Working Group on Accident Mechanics
Research, Reconstruction, Biomechanics, Prevention

How to calculate the N_{km}

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Definition:

Based on the hypothesis that a neck protection criterion should take into account a linear combination of shear forces and sagittal bending moments, the N_{km} was proposed to assess rear-end impacts.
The N_{km} criterion was defined according to the following equation:

$$N_{km}(t) = \frac{F_x(t)}{F_{int}} + \frac{M_y(t)}{M_{int}}$$

where $F_x(t)$ and $M_y(t)$ are the shear force and the flexion/extension bending moment, respectively. Performing crash tests using a standard dummy, both values should be obtained from the load cell positioned at the upper neck. F_{int} and M_{int} represent critical intercept values used for normalization.
Distinguishing positive shear, negative shear, flexion and extension, the N_{km} criterion identifies four different load cases: N_{fa}, N_{ea} N_{fp} and N_{ep}. The first index represents the bending moment (f: flexion, e: extension) and the second indicates the direction of the shear force (a: anterior, i.e., in positive x-direction, p: posterior, i.e., in negative x-direction). The sign convention according to SAE J211/2 was used. Consequently, positive shear forces measured at the upper neck load cell indicate that the head is moved backwards relative to the uppermost cervical vertebra.
The intercept values used to calculate the criterion are shown in the table below. They are meant to correspond to the human tolerance levels for the causation of AIS1 neck injury. These values were identified on the basis of volunteer experiments [Mertz and Patrick, 1993] and suggest tolerance levels up to which no injury is expected. For the maximum shear level tolerated, no difference was found with respect to the direction of the sagittal shear force.

load case	value	reference
extension	47.5 Nm	Goldsmith and Ommaya, 1984 Mertz and Patrick, 1993
flexion	88.1 Nm	
negative and positive shear	845 N	

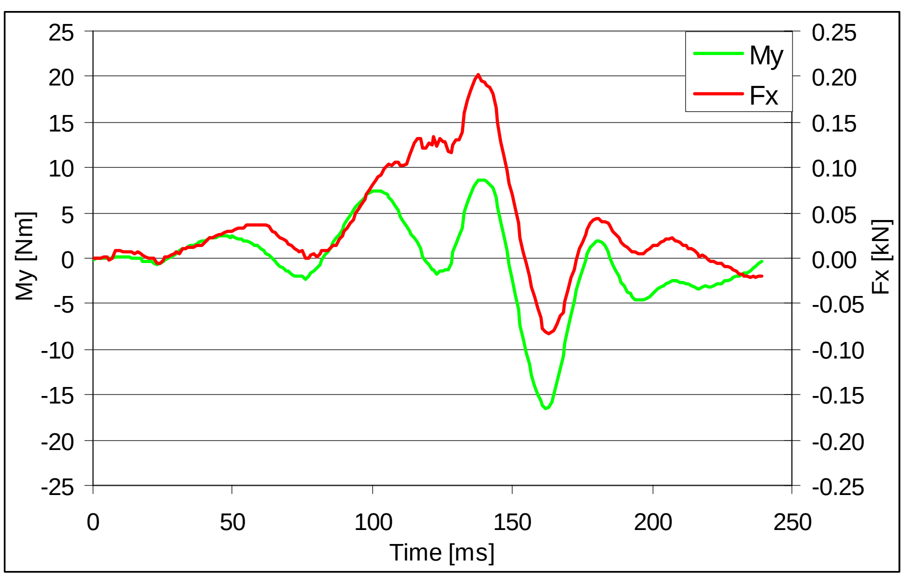
For the computation of the N_{km}, the two bending modes and the two load types under investigation are identified, then the load curves measured are divided by the according intercept value. Finally the N_{km} values are obtained by adding the adequate shear force and moment curves, while keeping the time scale unchanged, and determining the maximum of the resulting curve. Hence, N_{ep} for instance represents the maximum value in time when extension and negative shear occur simultaneously. Care must be taken to handle the signs of the measurement values correctly, i.e. for N_{ep}, the normalised extension moment and shear force will both have negative signs and the absolute value of the two curves must be calculated before addition. The other N_{km} values can be explained analogously.

To date, experience with N_{km} values was gained on the basis of data obtained from Hybrid III/TRID, BioRID, and RID2 dummies. Results indicate that, in the future, different intercept values or different tolerance levels may have to applied for the various dummies in question. The Working Group on Accident Mechanics recommends that, until more results are available, the intercept values mentioned here are used for the RID2 and the BioRID dummy. Furthermore, we strongly support the opinion that the Hybrid III dummy, with or without TRID neck, should not be used anymore for rear-end impact testing. Therefore, we also cease to consider this dummy in studies regarding e.g. intercept values or tolerance limits for the Nkm criterion.

