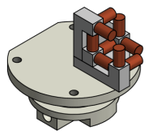
Rotational acceleration

Anvil - rigidity

- oblique anvil @ 45°, displacement@7 m/s ==> 1-2 mm
  The theoretical bending of the metal anvil support is 0,25 mm
  ==> the displacement witnessed is link to the base connection
- anvil must be adequately fixed <== high torque induced during the impact

Trasducers



DATA

- ROT speed Std deviation
  - 3aw
    TOP==>8,8%
    R45==>6,8%
  - NAP
    TOP==>10,8%
    R45==>33,2%
- ROT acc Std deviation
  - 3aw
    TOP==>4%
    R45==>7,4%
  - NAP
    TOP==>16,9%
    R45==>17,2%

9 accelerometer array (NAP scheme)

- PRO
  - Calibration
  - Easy to handle/repair/substitute
- CONS
  - The rot acceleration is calculated as the sum of the difference homolog acceleration divided by their distance. With a distance of 25 mm it is sufficient the usual ripple of one accelerometer (1g ==>392 read/s2) + the uncertainty granted by the calibration service: 1,5% ==> 150g ==> 2g ==>800 rad/s2 + if two accelerometers are controphase everything gets doubled
  - ripple ==> 250-300 rad/sec^2
  - mainly the algorithm is not robust regarding actual behaviour of accelerometers installed with short arm.
  - Problems when assessing composite materials <== delamination
  - mechanical vibration below 1.7 kHz (passing the CFC1000 filter)

three linear accelerometers and three Angular Rate Sensors (3aω scheme)

- PRO
  - Even if The 3aω scheme may be found to be unable to provide accurate angular accelerations or linear accelerations transformed to a remote location in the high speed head impact condition due to the required numerical differentiation, the distance of 25 mm is too short on the NAP to have the required accuracy.
- CONS
  - The angular accelerations uncertainty is linked to the accuracy of the required numerical differentiation.

Data Logging

- NI PCI 6250
- Algorithm Padgoankar

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L'algoritmo completo è:

      dX1 = axx(1) - axx(0): dX3 = axx(3) - axx(0)    'dX2 non c'è
      dY2 = ayy(2) - ayy(0): dY3 = ayy(3) - ayy(0)    'dY1 non c'è
      dZ1 = azz(1) - azz(0): dZ2 = azz(2) - azz(0)    'dZ3 non c'è

'Padgaonkar algoritmo
      DisteMsecQuad = DistAccelerom / 9810    'da mm a m
       AccRotL(j) = (dX3 - dZ2) / (2 * DisteMsecQuad)  'YES - asse y - piano xz
      AccRotR(j) = (dY2 - dX1) / (2 * DisteMsecQuad)  'NO - asse z - piano xy
       AccRotV(j) = (dZ1 - dY3) / (2 * DisteMsecQuad)  'SO-SO - asse x - piano yz

       AccRotazionale(j) = Sqr(AccRotV(j) * AccRotV(j) + AccRotR(j) * AccRotR(j) +
AccRotL(j) * AccRotL(j))
-----------------------------------
```

- sampling rate with 9 acc. array must be more than ≥ 20 kHz

Conclusions for 9 accelerometers

- The robustness of the method is heavily linked to the uncertainty of the locations of the sensors and the measurement noise
- accelerometer with typical ripple will lead to overestimate the max rot acceleration typical of at least 400 rad/s2, but probably 800 rad/s2
- mechanical vibration and delamination below 1.7 kHz (passing the CFC1000 filter) will induce to over estimate the rotational acceleration
- NAP instrumentation was unable to produce accurate angular displacement due to double numerical integration.

Conclusions for three linear accelerometers and three Angular Rate Sensors

- The angular accelerations uncertainty is linked to the accuracy of the required numerical differentiation ==> high sampling rate.

Pass/Fail criteria

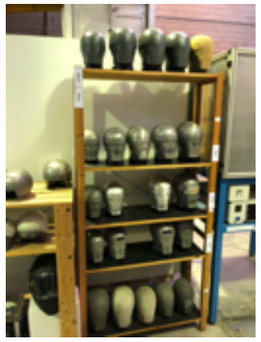
Research papers

- On the importance of the neck
  - KTH FEM
  - Neck
  - Strasbourg University
- On the cof
  - CoF
  - KU Leuven
  - NEW Biophidelic Headform

Measurement of Six Degrees of Freedom Head Kinematics in Impact Conditions Employing Six Accelerometers and Three Angular Rate Sensors (6aω Configuration)
Yun-Seok Kang, Kevin Moorhouse and John H. Bolte

Equipments available @NEWTON

- Headforms
  - Hybrid III 50th
  - EN960@AD Engineering
  - EN960@Cadex



- Skins
  - Dragon Skin 10 By Smooth ON
  - Sylicon cap
  - Protoype caps

- Trasducers
  - 9 accelerometers array (NAP scheme)
  - 3 accelerometer + 3 ars (3aw scheme)

- Data loggin
  - Cables (National Instruments)
  - DTS Slice Nano
  - Masde iCono
- Software
  - AD Engineering
  - DTS
  - Newton SIX

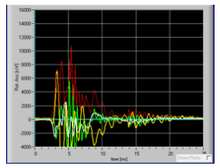
Headform - EN960 - Hybrid - use of the skin

TESTS

- COF DATA@NEWTON Coefficient of friction 60 headform on comfort padding
  - Bare Headform ==> 0,18-0,25
  - Rubber (dragon skin) ==> 0,8 - 0,9
  - Sylicon cap ==> 0,7-0,8
  - Hybrid 50th ==> 0,7-0,9
  - Prototype ==> 0,3-0,5
  - Human ==> Leuven university

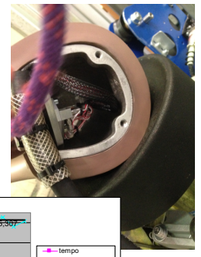
Conclusions

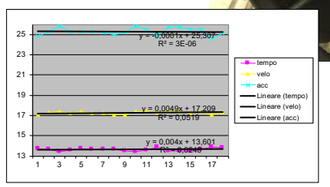
- ISO/EN headform are working properly
- Hybrid III 50th oscillations (???)
  - due to resonant effect ==> modal extraction==> no res freq found (!)
  - coupling of the skin Vs. skull
- 9 accelerometers array
  - Rot acceleration over estimate with 9 acc. array t



  - USE of silicon/rubber skin has a relevant effect

- different kind of skins may be available ==> evaluation is still in progress
  - heating of the rubber (Not seen during tests)
  - Difference in results due to ambient temperature
  - slippage between the rubber skin and the head





ID test	Acc. Cable	Fixing	Head		Size	w [rad/s]
2XL-B	Y	EL	EN	B	XL	26
4XL_NN-R	N	PAP	EN	B	XL	33
3M_N-R	N	EL	EN	R	M	24
1M-R	Y	EL	EN	R	M	15
	N	PAP	EN			
J-007-R	Y	PAP	EN	R	M	28,84

Fixing the helmet - accellerometers cable - elastic stripes - paper tape

TESTS

Conclusions

- use of elastic stripe will affect the results from 24rad/s to 15 rad/s
- use of accelerometer cables may affect the results on the base of the way it will affect the COG + moment of inertia:
  - weight of the cable
  - position of the cable

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