



Strömavtagare – kontaktledningsinteraktion

Gröna Tåget slutseminarium

6 Mars 2014

Sebastian Stichel, Per-Anders Jönsson
och Zhendong Liu

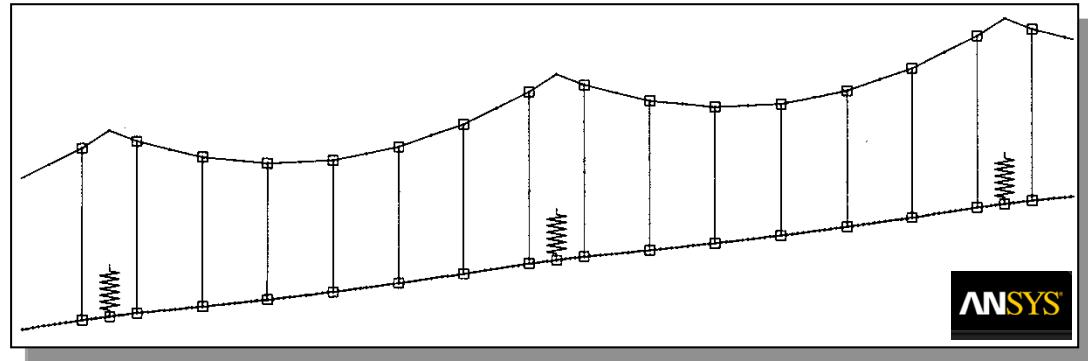
Innehåll

- Verifiering av 2D modellen
- Jämförelse FE-MBS
- Förbättringar – 3D modellen
- Aktiva strömvägtagare – några första steg
- Benchmark
- Parameterstudier
- Diskussion om framtiden

CaPaSIM – 2D FE-modell

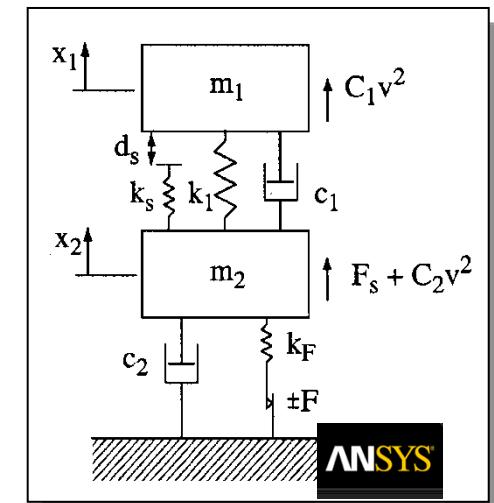
- Kontaktledning

- Kontakttråd Balkelement
- Bärlina Stångelement
- Y-lina Stångelement
- Bärtrådar Wire element
- Tillsatsrör Fjäderelement + punktmassa
- Klämmor Punktmassor



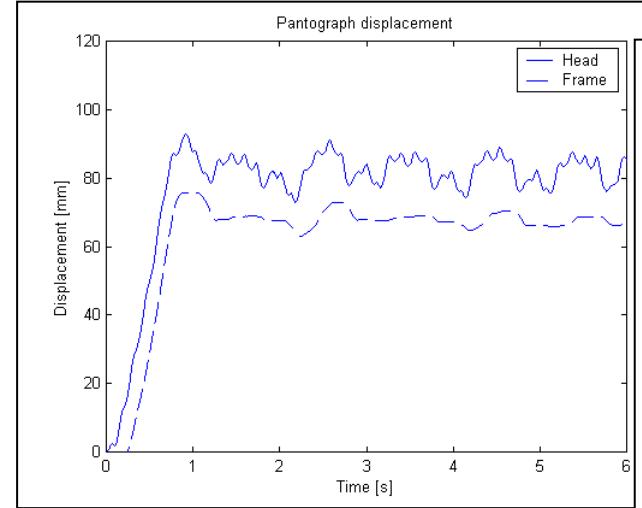
- Kontaktelement

- Strömvattagare
- Punktmassor
- Kopplingselement

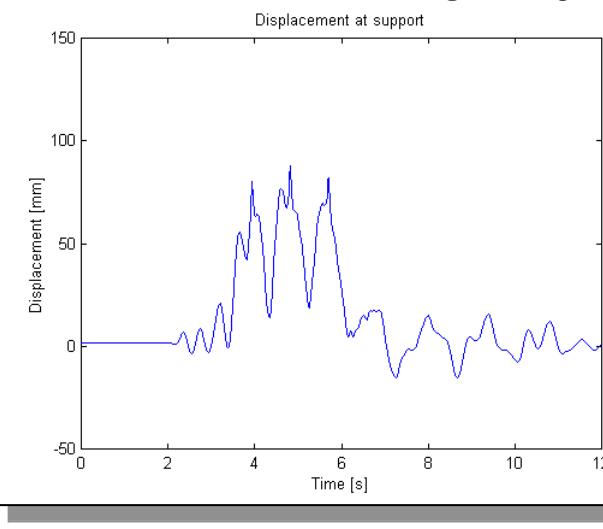


CaPaSIM – Dynamisk analys

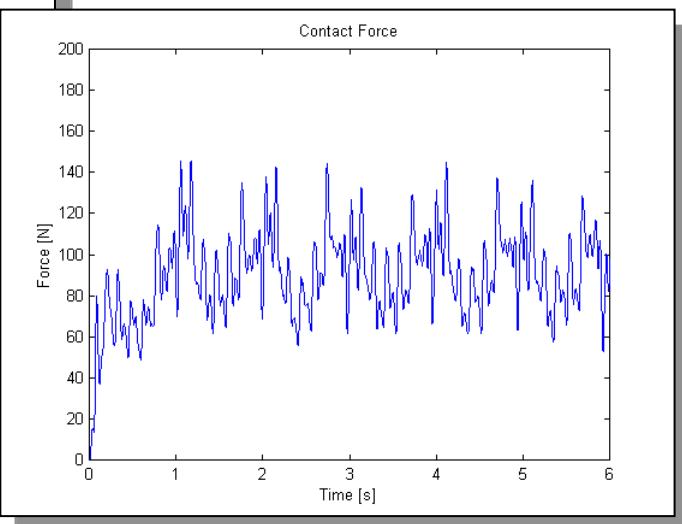
Strömvatagarhöjd



Kontaktledningshöjd



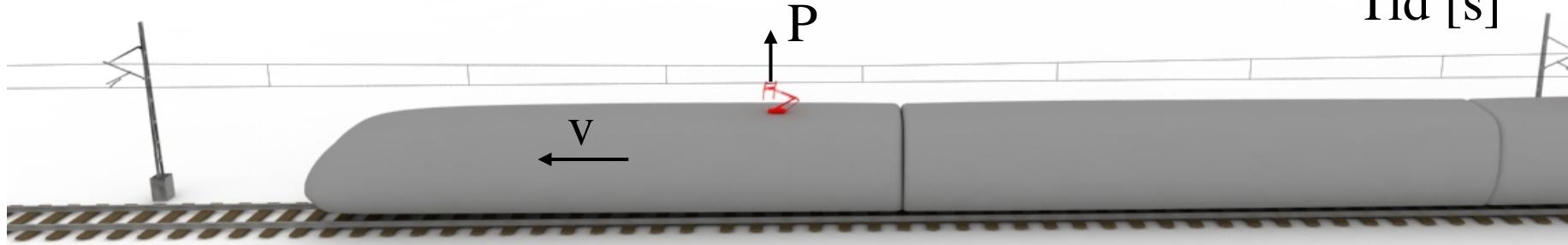
Kontaktkraft (P)



Tid [s]

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Verifiering av 2D-modellen

Bakgrund

- Uppdatering till aktuell ANSYS version
 - Ny kontaktmodell implementerad
- Verifiering av den nya kontaktmodellen
 - Jämförelse med POLIMI's beräkningsprogram
 - Jämförelse med Gröna Tåget mätningar

