authors:
Bastian Keding, Uli Franz*, Sebastian Stahlschmidt**, Jens Zschieschack****

****DYNAmore GmbH, Stuttgart, Germany**
***DYNAmore GmbH, Langlingen, Germany**

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Outline

- Introduction
- Kinematics of ES-2 arm
- Behaviour in vehicle model
  - upper arm joint
  - clavicle joint
  - conclusions
- Barrier tests
  - considerations on shoulder joint
  - considerations on clavicle movement
  - conclusions
- Summary

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Introduction

It is often stated that arm movement of ES-2 model has an influence on injury values. The arm movement is influenced by friction parameters, airbag deployment and shape and material of door trim.

This presentation tries considers load cases which show the influence of arm rotation.

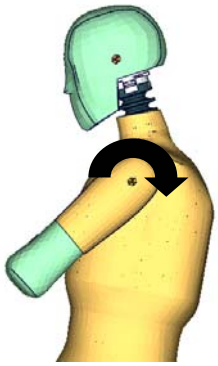
Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Kinematics of ES-2 Arm

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

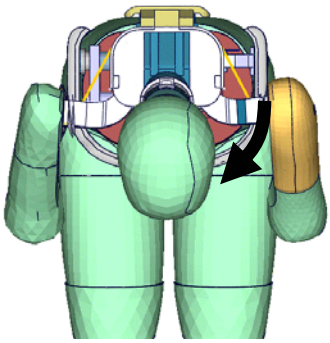
Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Kinematics



rotation of arm joint

- revolute joint



movement of clavicle

- movement is guided by surrounded parts

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

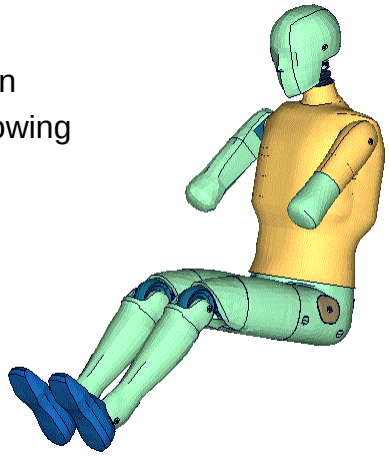
Considerations in Passenger Car Model

- for the considerations a sub-model has been generated
- b-pillar, door trim, seat model and side airbag model has been taken from complete passenger car model
- intrusions of door trim and b-pillar were added as displacement boundaries

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

The current official release of ES-2 model version 3.3 has been taken as base model for the following comparisons.



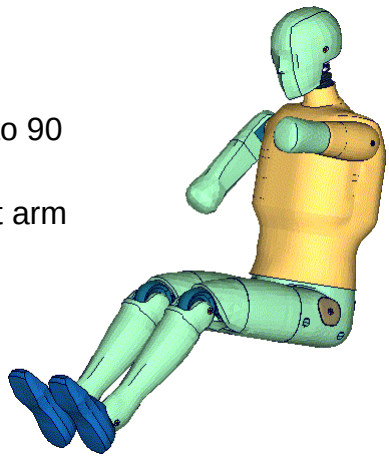
Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

DYNA MORE

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Modification 1

- arm has been rotated from 40 to 90 degree
- this correlates with a significant arm movement, initially



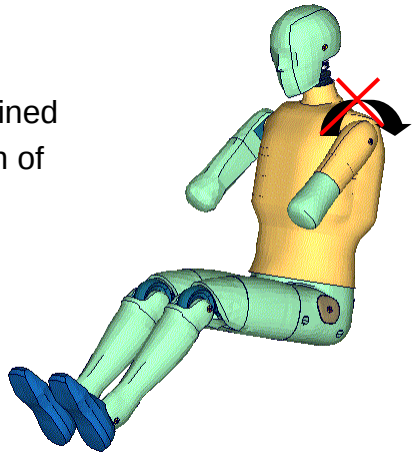
Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

DYNA MORE

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Modification 2

- rotation of arm joint is constrained
- this corresponds to no rotation of the arm

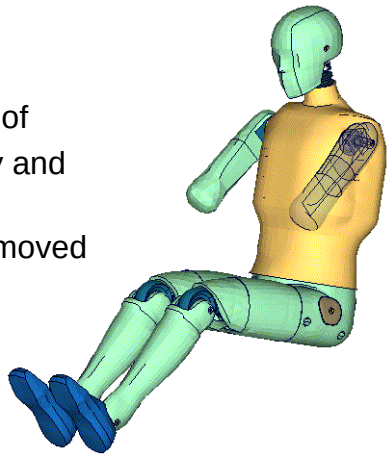


Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Modification 3

- ES-2 arm has been taken out of contact between ES-2 dummy and barrier models
- this correlates with a clavicle moved entirely forward, initially

