The Optimization of the LSTC Hybrid III Dummies to enhance the numerical stability and to fulfill the current standards

Wolfgang Lietz
CAD-FEM GmbH, Grafing b. München

LS-DYNA

CADFEM

Abstract

- Many years ago LSTC developed Hybrid III-Dummies. One group of these have on the outer surface deformable parts. The dummies are free and without charge for user's of LS-DYNA.
- In the last years on on hand the dummies changed and on the other hand the expectations on the dummies were growing.
- This paper describes the the overall validation and optimization process of the whole dummy and in detail the optimization work for the neck validation of the 95% Dummy.

Outline

- Applications
- Dummy overview
- Status
- Targets
- Validation
- Example 95% Dummy neck validation
- Conclusion

Application

- The main industrial areas of the dummies are the automotive, the train and the aircraft industry. They are predominant used as a load device for seats and instrument panels. An other application is the assessment of a survival space in cockpits. Required are the dummies in crash test as in FMVSS 301, Euro NCAP and a lot of others.
- Dependent on requirement there are a lot of high sophisticated dummy models on the market. This can be a dummy for the evaluation of injury criteria's or a special purpose dummy e.g. a pregnant dummy.

Dummy overview

- Dummy models are used to evaluate the human behavior in specific and potential dangerous situations.
- Dummies were developed for a specific loading condition.
  - Automotive frontal impact -> Hybrid III
  - Head impact -> Free motion head form
  - Pedestrian protection -> Head and leg devices
  - Neck injury -> Trid neck, …
  - Child protection -> specific children dummies
- FEA models can be from varies from a simple chain of “point masses” to “high sophistic” research models with details like muscles or organs.

LSTC Dummy overview

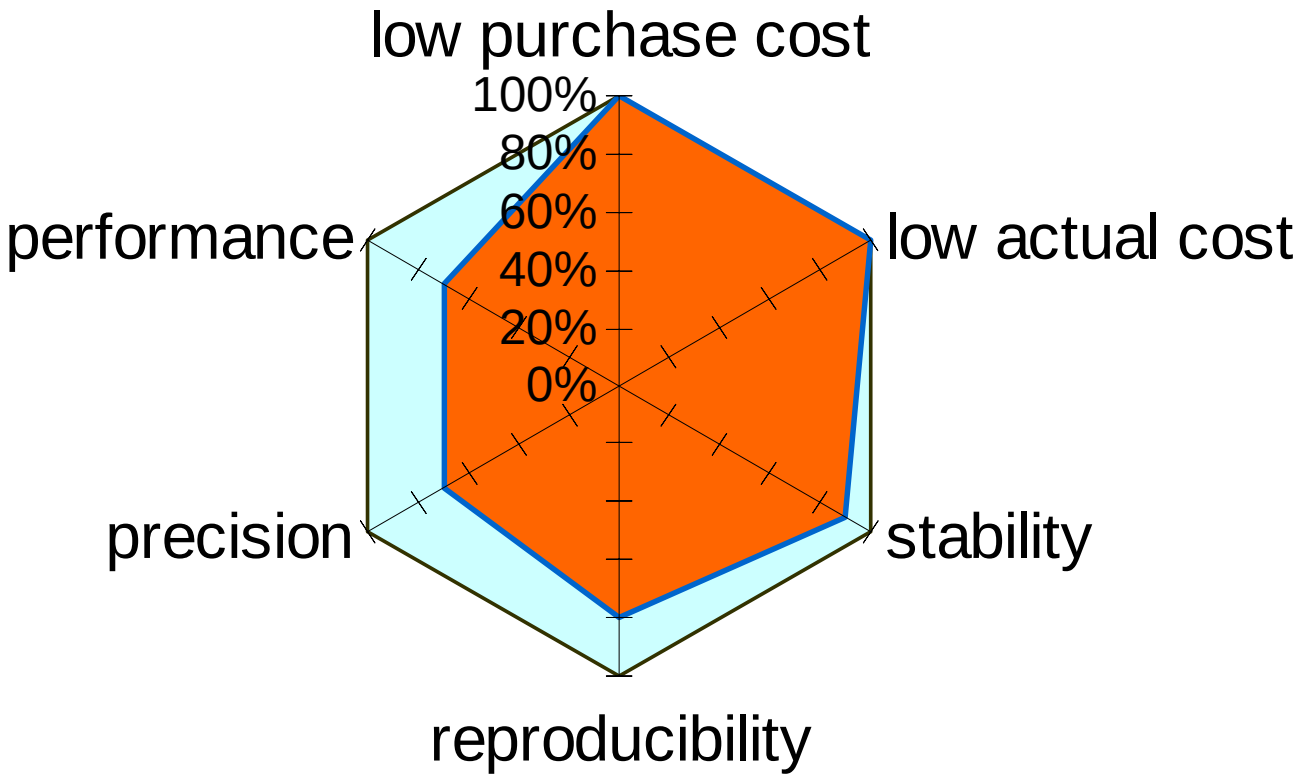
- Many years ago LSTC developed Hybrid III-Dummies. Now there exists three groups of dummies. The first group contains scalable dummies build by ellipsoid. The second group contains dummies which are build mostly from rigids. The third group has on the outer surface deformable parts.
- The dummies are free and without charge for user's of LS-DYNA.
- In the last years on on hand the dummies changed and on the other hand the expectations on the dummies were growing.