Verifiering av 2D-modellen

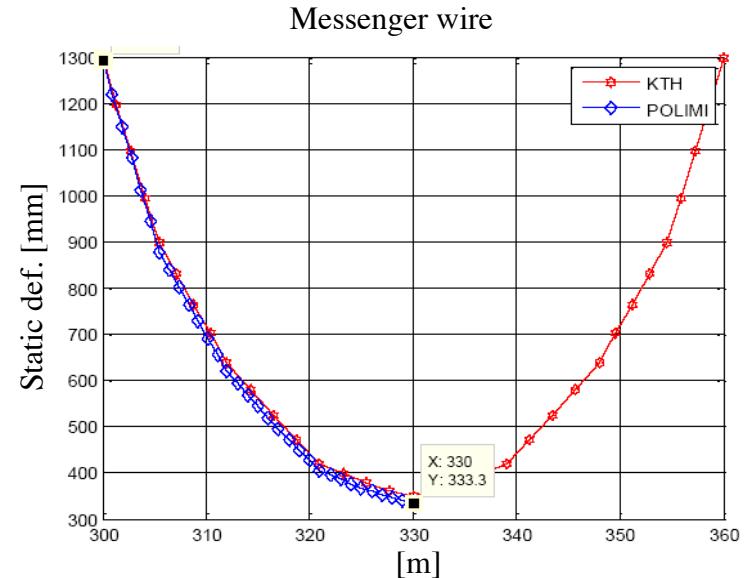
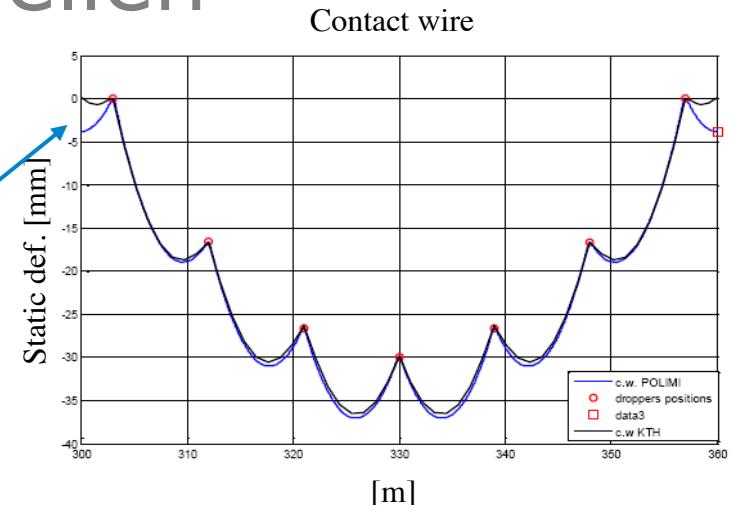
- Jämförelse med POLIMI's program (PCaDA)
 - Samarbete med Politecnico di Milano där doktoranden Marco Carnevale arbetade på KTH under ett halvår.



Verifiering av 2D-modellen

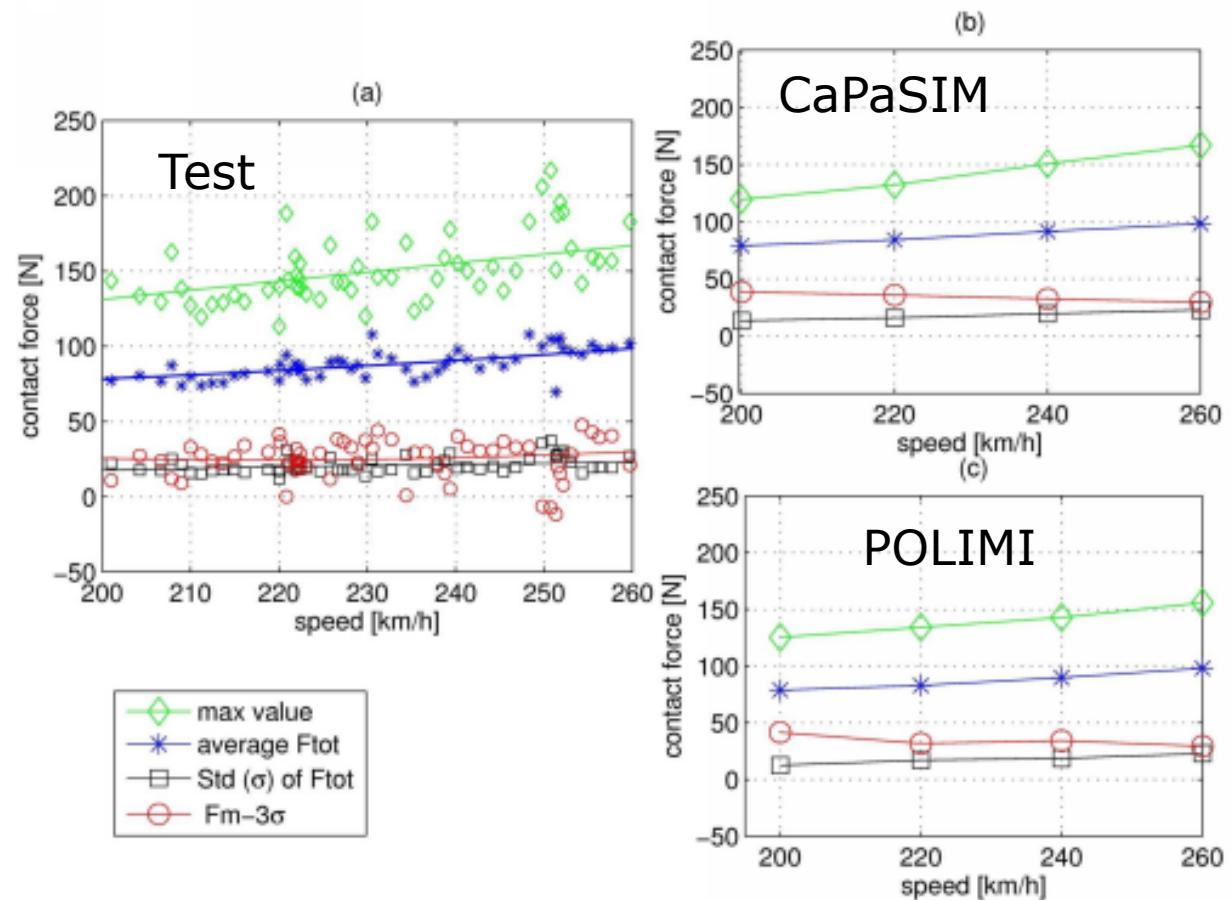
- Jämförelse av modeller
 - POLIMI's 2D modell och CaPaSIM
 - Statisk analys
 - SYT 7.0/9.8

**Skillnad i
modellering av
tillsatsrör.**



Verifiering av 2D-modellen

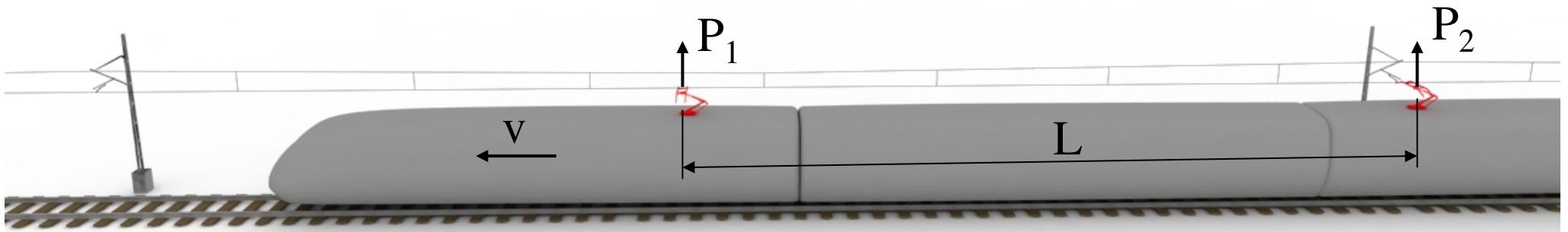
- Jämförelse mellan programsystem
 - POLIMI
 - CaPaSIM
- Jämförelse mätning och simulerings
- System
 - SYT 7.0/9.8
- Teststräcka
 - Skövde - Töreboda



Verifiering av 2D-modellen

Sammanfattning

- Implementerad ny kontaktmodell
- Jämfört simuleringsresultat från 2D-modellen
 - Med POLIMI's model
 - Med mätningar utförda inom Gröna Tåget
- Publicerat ett papper tillsammans med POLIMI





