IRTENZ

Technology 2000

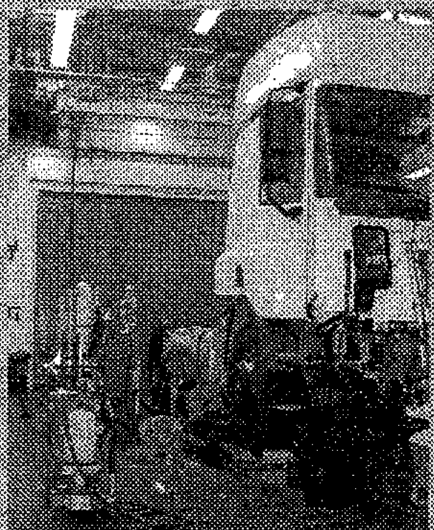
SIMON DE COCK

VEHICLE DEVELOPMENT

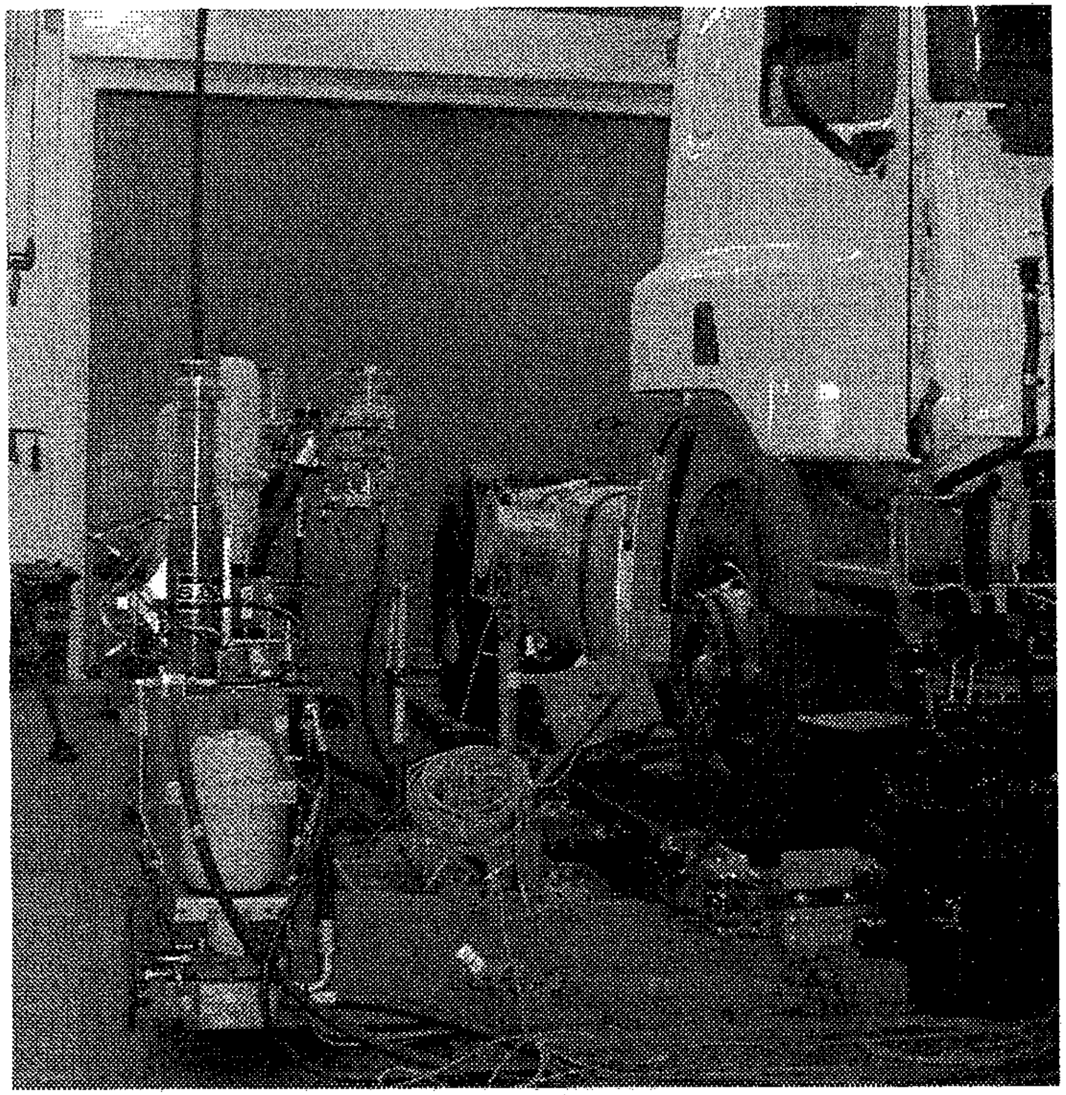
Chassis future proofing

The way to ensure structural durability in service:

- Development of design criteria and sign off standards
- Test methods used



The road simulator.



Vehicle on rig (6-poster)

Chassis future proofing: contents

- How big is the problem?
  What breaks a truck and why?
- Methods used at DAF and PACCAR USA for test requirement specification
  - For vehicles
  - For components
- Test methods
  The concept of vehicle independent testing

What breaks a truck and why?