Dummy status

- Assessment of the dummies from CAD-FEM and in collaboration with our customer showed a need to rework the dummy.
- A Dummy How-To is missing.
- Some customers made modifications to the dummy for higher calculation stability. Some of this modification had a bad influence to the behavior.

Targets for a FEA-Dummy model

- **General purpose dummy**

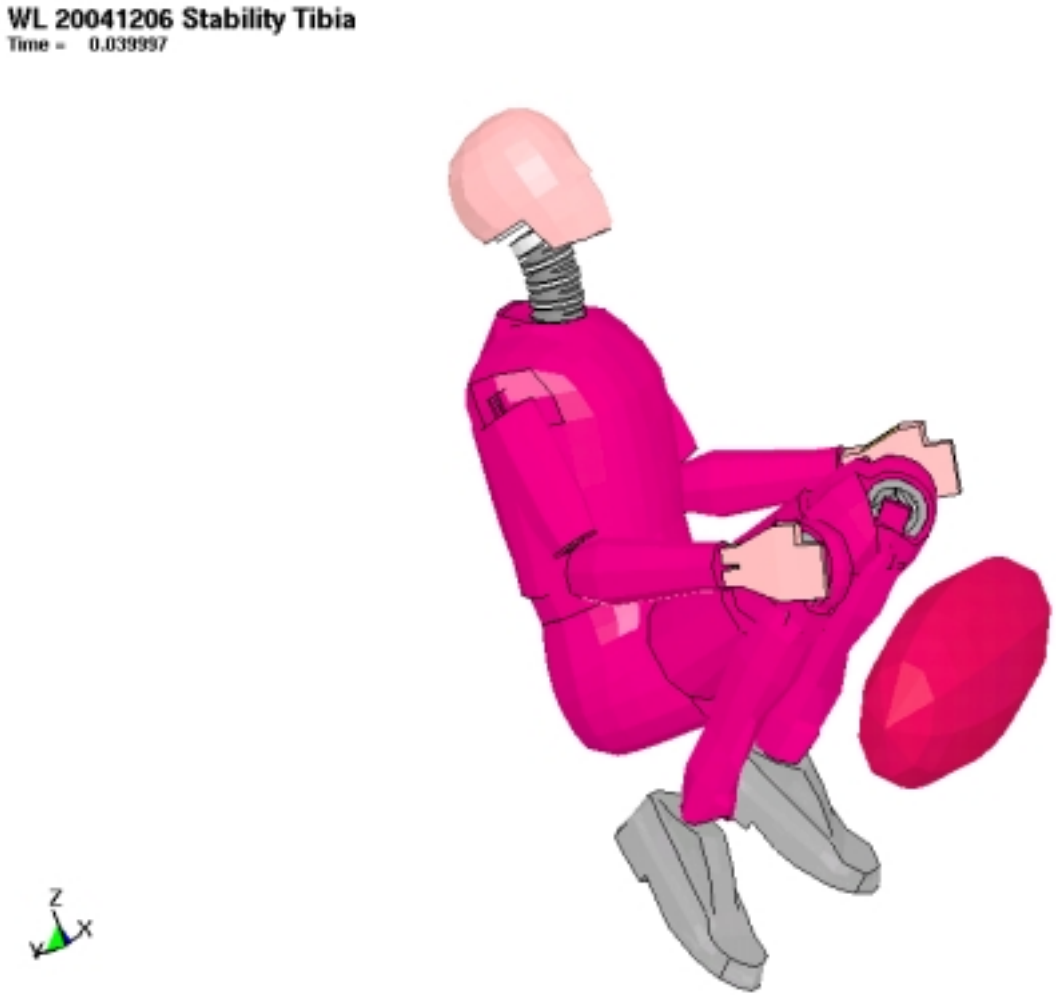


Targets for a FEA-Dummy model

- Description of Dummy usage and behavior.
- Optimization regarding the requirement as described in FMVSS Part 572 and SAE-EA 26.
- Increase the stability of the dummy. A LS-DYNA run should not abort by a failure of the dummy itself.