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OF TECHNOLOGY

Master Thesis Roberto Tieri

POLITECNICO DI MILANO
School of Industrial Engineering
Master of Science in Mechanical Engineering

KTH - Kungliga Tekniska Högskolan
Department of Aeronautical and Vehicle Engineering
Railway division



Innovative active control strategies
for pantograph catenary interaction

Advisors: Prof. Andrea COLLINA
Prof. Sebastian STICHEL

Supervisors: Ing. Marco CARNEVALE
Ing. Per-Anders JÖNSSON

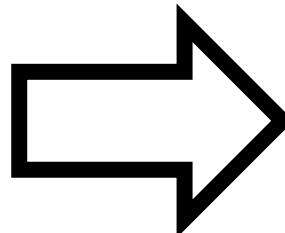
Master thesis of:
Roberto TIERI
Matr. 755458

Academic year 2010-2011

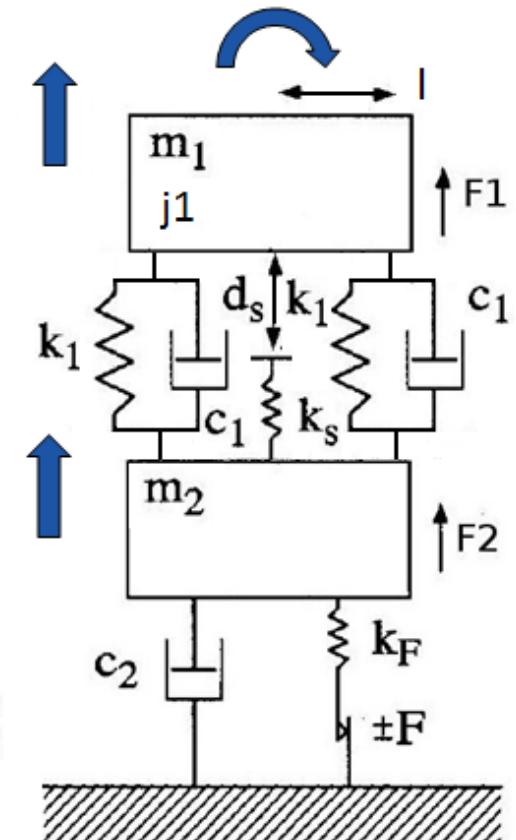
Enkel flerkroppsodynamikmodell

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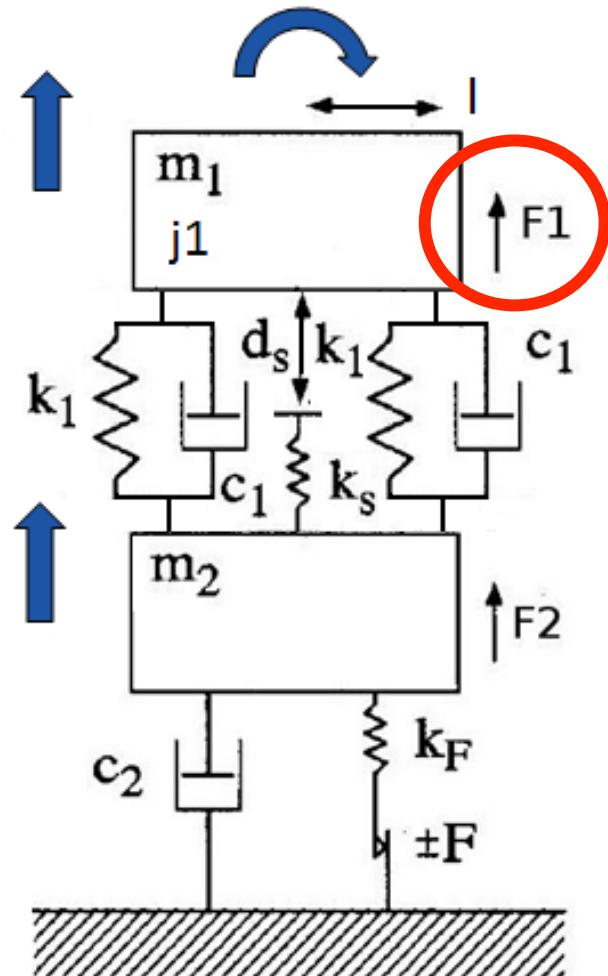
Real pantograph