How big is the problem?

To the vehicle development division the problem is moderate for most components and considerable for some, on-going push for lighter vehicles:

- Cabs fractured all over on first prototypes.
- Chassis member failure
- Cab stabiliser failure

A good vehicle model and low staff turnover help

Principal sources of structural damage

Structural damage is inflicted by:

- Maneuvers (braking, cornering etc.)
- Driving on roads with poorest pavement quality

Maneuver loads are relatively accessible by means of modeling and measurement.

Response to pavement excitation is more complex:

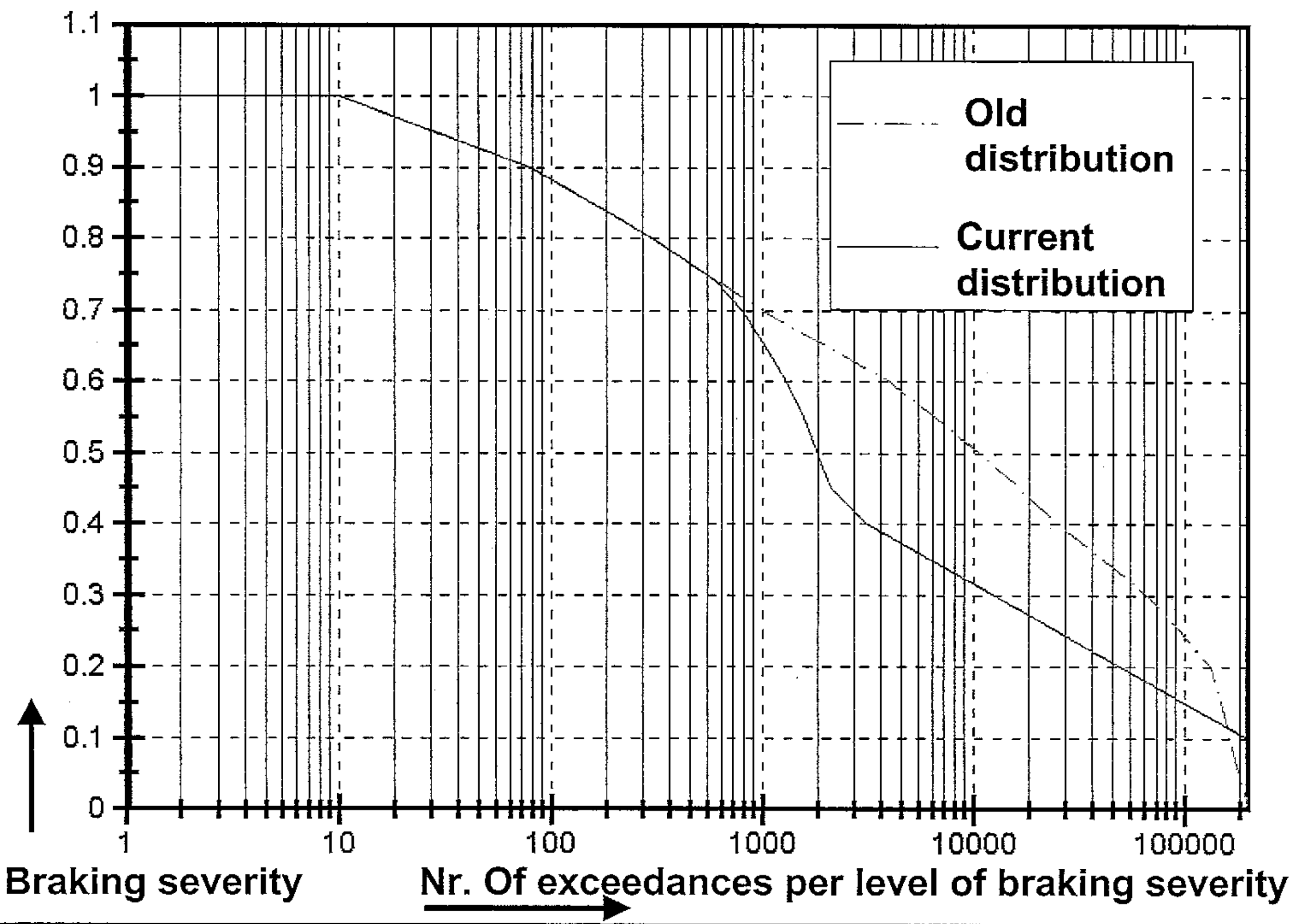
- Modeling of road-tire interface is a special problem
- Severity and nature of road input not easy to obtain