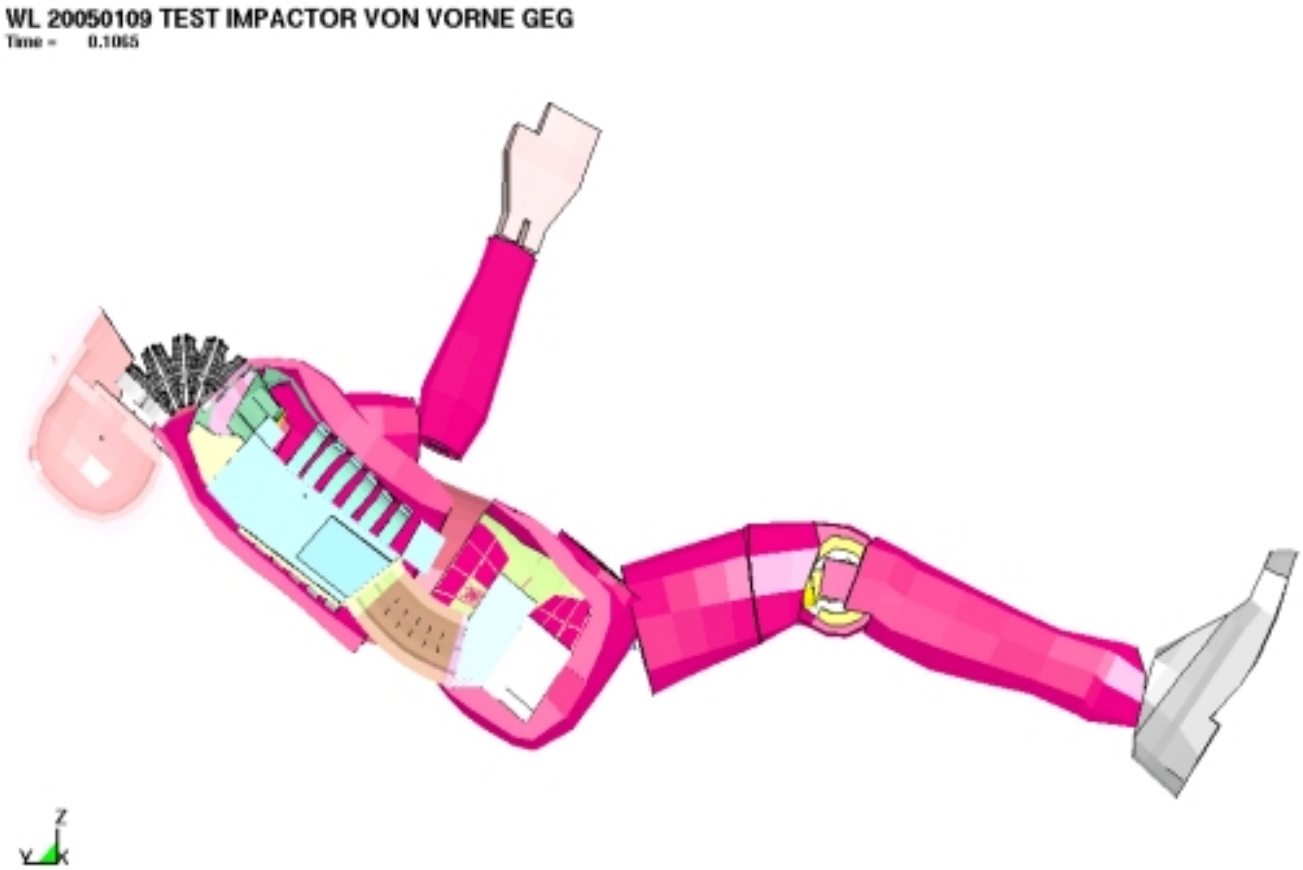
Examples for the dummy stability

- Test of the lower legs



Examples for the dummy stability

- Test of the chest



Dummy validation

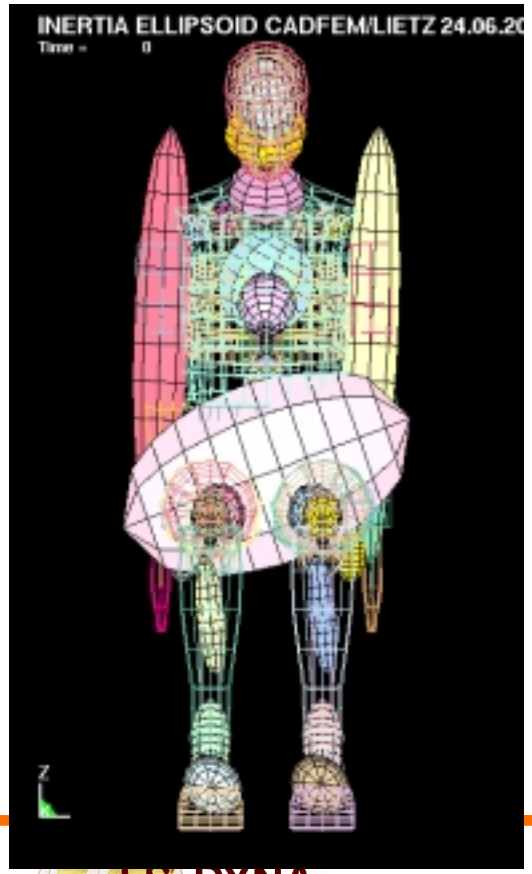
- Validation procedure SAE-EA 26
    - Expected in 2005 FMVSS Part 572
- Drop test
- Neck performance
- Chest compression
- ….

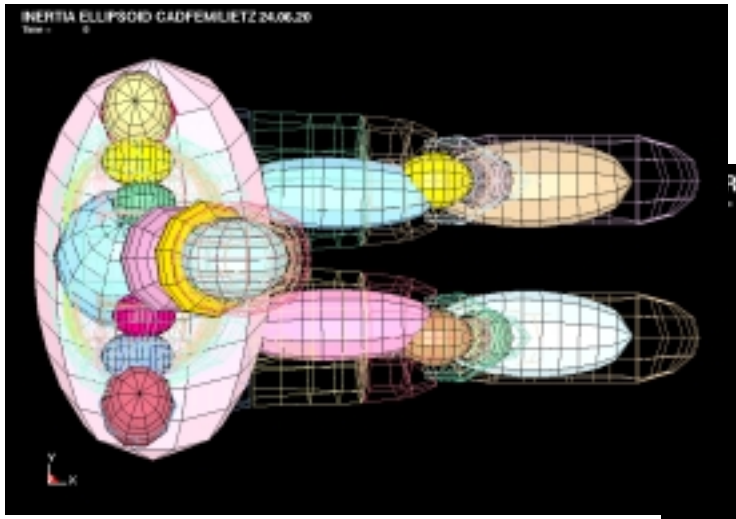