Example:

Data:

Data representing the shear force and sagittal bending moment (i.e. extension, flexion) is needed to calculate the N_{km}. The sign convention according to SAE J211/2 has to be used, i.e. positive shear is obtained by e.g. pulling the head of the dummy backwards (because the load cell is mounted in the upper part of the dummy's head joint), and flexion is characterized by the positive values of the bending moment, i.e. by pushing the chin of the dummy towards the sternum. The figure below shows an example of data obtained from a sled test experiment (the data can be downloaded in ASCII-format from http://www.agu.ch).

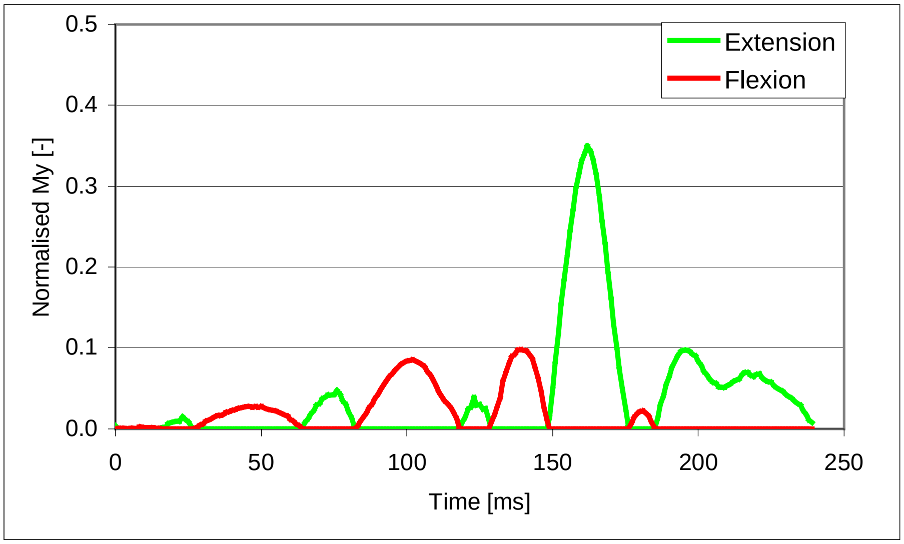


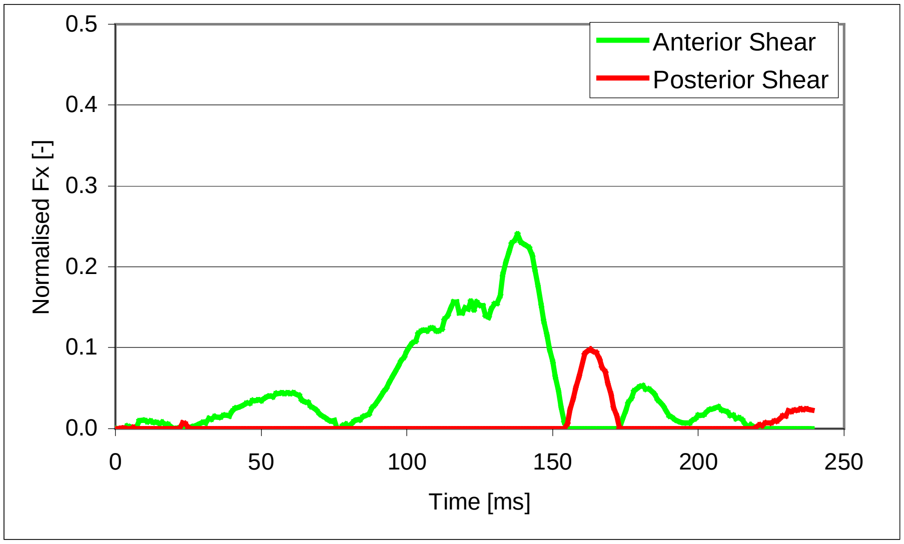
Step 1:

Generate four curves from the original measurement data:

Normalised flexion moment:	= My(t)/88.1 Nm where My(t) is >0,	=0 where My(t) <=0.
Normalised extension moment:	= -My(t)/47.5 Nm where My(t) is <0,	=0 where My(t) >=0.
Normalised anterior shear force:	= Fx(t)/0.845kN where Fx(t) is >0,	=0 where Fx(t) <=0.
Normalised posterior shear force:	= -Fx(t)/0.845kN where Fx(t) is <0,	=0 where Fx(t) >=0.