Vehicle response to maneuver loads

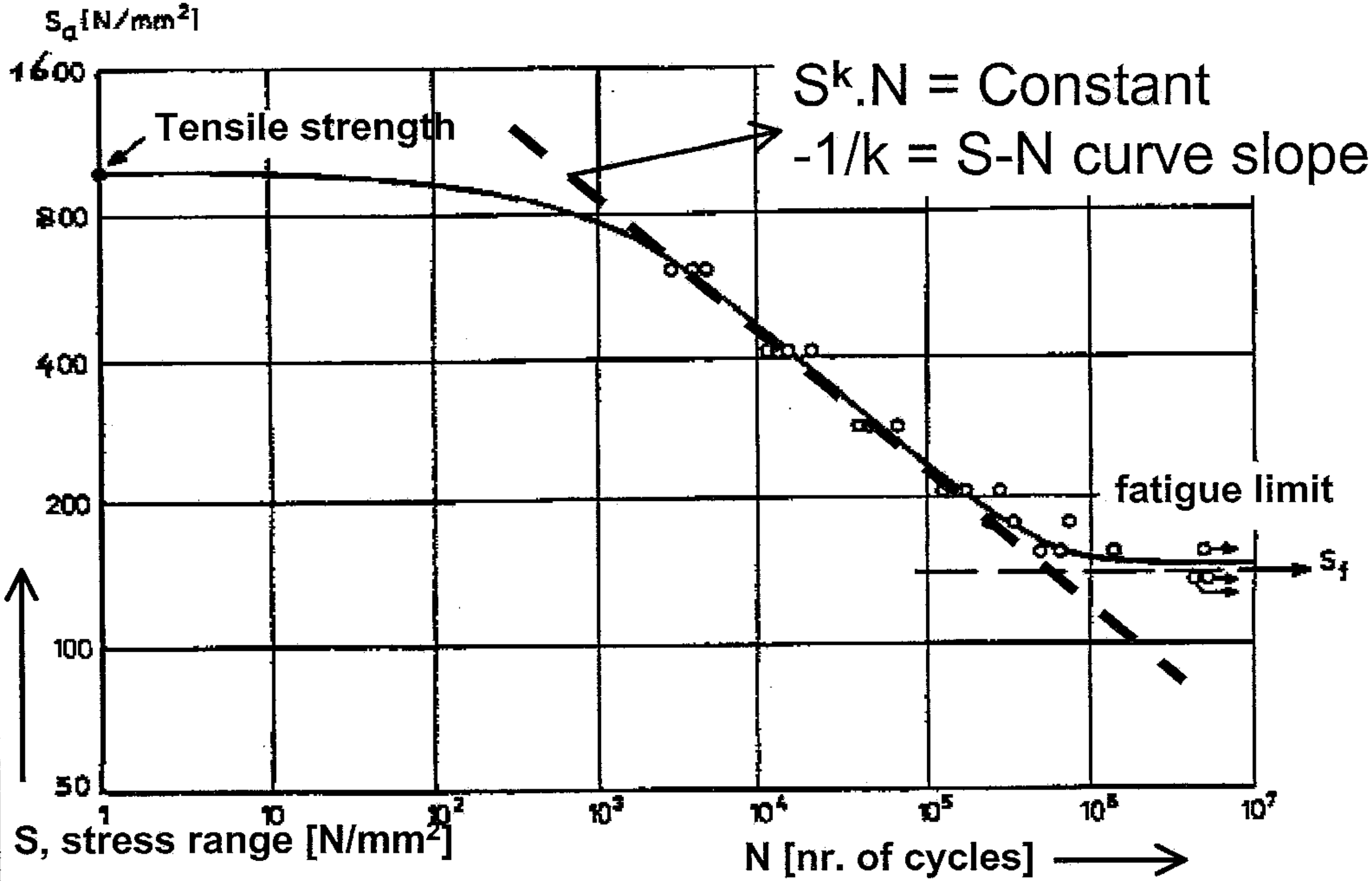
- Vehicle response may be measured on the test site.
- Excitation is accessible by FE or multi body modeling and by measurement (instrumented wheel).
- Maneuver loading is expressed in terms of the severity distribution of brake applications, cornering at high/medium/low speed, etc.

  The variation in payload and speed applies to each of these separately.

A typical maneuver load distribution



The effect of load cycle magnitude



Vehicle response to pavement excitation

Excitation is complex:

- Left and right side, single/twin mounted tires
- Lots of axles, semitrailer is important also!

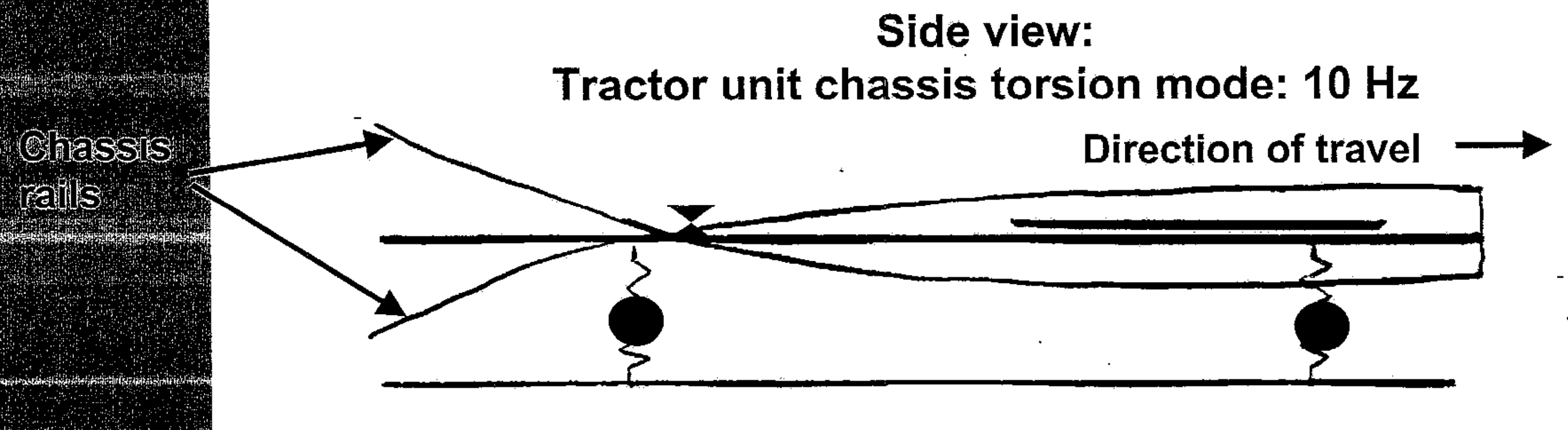
Model the motion in terms of symmetric/antisymmetric movement instead of left/right:

- Road surface symmetric/antisymmetric components are totally incoherent, whereas left/right are not.
- Most vehicles have vibration modes split up in one symmetric and one antisymmetric group.

Symmetric versus antisymmetric response

Antisymmetric excitation:

- anti-roll bar active (3 x as stiff as main springs)
- dampers placed inboard from the wheels.
- Excitation at antinodes of chassis torsion mode

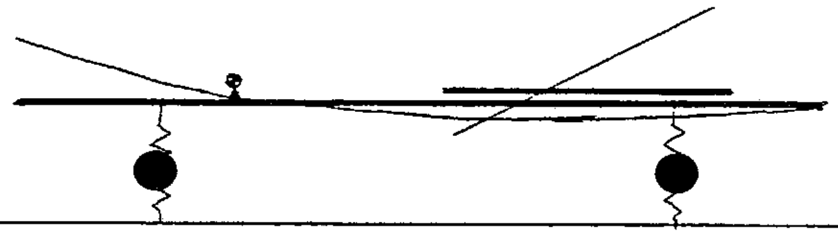


Symmetric versus antisymmetric response

Symmetric excitation:

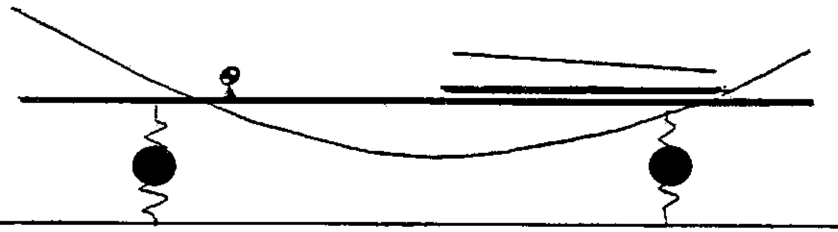
- anti-roll bar inoperative, excitation through soft springs
- full effect of axle damper forces
- Excitation near nodes of first chassis bending mode,