95% Dummy modifications

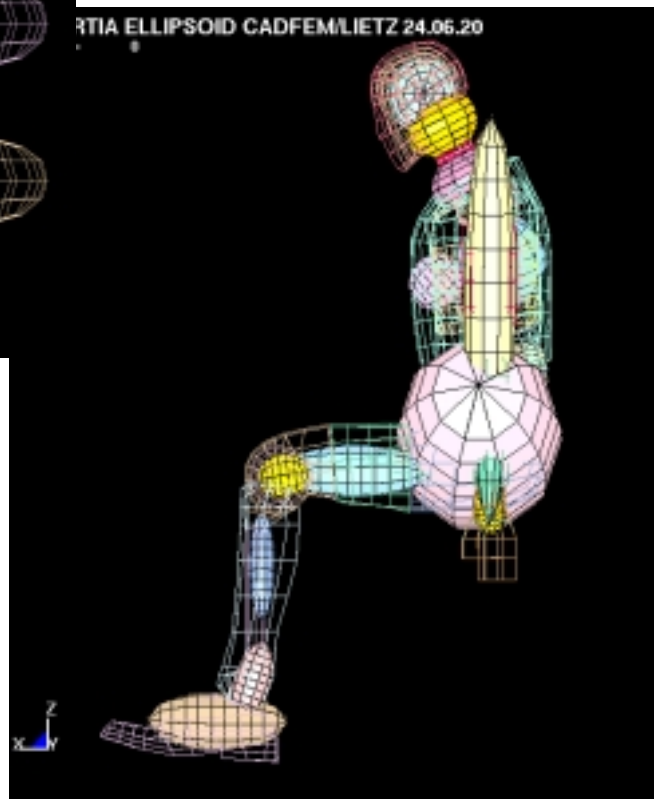
- Remeshing
- Adjust joint stiffness and stop angles.
- Adjust masses
- Adjust moments of inertia
- Adjust center of gravity
- Use of advanced LS-DYNA options e.g. *CONTACT_

95% Dummy part inertias

- The pictures showing the actual ellipses of the principal inertias of a dummy.