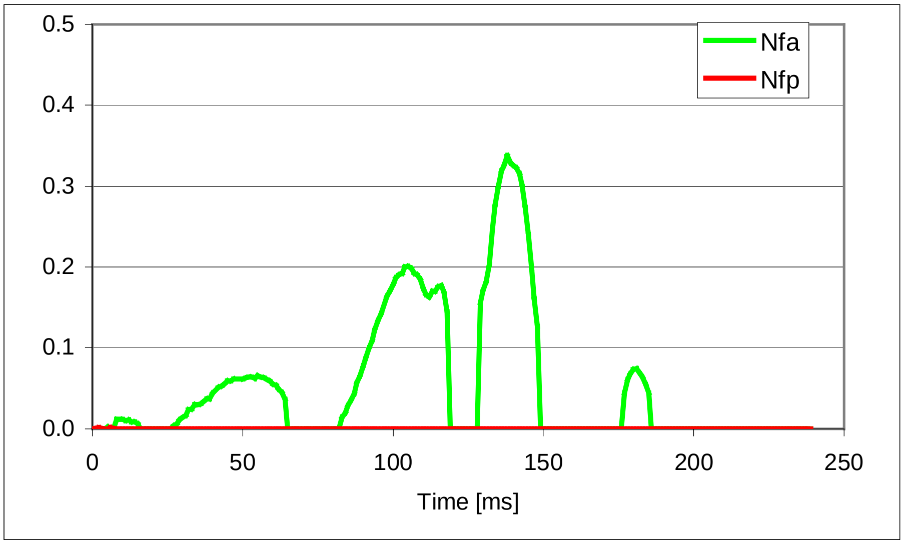
This should result in the curves below:

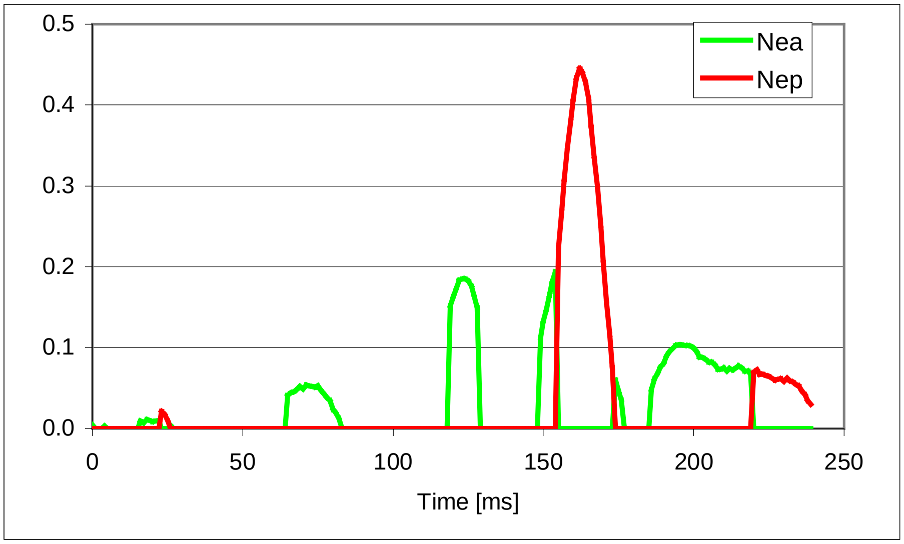




Step 2:

Add the normalised flexion moment curve and the normalised anterior shear curve at the time points where the values of both curves are simultaneously > 0. This results in the Nfa curve. Proceed in an analogous way to obtaion Nfp, Nea, and Nep curves:





Step 3:

Determine the peak values[1] in the four resulting curves. In this example, this would result in:

Nfa	Nfp	Nea	Nep
0.337	0.002	0.194	0.445

[1] It is necessary to check whether the results obtained are reasonable with respect to the crash test performed. If, for instance, one of the N_{km} values calculated occurs at a time which is not relevant for the test (e.g. at a time when the dummy is already restraint by a unrealistic seat belt, or, generally, during the forward-rebound phase when the dummy in question is not suited for that load case), the next-to-highest peak prior to that point in time has to be taken.

Literature

More information can be found in the literature references below. This represents a selection of papers only, publications which refer to the Nkm criterion have become numerous lately.

2001:

A new neck injury criterion candidate for rear-end collisions taking into account shear forces and bending moments

Schmitt K-U, Muser M H, Niederer P
2001, Proc. ESV Conf. (Amsterdam), Paper No. 124

2002:

Nkm — a proposal for a neck protection criterion for low speed rear-end impacts

Schmitt K-U, Muser M H, Walz F H, and Niederer P
2002, Traffic Injury Prevention, Vol. 3(2), pp. 117-126

Injury criteria applied to seat comparison tests

Muser M H, Walz F, Schmitt K-U
2002, Traffic Injury Prevention, Vol. 3(3), pp. 224-232

2003:

How injury criteria correlate with the injury risk - a study analysing different parameters with respect to whiplash injury

Muser M, Hell W, Schmitt K-U
2003, Proc. ESV Conf. (Nagoya), Paper No. 68

Validation of neck injury criteria using reconstructed real-life rear-end crashes with recorded crash pulses

Kullgren A, Krafft M, Eriksson L, Boström O
2003, Proc. ESV Conf. (Nagoya), Paper No. 344

Influence of seat geometry and seating posture on NICmax and Nkm AIS1 neck injury predictability

Eriksson L, Kullgren A
2003, Proc. IRCOBI Conf. (Lisbon), pp. 217-231