Mathematical 3 d.o.f model

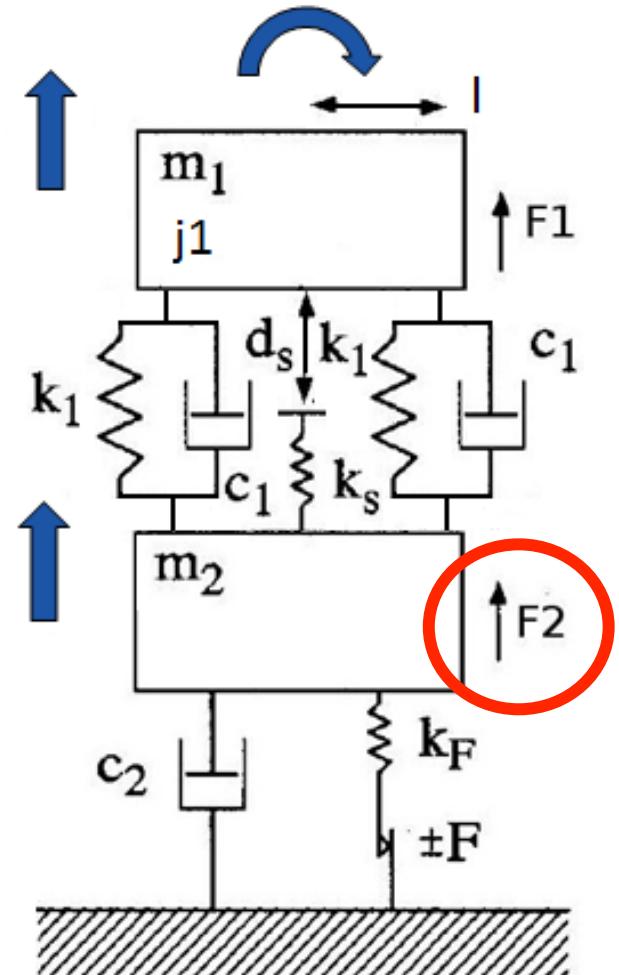


Proposed model



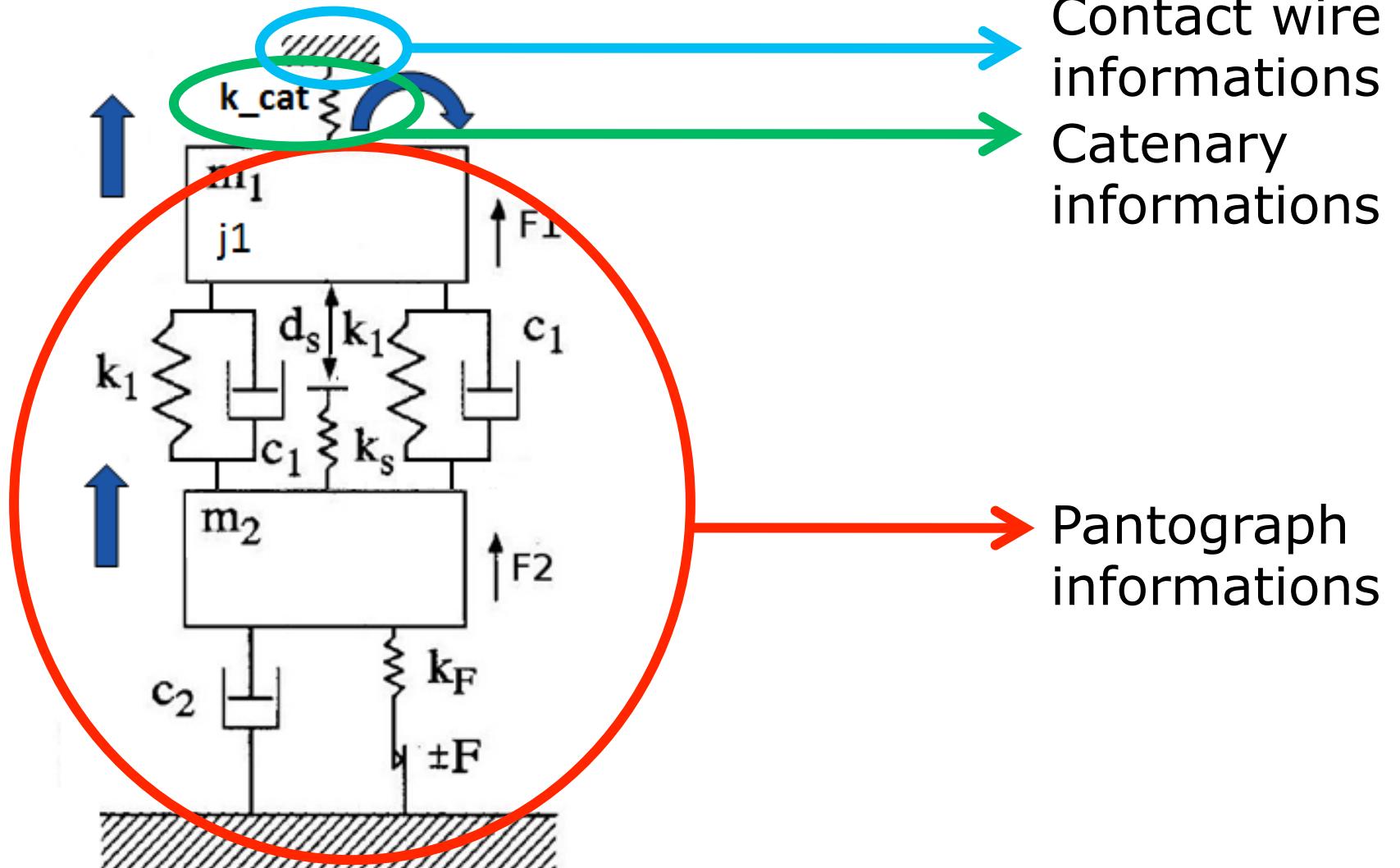
Uplift force (aerodynamic test)

Proposed model – Pantograph (12/17)