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95% Dummy neck validation

- Specific pendulum (size, mass, inertias)
- Pendulum test for flexion and extension with a deceleration in a specific corridor.
- Neck response in moment, rotation and timing in specific ranges

95% Dummy head/neck inertias

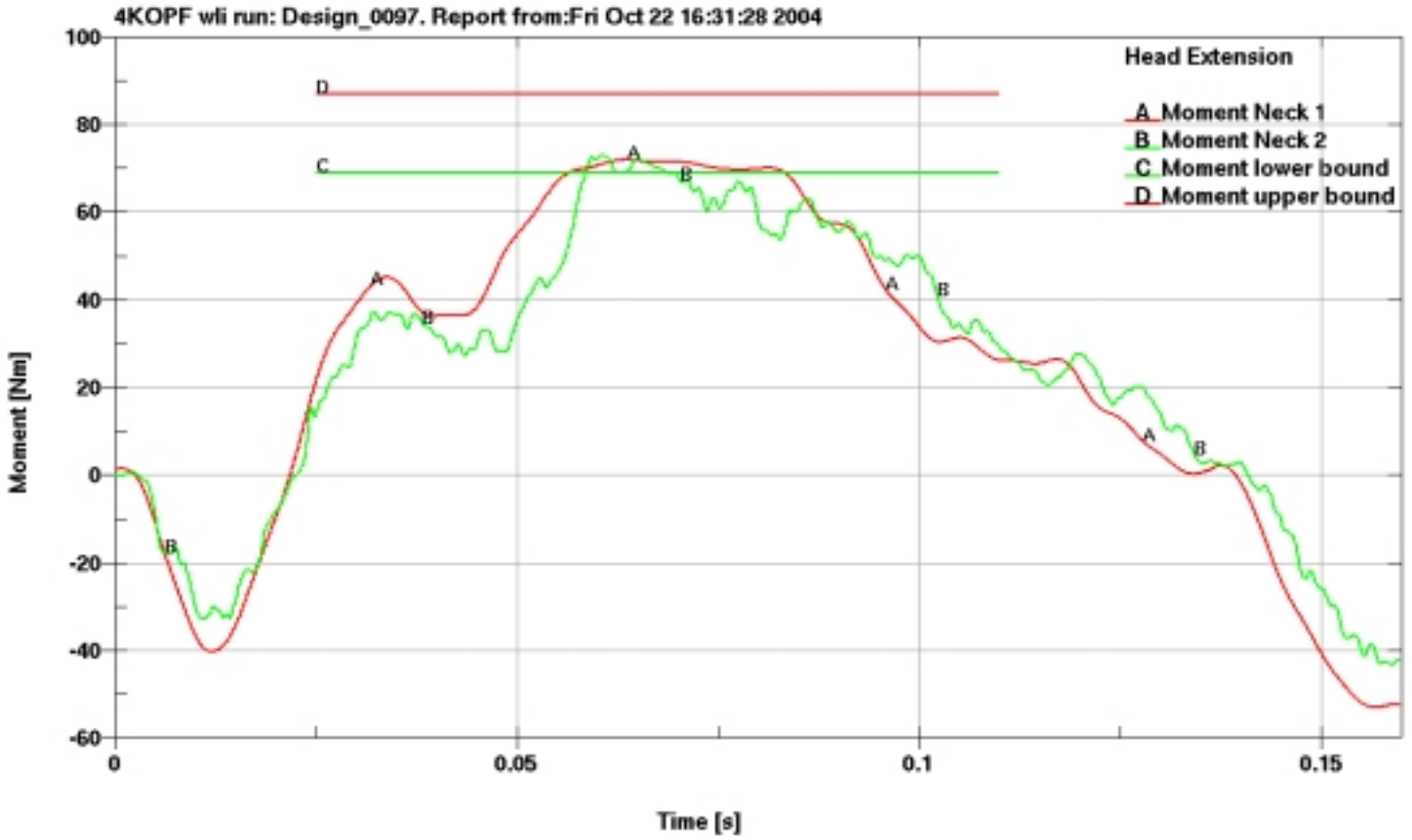
```
Units: t mm sec.
Total mass = 0.001637775348 t
sum of inertias [t * mm^2]:
[  1.154690000000E+00  4.353167182000E-04  9.936070000000E-05 ]
[  4.353167182000E-04  1.158580000000E+00 -2.227877000000E-04 ]
[  9.936070000000E-05 -2.227877000000E-04  1.007025702000E+00 ]
Part mass inertia relative to:
[  7.240090034194E+01  2.982799238611E-01 -1.353795840156E+02 ]

[  2.601264934510E+00  2.059279319584E-04 -9.459002168037E-03 ]
[  2.059279319584E-04  2.605379229942E+00  2.309008434161E-03 ]
[ -9.459002168037E-03  2.309008434161E-03  4.190681011274E-03 ]

Principal moments of inertia:
[  3.755936737027E+00 ]
[  3.764010928077E+00 ]
[  1.011182882360E+00 ]
Principal directions:
[  9.968858385091E-01  7.878449016615E-02  3.410145052112E-03 ]
[ -7.878234651240E-02  9.968915519391E-01 -7.586503503783E-04 ]
[ -3.459314674407E-03  4.876285615191E-04  9.999938976616E-01 ]
```