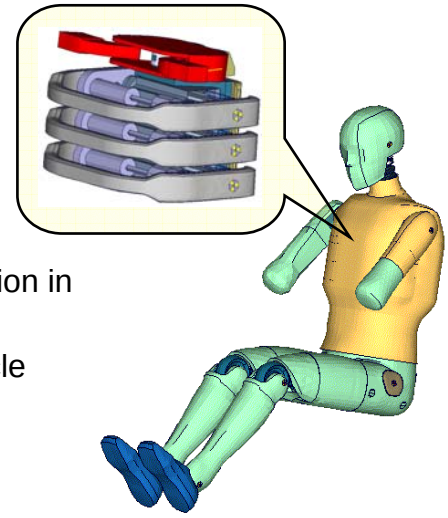


Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Modification 4

- rotation of clavicle is constrained
- this corresponds to no rotation in clavicle
- elastic deformation of clavicle is possible

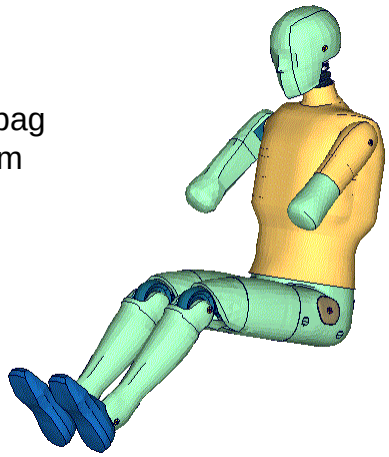


Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Modification 5

- base model, but friction of airbag to environment is reduced from 0.25 to 0.0



Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Injury Results of ES-2 in Car Structure

-

Upper Arm Joint Modifications

normalised rip intrusions

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod. 1 rigid arm joint	0.98	0.96	1.00	6 at 60 ms	---
ES-2 v3.3 basic model	1.00	1.00	1.00	6 at 60 ms	38 at 60 ms
ES-2 v3.4 – mod. 2 arm 90° position	0.97	1.06	1.04	1 at 60 ms	*10* at 60 ms

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Injury Results of ES-2 in Car Structure

-

Clavicle Joint Modifications

normalised rip intrusions

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod. 4 rigid clavicle	0.97	0.94	0.98	0 at 60 ms	40 at 60 ms
ES-2 v3.3 basic model	1.00	1.00	1.00	6 at 60 ms	38 at 60 ms
ES-2 v3.4 – mod. 5 no airbag friction	0.86	1.00	1.02	21 at 60 ms	85 at 60 ms

Why is the influence so low?

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Considerations in Passenger Car Model

- the modifications lead to almost no changes in the rib intrusions
- the design of restrain system is such rotations in clavicle are very small

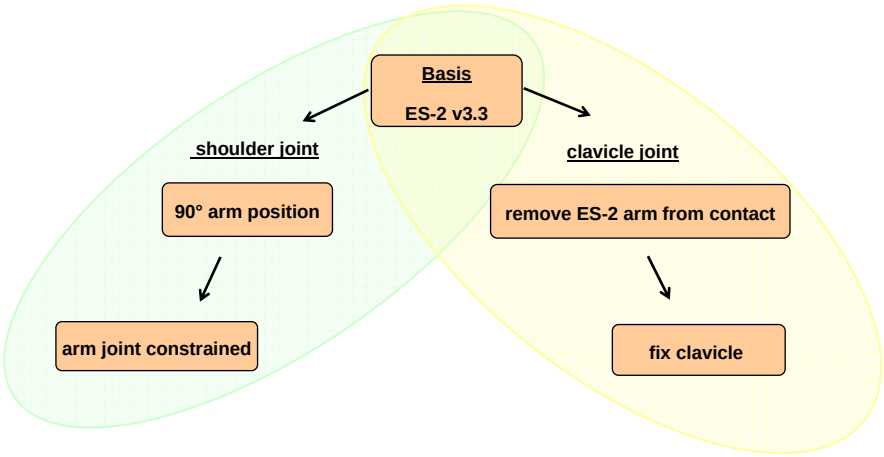
Has the arm movement really an influence?