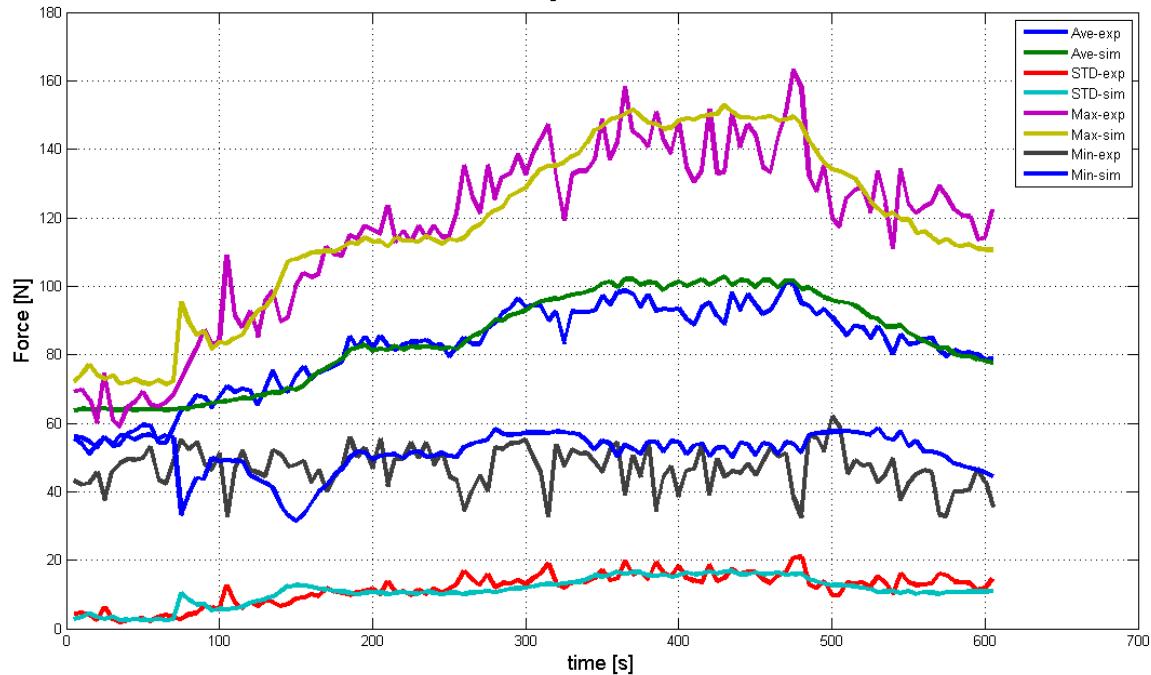
Static air spring pre-load

Proposed model – Contact model

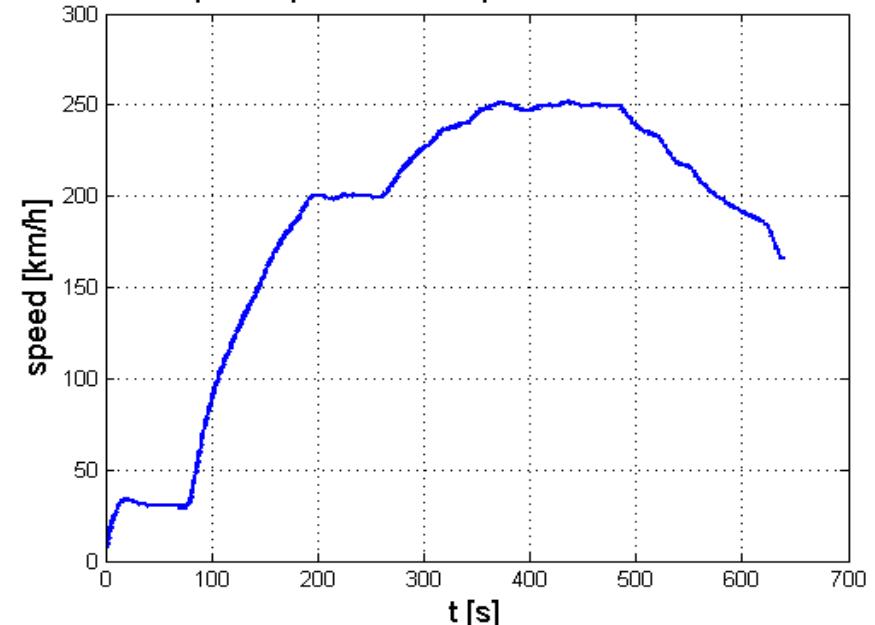


Comparison of contact force Västerås- Grillby

Real Time analysis SYT 15/15

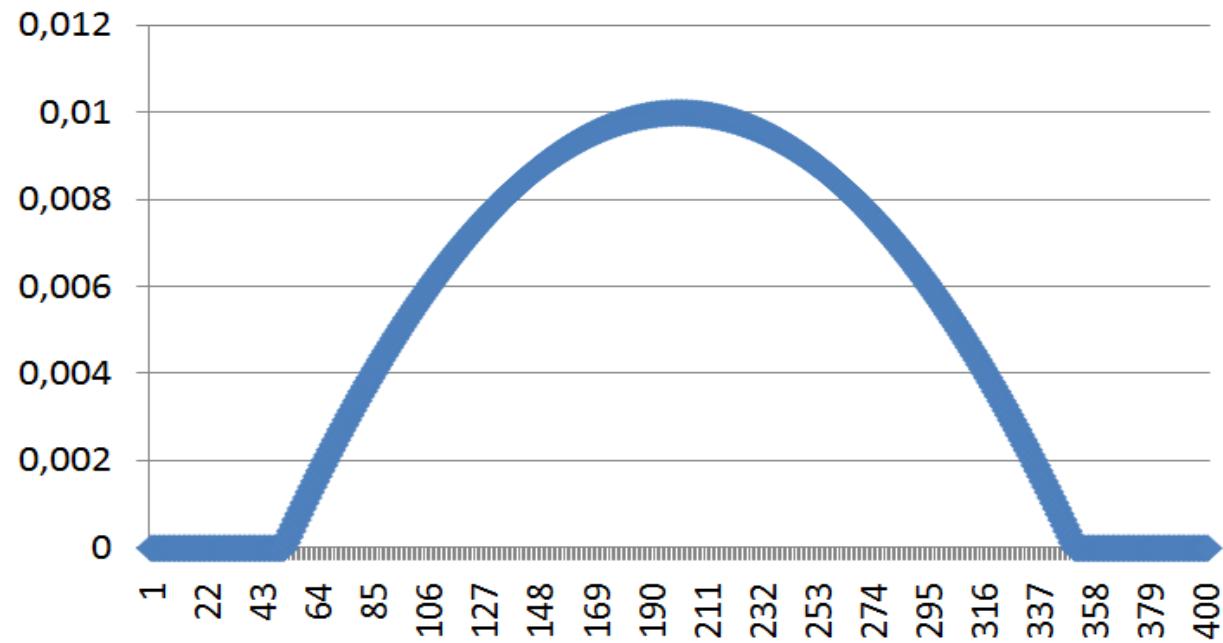


Speed profile - experimental results



Simulation Results – Application

Shaped ± 300 mm
Pantograph's
Strips

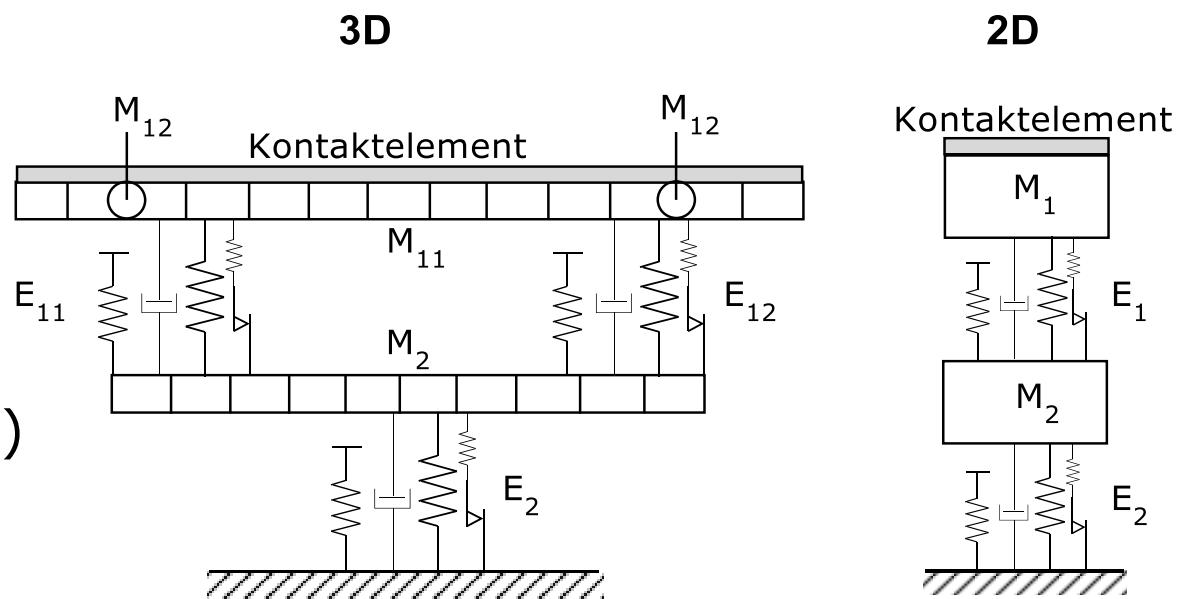


Förbättringar - 3D modellen



Skillnader i 3D modell relativt 2D

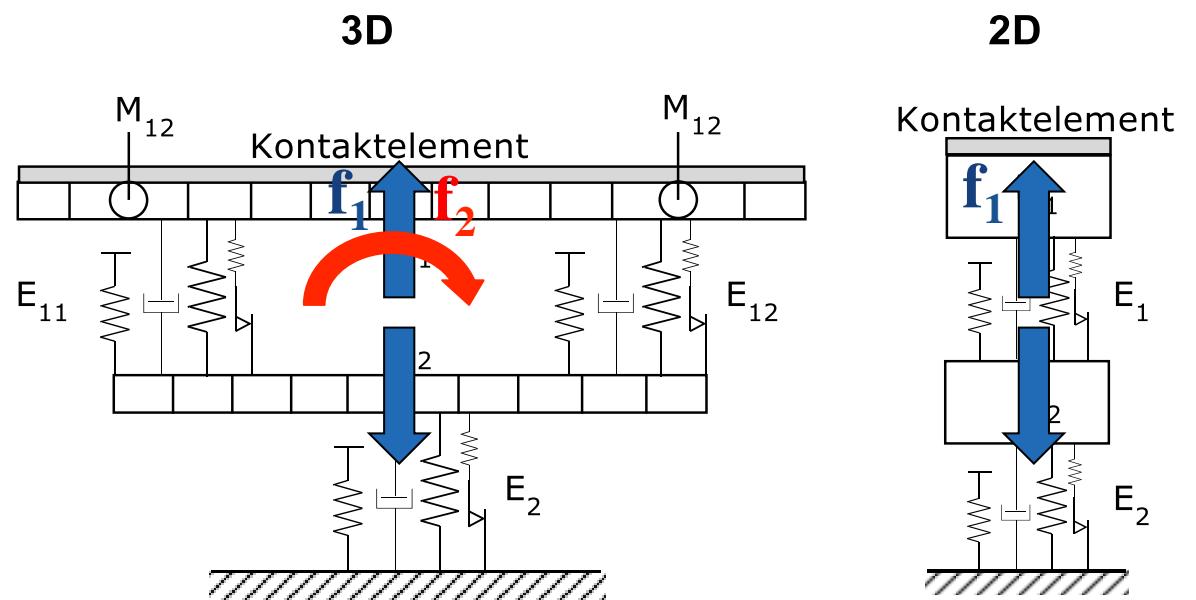
- Kontaktledning
 - Zick-zack geometri
 - Tillsatsrör
- Strömvattagare
 - Rollfrihetsgrad hos huvudet
- Kontaktformulering
 - Linje – Linje (korsande)



Förbättringar - 3D modellen

Egenfrekvenser

	3D	2D
f1	5.6	5.6
f2	5.9	-

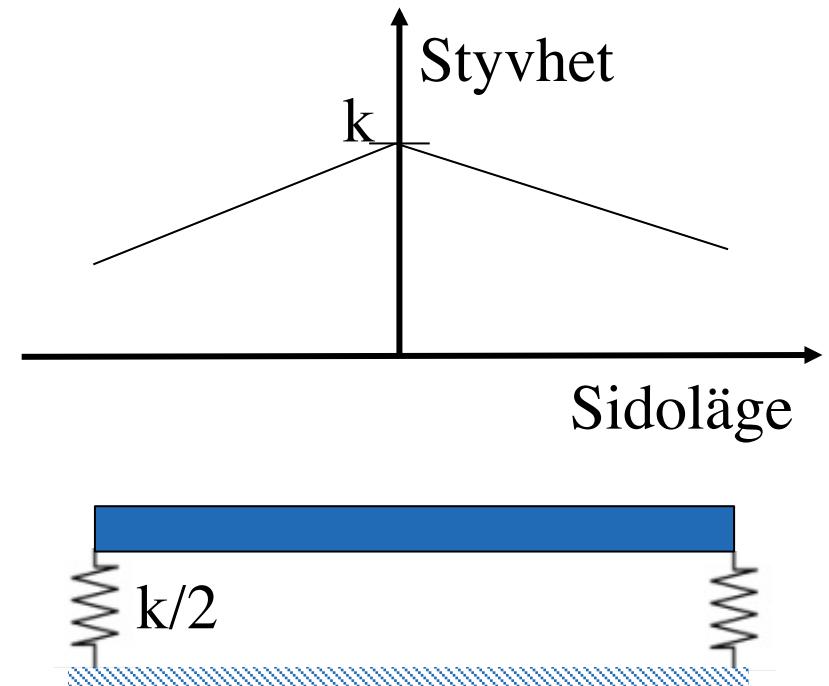
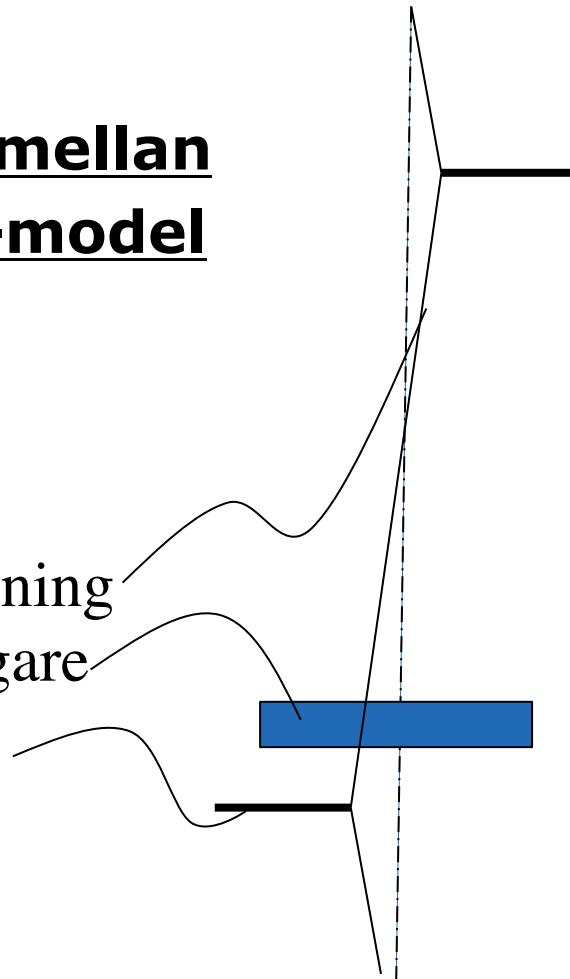