95% Dummy neck optimization

- 25 Parameter
  - Rubber material parameter e.g. bulk modulus
  - Shape of curves for discrete elements
  - Contact parameter
  - Diameter of Spine
- 20 Responses
- Optimization with LS-OPT
  - thank you for support from N. Stander and W. Roux (LSTC)
- Optimization with Optislang
  - thank you to J.Will (Dynardo)

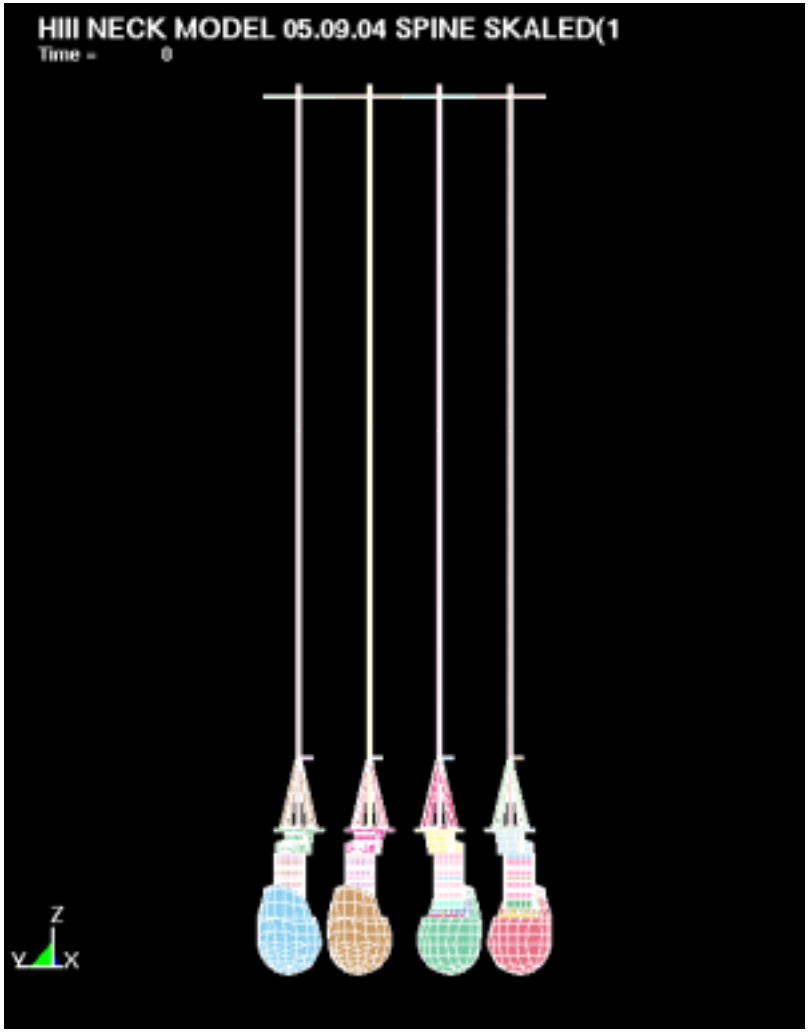
95% Dummy neck optimization

- Moment in load case extension
  - Target: maximum must between the bounds



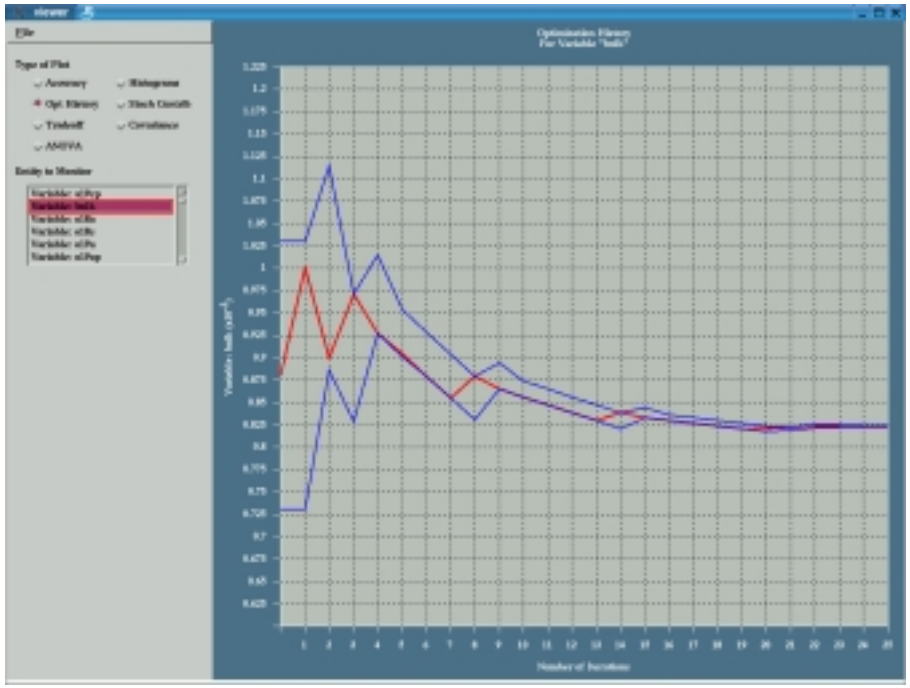
95% Head/Neck pendulum model

- Model:
  - 1th model flexion high velocity, high deceleration
  - 2nd model flexion low velocity, low deceleration
  - 3rd model extension high velocity, high deceleration
  - 4th model extension low velocity, low deceleration