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Barrier Tests

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

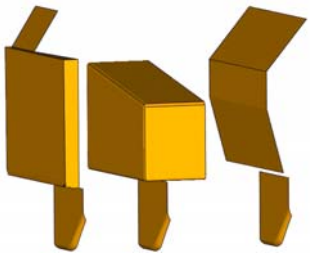


Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Barriers

- tree different barriers with two velocities



	3.5 m/s	4.5 m/s
plane barrier	✓	✓
door barrier	✓	✓
convex barrier	✓	✓

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

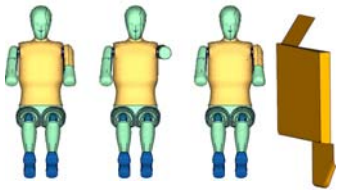
Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Considerations on Shoulder Joint

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Plane Barrier v=3.5 m/s



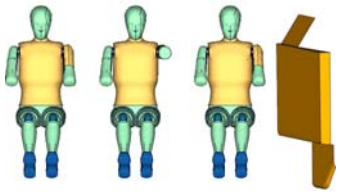
- nearly same rib intrusions in all runs
- same clavicle rotation in all runs
- arm rotation is different

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.1 90° arm position	7	9	13	25	*-4, 2*
ES-2 v3.3 basic model	9	10	13	25	-18, 0
ES-2 v3.4 – mod.2 rigid arm joint	7	8	11	24	---

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Plane Barrier v=4.5 m/s



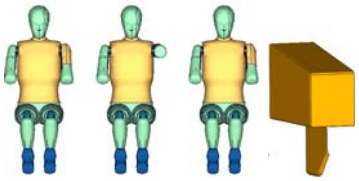
- observations similar with lower speed

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.1 90° arm position	15	17	20	29	*-3, 4*
ES-2 v3.3 basic model	17	18	21	29	-19, 3
ES-2 v3.4 – mod.2 rigid arm joint	15	17	19	29	---

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Door Barrier v=3.5 m/s



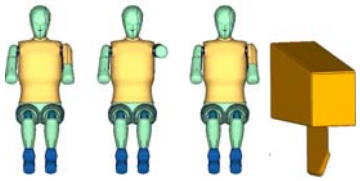
- barrier contacts lower part of arm
- contact determines clavicle rotation
- no arm - barrier contact for 90° arm position model

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.1 90° arm position	36	30	27	0	*-3, 3*
ES-2 v3.3 basic model	22	21	21	15	-5, 6
ES-2 v3.4 – mod.2 rigid arm joint	22	21	21	15	---

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Door Barrier v=4.5 m/s



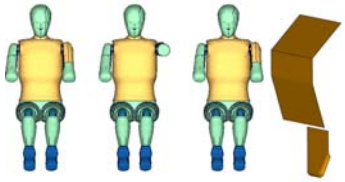
- observations similar to lower speed

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.1 90° arm position	46	39	35	2	-5, 3
ES-2 v3.3 basic model	33	30	29	16	-4, 8
ES-2 v3.4 – mod.2 rigid arm joint	33	30	29	16	---

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Convex Barrier v=3.5 m/s



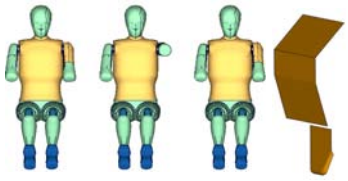
- different arm rotations, but no significant influence on rib intrusions
- similar clavicle rotation
- differences in upper ribs

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.1 90° arm position	25	30	34	17	-9, 0
ES-2 v3.3 basic model	20	24	30	22	-19, 10
ES-2 v3.4 – mod.2 rigid arm joint	18	23	30	20	---

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Convex Barrier v=4.5 m/s



- observations similar to lower speed

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.1 90° arm position	37	40	44	19	*-16, 0*
ES-2 v3.3 basic model	30	34	40	24	-20, 16
ES-2 v3.4 – mod.2 rigid arm joint	28	33	39	23	---

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Conclusions of Arm Rotation

- arm rotation itself has a minor influence for the rib intrusions in the considered load cases
- loads on the arm determine the clavicle rotation.
- clavicle rotation seems to have a significant influence on the rib intrusions

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

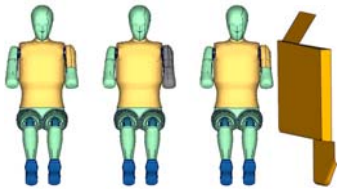
Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Considerations on Clavicle Movement

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Plane Barrier v=3.5 m/s



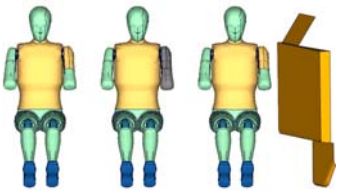
- rib intrusions shows high sensitivity on clavicle movement