Förbättringar - 3D modellen

Skillnader mellan 2D och 3D-model

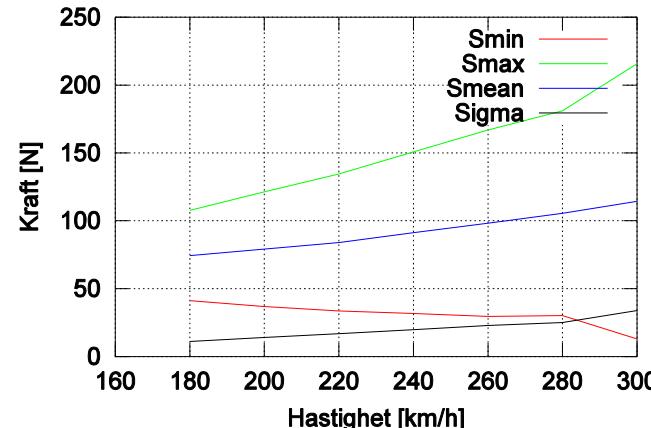
Styvhets

Kontaktledning
Strömvattagare
Tillsatsrör

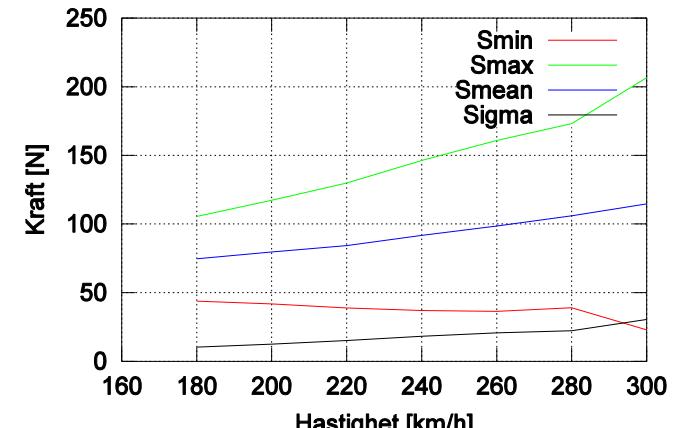


Förbättringar - 3D modellen

2D



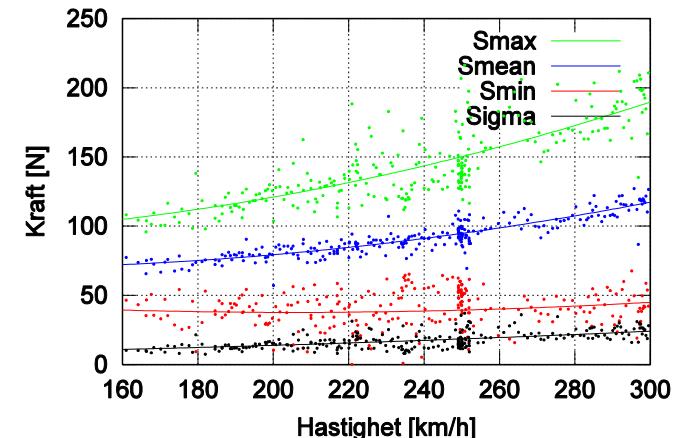
3D



Validering

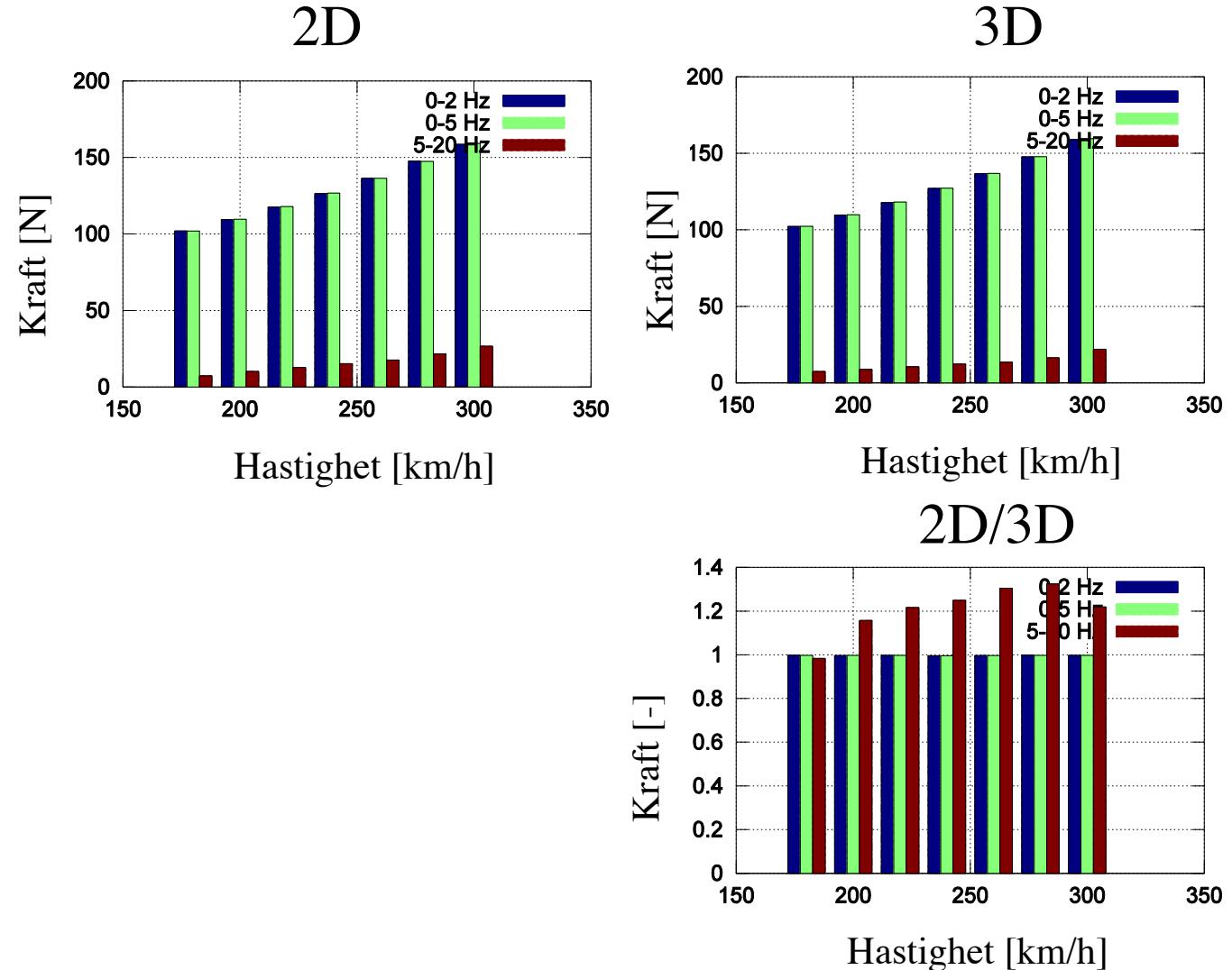
- SYT 7.0/9.8
- Bra överensstämmelse med mätresultat
- Något bättre överensstämmelse med 3D än med 2D modell upp till 280 km/h