Engine resonator effect



Engine pitch: 7 Hz

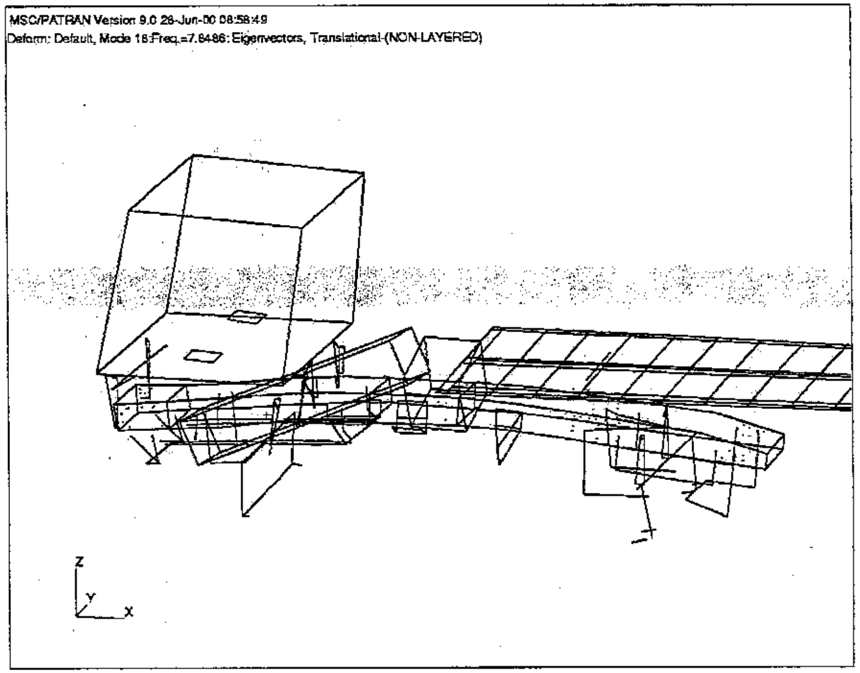
First chassis bending: 13 Hz

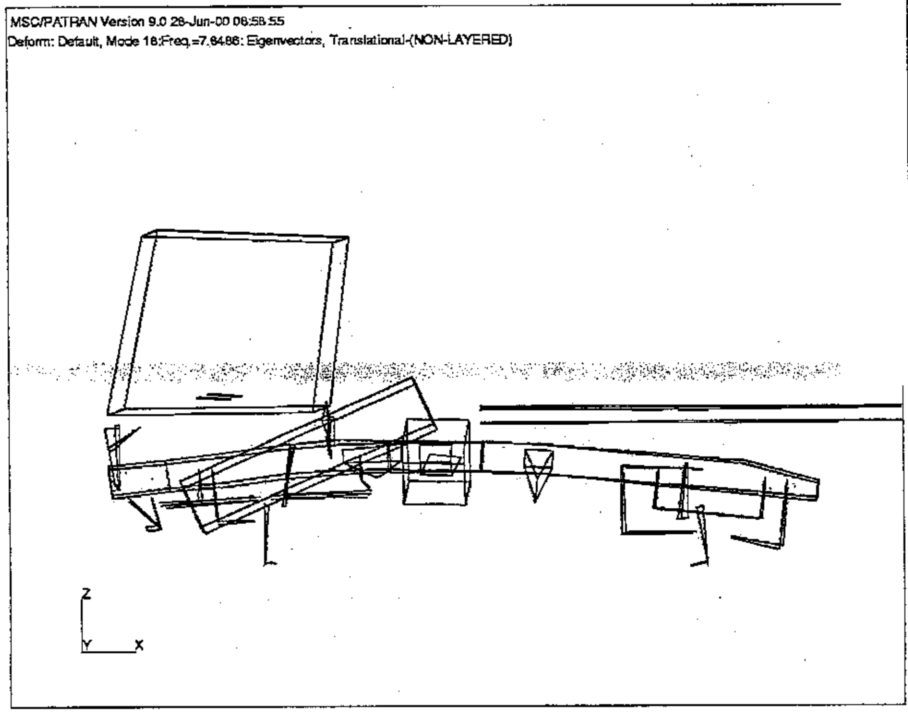


Conclusion:
Chassis response dominated by antisymmetric motion

Example of elastic mode shape on a truck

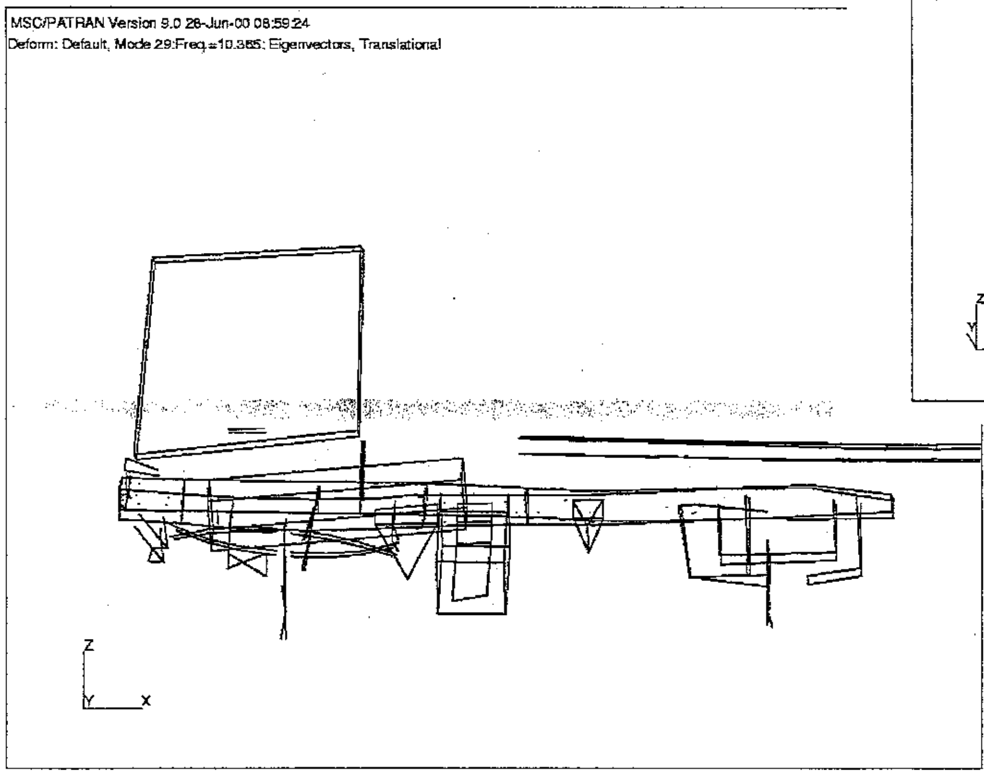
Engine pitch mode: 7.8 Hz

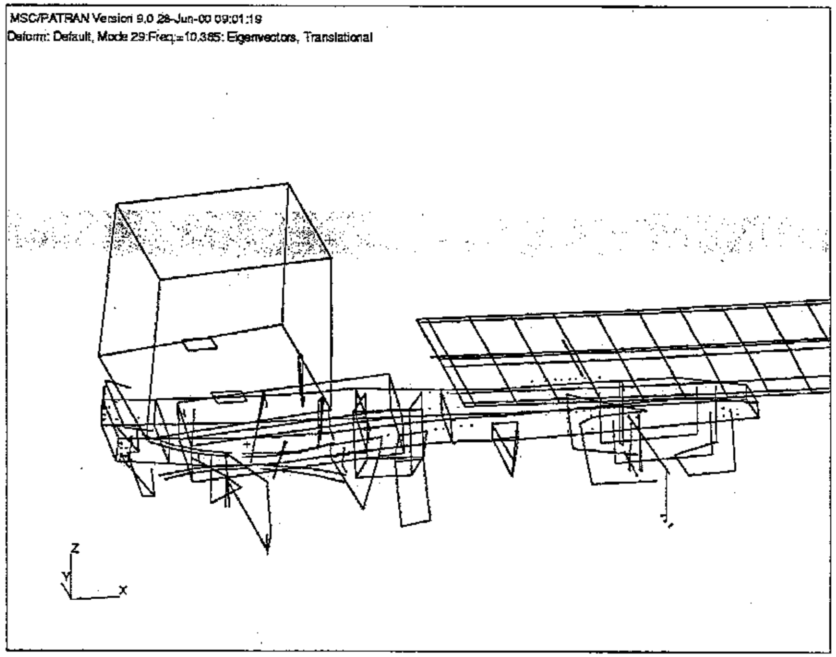




Example of elastic mode shape on a truck

Front axle roll, chassis torsion, engine roll, components: 10.4 Hz





Test requirement specification

PACCAR USA (tractor units only):

- Carefully select a "worst case" user, define mileage required for vehicle target life.
- Perform long term strain measurements in service (~ 16 strain locations, user drives the vehicle). Extrapolate load spectra to target life mileage .