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.3 arm without contact	19	20	21	maximum	---
ES-2 v3.3 basic model	9	10	13	25	-18, 0
ES-2 v3.4 – mod.4 rigid clavicle	7	1	2	5	-8, 14

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Plane Barrier v=4.5 m/s



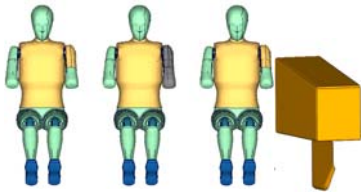
- similar to lower barrier speed

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.3 arm without contact	27	28	28	maximum	---
ES-2 v3.3 basic model	17	18	21	29	-19, 3
ES-2 v3.4 – mod.4 rigid clavicle	10	4	8	7	-9, 18

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Door Barrier v=3.5 m/s



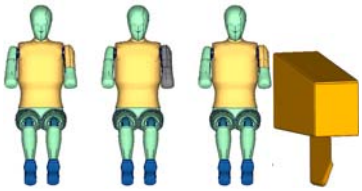
- different clavicle rotation
- barrier contacts lower part of arm
- contact determines clavicle rotation
- base model close to modification 4

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.3 arm without contact	37	31	28	Maximum	---
ES-2 v3.3 basic model	22	21	21	15	-5, 6
ES-2 v3.4 – mod.4 rigid clavicle	18	17	18	2	-3, 28

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Door Barrier 4.5 m/s



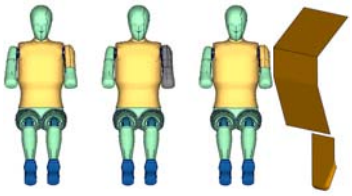
- similar to lower barrier speed

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.3 arm without contact	47	40	35	Maximum	---
ES-2 v3.3 basic model	33	30	29	16	-4, 8
ES-2 v3.4 – mod.4 rigid clavicle	29	27	27	3	-4, 39

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Convex Barrier v=3.5 m/s



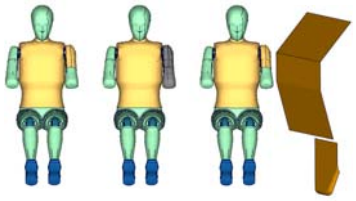
- significantly different clavicle rotation
- slightly different arm rotation
- basic model is between 2 modifications

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.3 arm without contact	32	35	37	maximum	---
ES-2 v3.3 basic model	20	24	30	22	-19, 10
ES-2 v3.4 – mod.4 rigid clavicle	13	9	17	5	-14, 14

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Convex Barrier v=4.5 m/s



- similar to lower barrier speed

ES-2	upper rib [mm]	middle rib [mm]	lower rib [mm]	clavicle rot [°]	arm rot [+/- °]
ES-2 v3.4 – mod.3 arm without contact	41	43	45	maximum	---
ES-2 v3.3 basic model	30	34	40	24	-20, 16
ES-2 v3.4 – mod.4 rigid clavicle	18	18	28	6	-16, 26

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Conclusions of Clavicle Movement

- clavicle movement has significant influence on injury values.
- rotations of clavicle interrupts the load path from impacting parts to the spine via the clavicle box. As result higher rib intrusions may be observed.
- movement of clavicle is determined by the shapes and properties of the trims, the restraint system, and the friction between the interacting parts.

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Classification of load cases

-

Arm and Clavicle Rotation Matrix of ES-2 Models

	less clavicle rotation	large clavicle rotation	
less arm rotation	door mod 1	door mod 2- 4	
large arm rotation	vehicle mod 1- 5	plane mod 1- 4	convex mod 1- 4

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Summary

Arm rotation (shoulder joint) has limited influence on rib intrusions.

Clavicle movement hat significant influence on rib intrusions.

Major influence on clavicle rotation is the airbag deployment, frictional values, shape and behaviour of parts connecting the arm during impact.

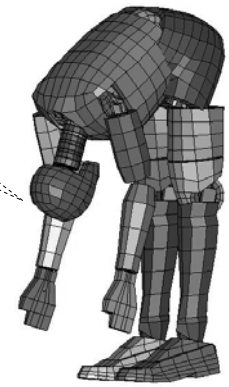
Models with significant clavicle movement are more sensitive against changes of the properties listed above.

In considered vehicle the clavicle movement is very low, hence less sensitive regarding changes of the properties listed above

Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH

Influences of Arm Rotation for Side Impact Dummy Injury Measurements

Any questions!?



Ulm, 13th of October 2006
Bastian Keding DYNAmore GmbH