Test



Förbättringar - 3D modellen

Skillnader mellan
2D och 3D-model
 SYT 7.0/9.8



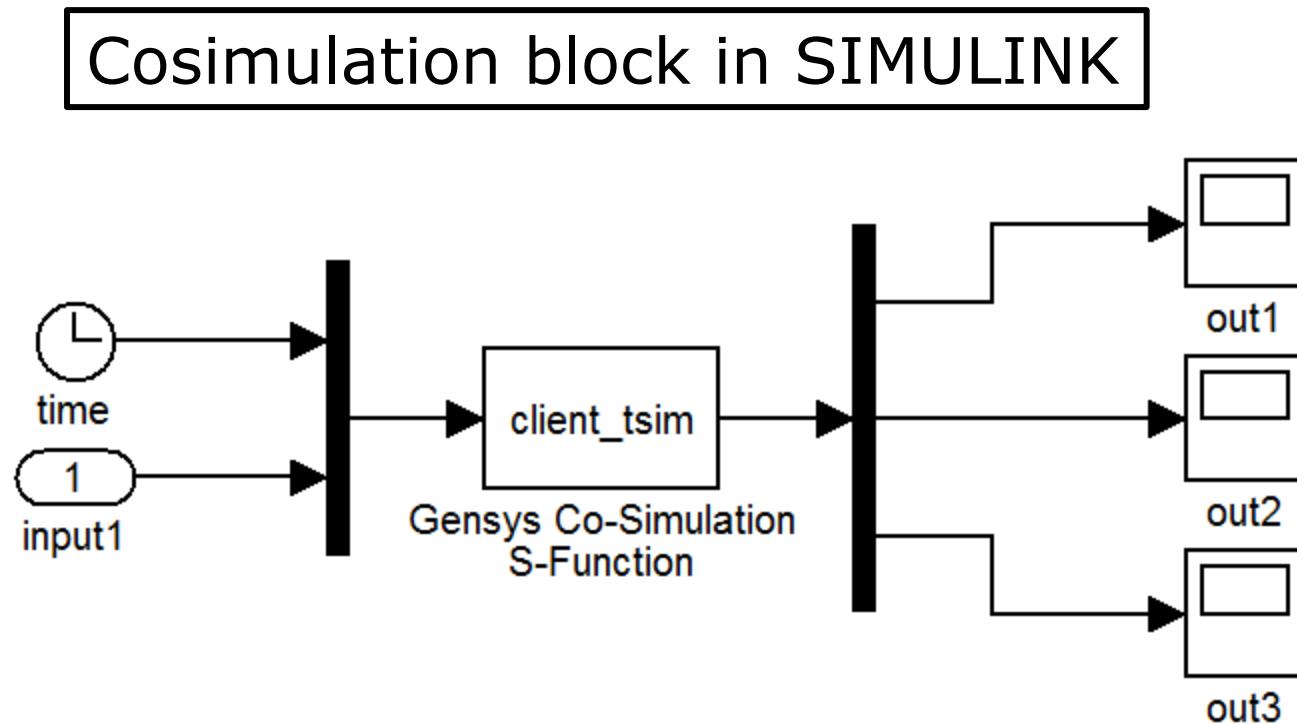
Förbättringar - 3D modellen

Sammanfattning

- 3D modell implementerad
- God överensstämmelse med mätresultat
- Lägre transienter vid stolppassage
- Markant skillnad i respons mellan 2d/3D modellerna för frekvensintervallet 5-20 Hz

Active Control – Two master theses

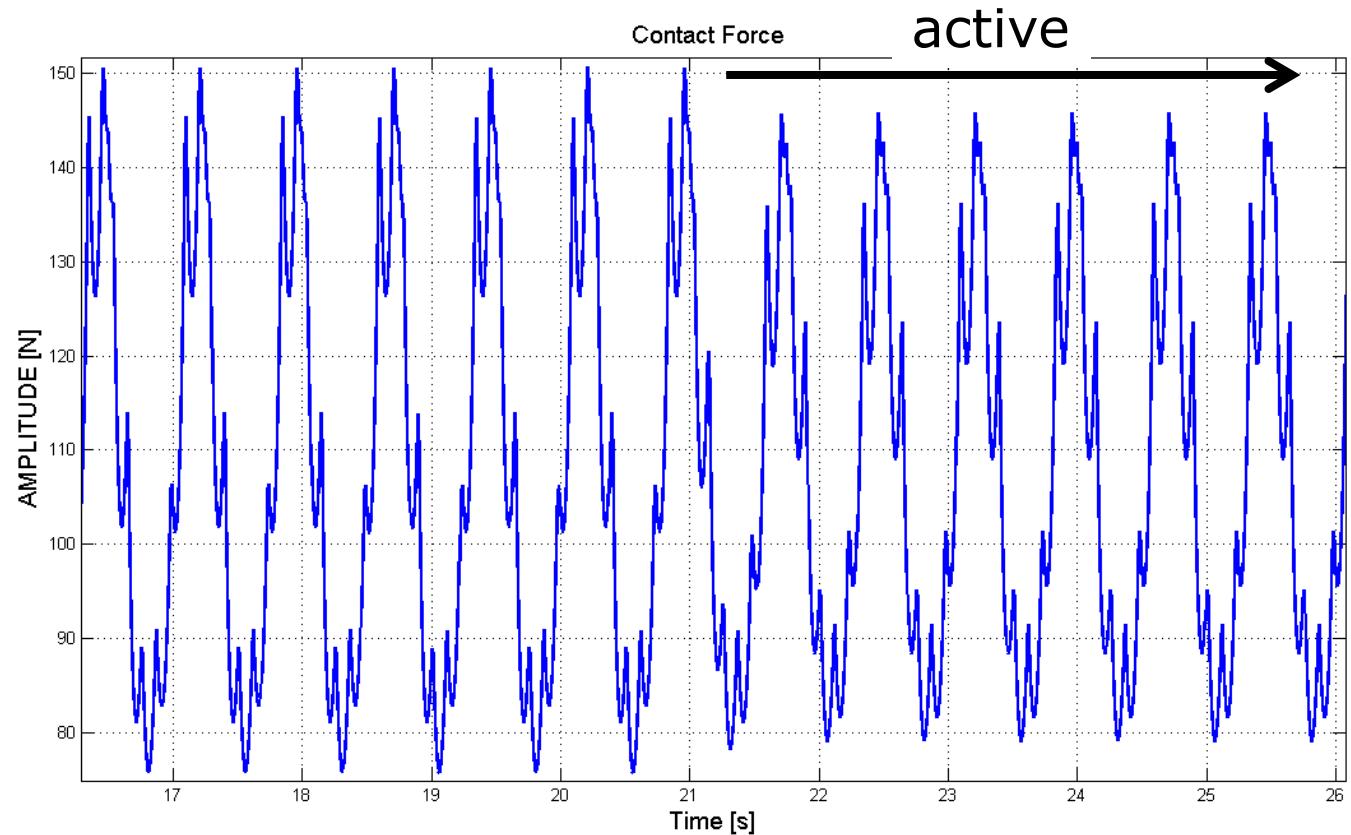
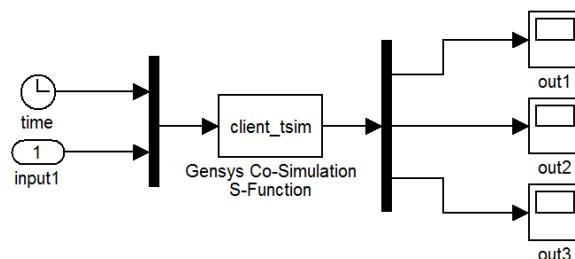
Thesis 1: Cosimulation between GENSYS and SIMULINK