- Perform strain measurements on the PACCAR test tracks using the same vehicle (standard items: maneuvers & pavement types). Determine load spectra for each item.
- Find a combination of standard items that leads to a good match with the load spectra as measured in service <u>on all locations.</u> This mix of standard test items may now be used as the requirement specification for this family of vehicles.
- Component requirement & test specifications may be derived from measurements on the test site using this mix.

Test requirement specification

Translation of Service conditions to test site events

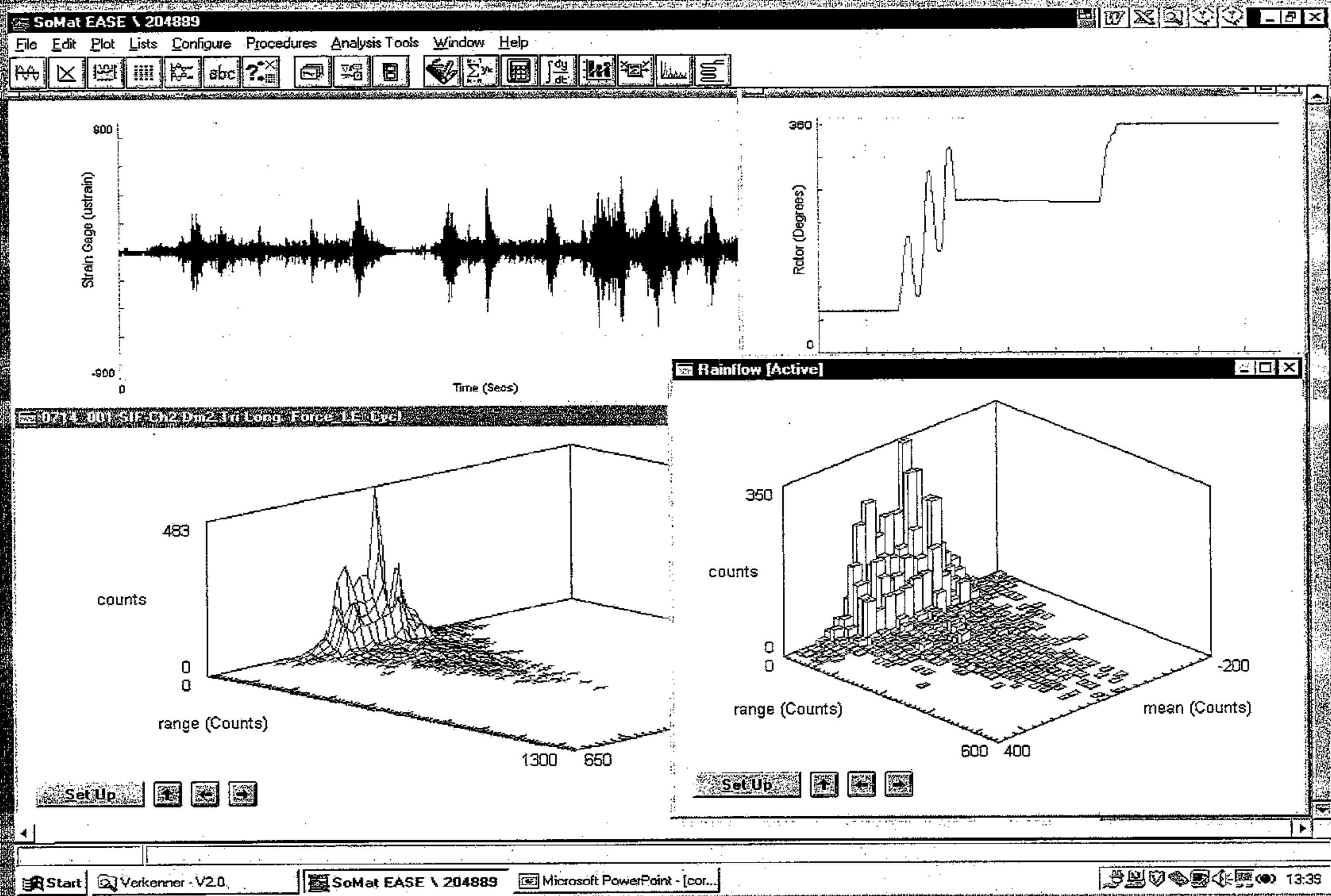
Getting it right is difficult:

- For all locations on the vehicle at a time.
- For a range of values of S-N curve constant K (3.....7).
- Vehicle speed is fundamentally "untranslatable" because of the wheel base effect. Selecting one test speed leaves one exposed to powerful favourable or unfavourable extremes, sometimes both simultaneously on the same component (symmetric and antisymmetric responses for instance).

For the first 2 items excellent software is now available to obtain the best match out of a given set of measurement data.

Vehicle speed in the test must still match service conditions.

Test requirement specification



Test requirement specification

DAF TRUCKS (tractor units, rigids, tippers, etc.):

- Define one "vehicle application" for each type of use; there is at least one per axle configuration, often more (now some 500 for the entire medium line family for instance).
  Define target life mileage for the vehicle family (1.2 m km).
- Each application is defined in terms of amounts of maneuvers and mileage on various types of pavement The pavement types are standard ones (10) as described in a photo book.
  Each application is characterised by the distribution of GVW, traffic type and "hilliness" (Service Conditions Handbook).
- Similar type maneuvers are all rated equally for different vehicle types. The standard pavements all have a Severity Rating which allows "translation" to one reference (Belgian blocks).
  In this way the 90 percentile vehicle may be found for each of the maneuvers and for pavement damage.

Test requirement specification

DAF: Vehicle application sheet

Printdatum 29-2-00
Tijd 15:57

Voertuigtoepassing **9PP19103**
Datum van opstellen 01-03-00

Type	**FAD 95 XF355**
Omschrijving	Kipper
Voertuignormlevensduur km	540000
Voertuignormlevensduur jaren	7
Land	Israel
Verkoopaantal per jaar	200 (jaar 1999)

Astype 1355T

1 Voertuiggewicht [ton]

	varieert van	tot	zwpt
aslast voor	0	0	18
aslast achter	0	0	26
GCW			63
GVW			44

3 Hellingspatroon

	varieert van	tot	zwpt
vlak	0	0	60
heuvelachtig	0	0	38
bergachtig	0	0	2
		Totaal	100 %

4 Snelheidspatroon

	varieert van	tot	zwpt
lokaal werkverkeer	0	0	3
stadsverkeer intern	0	0	5
stadsverk. doorgaand	0	0	10
interstedelijk verkeer	0	0	70
lange afstand verkeer	0	0	12
		Totaal	100 %

Rangeerfaktor 15 bochten per 1000 km
Stroefheid 100 %

5 Klimaat geen specifieke info

equivalentiefactoren geldend voor:
groep: **voertuig (gemiddeld)**
k-factor: **3,50**

2 Wegdek

wegtype foto	omschrijving	eq. faktor	% van voert.nivd	eq. pave-km
1.1	asfalt goed	0,0008	80,0	360
1.2	asfalt matig	0,0061	15,0	496
1.3	asfalt slecht	0,05	0,0	0
2.1	beton goed	0,0021	0,0	0
2.2	beton matig	0,0033	0,0	0
2.3	beton slecht	0,0368	0,0	0
3.1	klinkerweg goed	0,003	0,0	0
3.2	klinkerweg matig	0,02	0,0	0
3.3	klinkerweg slecht	0,2	0,0	0
4.1	pave goed	0,04	0,0	0
4.2	pave matig	0,1	0,0	0
4.3	pave slecht	1	0,0	0
5.1	steenslag goed	0,01	1,0	54
5.2	steenslag matig	0,05	2,0	540
5.3	steenslag slecht	0,5	1,0	2700
6.1	gravel goed	0,01	0,0	0
6.2	gravel matig	0,05	0,0	0
6.3	gravel slecht	0,5	0,0	0
6.4	wasbord goed	10	0,0	0
6.5	wasbord slecht	3	0,0	0
7.1	hard zand goed	0,02	0,0	0
7.2	hard zand matig	0,1	0,0	0
7.3	hard zand slecht	0,5	0,0	0
8.1	droog zand goed	0,01	0,0	0
8.2	droog zand matig	0,05	0,0	0
8.3	droog zand slecht	0,5	0,0	0
9.1	nat zand goed	0,01	0,0	0
9.2	nat zand matig	0,05	0,0	0
9.3	nat zand slecht	0,5	0,0	0
10.1	terrein goed	0,01	0,0	0
10.2	terrein matig	0,05	0,0	0
10.3	terrein slecht	0,5	0,0	0
	Totaal eq. pave km			4149
			99	