Optimization by response surface

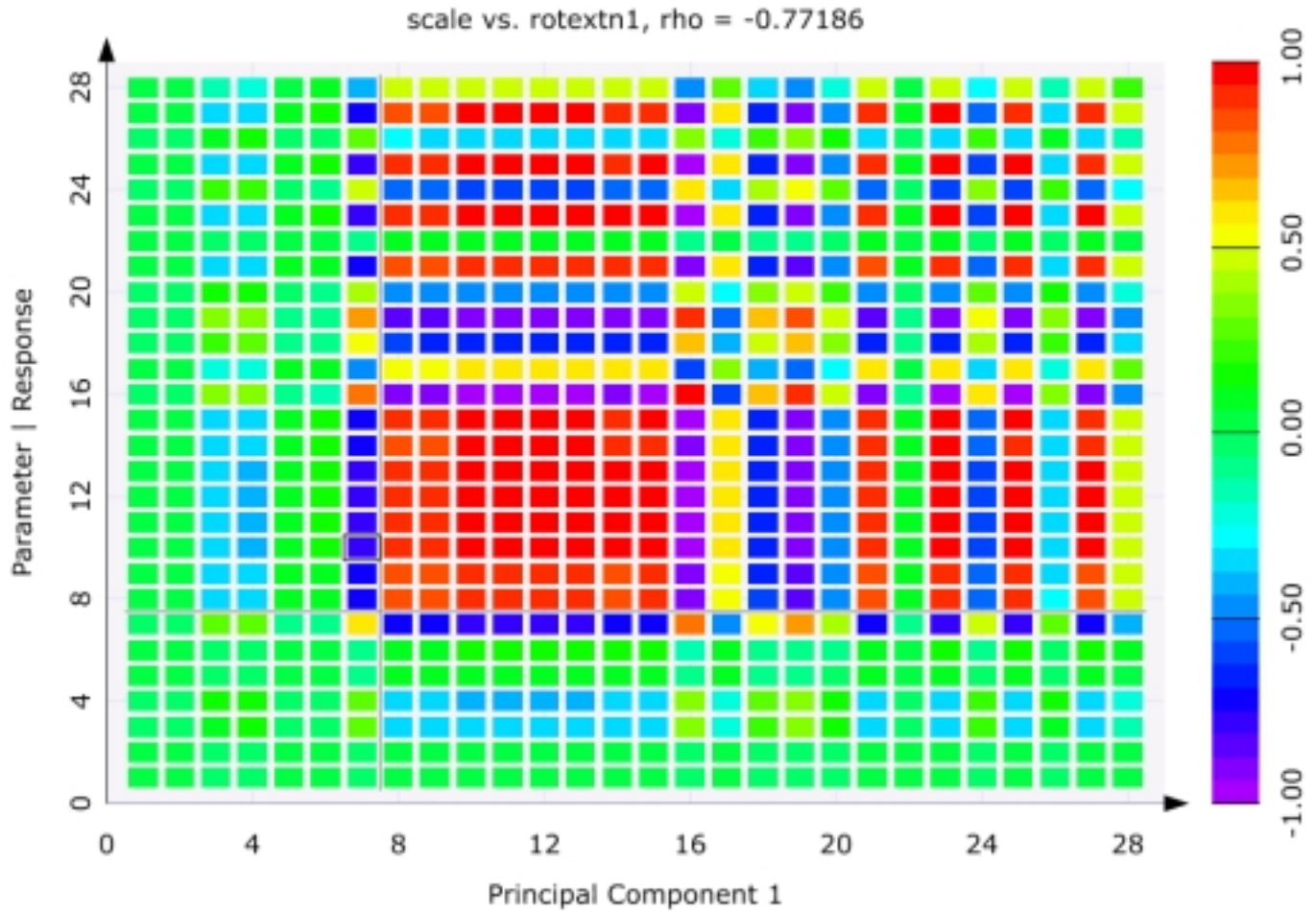
- Optimization History



- ANOVA

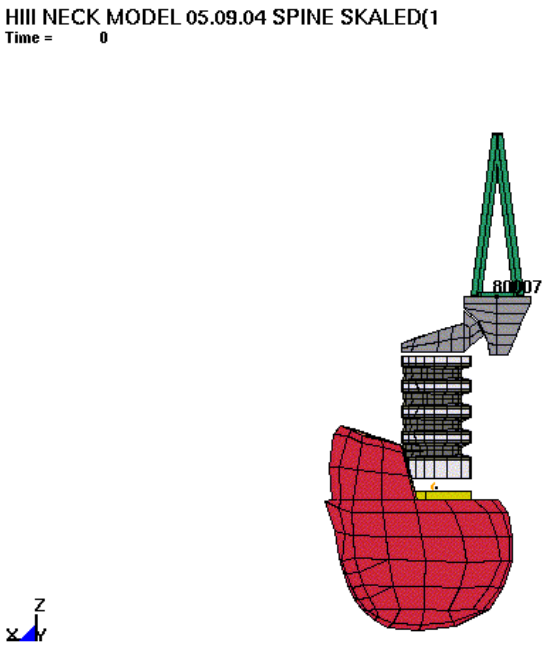
Optimization by genetic algorithm

- Correlation matrix, first principal component

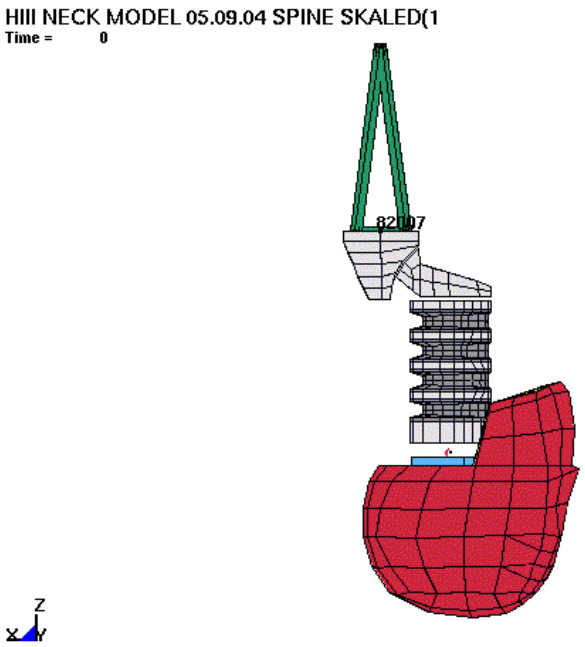


95% Head/Neck responses

- Flexion



- Extension



Conclusion

- It is possible to adjust the dummy to fulfill most of the validation procedures
- Some of the requirements make no sense to check
  - E.g. foot performance for FE-Dummies with shoe's
- Limitations
  - Some data are not available because there are not specified or not known.
  - If a dummy is loaded local e.g. impact of the head to a small rigid part will not give a good correlation between test and simulation. For this purpose you need more complex models see the free motion head form.