Test requirement specification

DAF: Vehicle application sheet

6 Opmerkingen 10% overbelading
FAD ombouw naar FTD (koppelschotel)

Verrichtingen per voertuignormlevensduur

	oud (1995)	*vanaf 2000, zie [1]*
Snelle stuurbewegingen L/R	**148320**	**741600**
Langzame stuurbewegingen L/R (	**14832**	**74160**
Bochten lokaal werkverkeer L/R		**16200**
Rangeren L/R		**8100**
Sturen in stand L/R		**810**
Remmingen ('methodiek 2000')	**343035**	**459270**
Eq. heuvelachtig motor km's		**421200**
Eq. Stad/bergachtig pignon km's		**81454**

beladingsgraad (als functie van gereden km's):

percentage leeg:	**50%**
percentage vol:	**25%**
percentage overbeladen:	**25%**
	100% (totaal)

(1): kollektiefvormen voor 'snelle' en 'langzame bochten' en 'remmen' gewijzigd; zie rapport 51520/00-050 (G.O.-boek versie 2000)

~~equivalent pave km's als functie van de k-waarde en per hoofdcomponentgroep~~		voor k=	groep:
oude eq. pave km's (onafhank. van k-factor en groep, gebaseerd op oude eq.factoren):	**4131** km	**onafh.**	**voertuig (gemiddeld)**
standaard eq. pave gehele voertuig adv nieuwe equivalentiefactoren ('methodiek 2000'):	**4149** km	**3,5**	**voertuig (gemiddeld)**
equivalent pave km's voor gekozen groep en specifieke k-factor:	**4149** km	**3,5**	**voertuig (gemiddeld)**

eq. pave. opgesplitst naar de hoofdcomponentgroepen als functie van de k-factor:

	k=3	k=5	k=7	k=9
1: Cabine	4125 km	3371 km	3312 km	3299 km
2: Wielophanging	4514 km	3544 km	3392 km	3339 km
3: Chassis	5279 km	3786 km	3669 km	3589 km
4: Assen	4551 km	3584 km	3432 km	3370 km
5: Componenten	4358 km	3363 km	3304 km	3296 km
6: Motor	5245 km	3515 km	3364 km	3316 km
7: voertuig (gemiddeld	4829 km	3592 km	3476 km	3410 km

Test requirement specification

DAF TRUCKS (contd.):

- Per component: measure the component load spectrum in each maneuver on the test site, then find the <u>90 percentile vehicle for that component.</u>
  Determine life requirement and failure rate allowed:
  - Safety critical: 10 % failures @ 2 x life (90 % confidence)
  - impaired serviceability: 10 % failures @ 1 x life (90 % conf.)
  - other: 10 % failures @ 1 x life (50 % confidence)
- Translate this into a test requirement (number of specimens, test level, number of load cycles) using the standardised load spectrum shapes, standardised nr. of corners per km etc.

Maneuvers and pavement types are all present at the test site.

Test requirement specification

Differences in test methods PACCAR - DAF TRUCKS

- DAF make more components in house (engines, axles). The truck is an integrated concept with (relatively) few options. PACCAR have many out-sourced components in their vehicles (CUMMINS, Caterpillar, Eaton, Rockwell). There are often alternative options for the same component.
- PACCAR Test Centre test vehicles to check compliance with requirements. DAF do the same but in addition very often test to failure to find the margin of safety for specific components. There is more testing on single components at DAF for component development.

Test methods

Driving test vehicles through the 90-percentile test is impractical:

- Takes very long, gruesome to test drivers
- Need to test more specimens or test longer to obtain required confidence level.
- Requirements differ per component.
- First prototypes badly needed for many other tests.
- Weather factor (holes in pothole road frozen over!).

Rig testing is the only feasible alternative to finish up in time and with the confidence level required.

Test methods: rig testing

Tests depend on how much is known about the vehicle:

- If many new design elements, component response not fully measured at the test site, novel surface finish on component: test the whole vehicle or a large assembly of it on a multi-axis rig, real time simulation.
  - These tests find unknown (new) weak spots early on.
  - They also effectively take over the role of the driven tests for structural durability sign off at the end of the development cycle.
- If component response is known in detail, or loads on component are known in detail, with familiar surface finish: single axis rig, sinusoidal block testing.
  - These tests serve as development tools in the broad middle phase of development.

Test methods

Test Rig types used:

- Multi-axis rigs for testing of a whole combination or large sub-assembly. Real time simulation.
  - Road simulator (poor pavements).
  - Maneuver load rig, multi axle vehicles, tippers etc.
- Two-axis rig for testing of a whole vehicle, real time simulation (poor pavement).
- Two-axis rigs for testing sub-assemblies (real time simulation or sinusoidal block testing).
- Single axis rigs (sinusoidal block testing)

Vehicle independent testing.

the road simulator:

Direct excitation at the tires using the “raw” road profile doesn’t lead to a good result. A traditional road simulator needs road measurements of the vehicle motion in order to achieve a good simulation.

The DAF road simulator uses a combination of novel design features in the wheel pans and a special signal processing strategy for the excitation signals to obtain a good simulation quality.

<u>This without the need for prior measurements on the road.</u>