Active Control – Optimal control

Ca. 15% reduktion
av standardavvikelse
av kontaktkraften

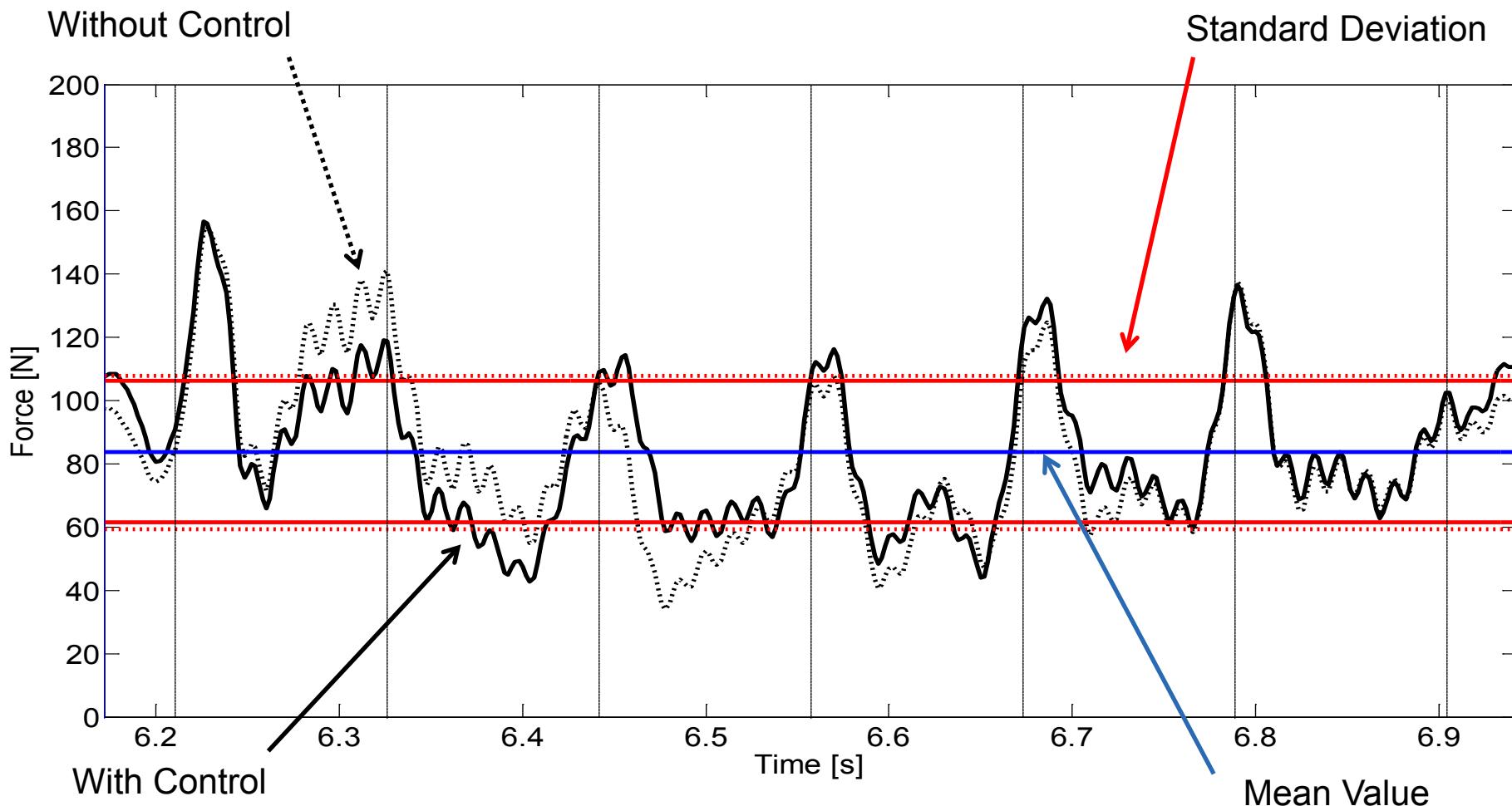
→ 50 km/h högre
hastighet



Active control – master thesis Schaer

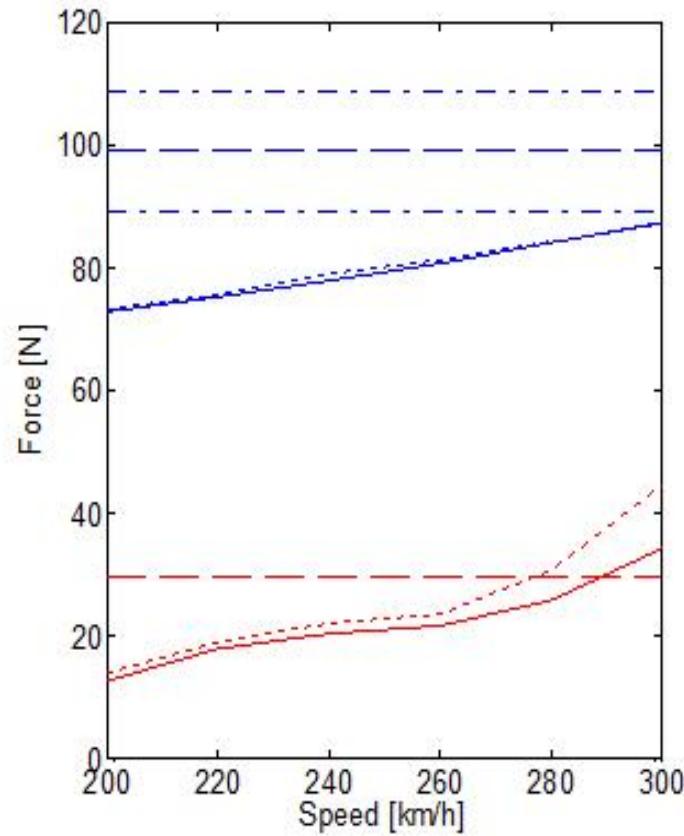
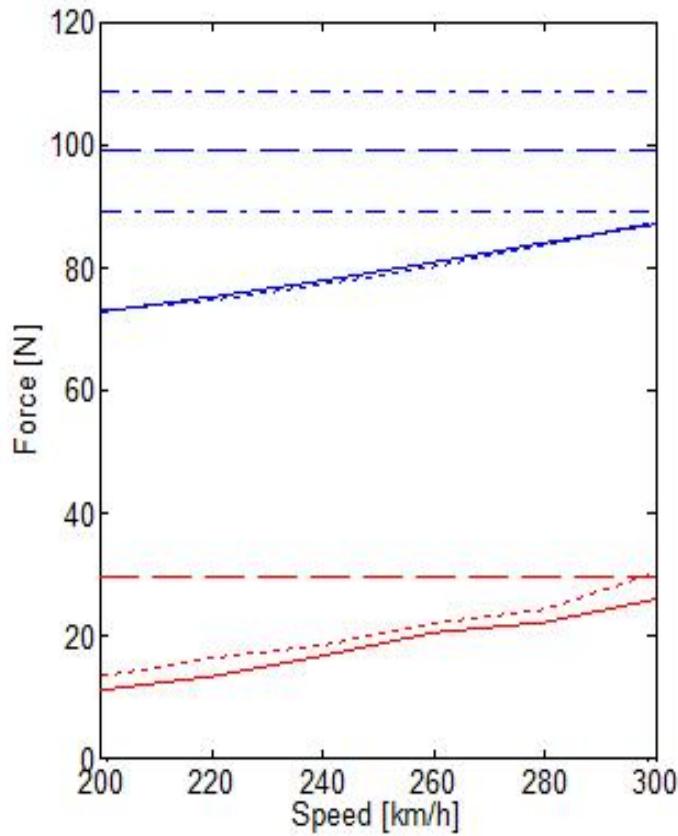
- Controller design in Matlab/Simulink
- Simulation with a full finite element model in ANSYS
- H^∞ control

Time domain result 280 km/h



Results two pantographs

- Including a controller, same reference value



Standard Deviation Reduction:

First:
1.6 to 4.4 N
7 to 18%

Second:
1 to 10 N
5 to 23 %

Conclusions master thesis Schaer

- Two pantographs within 100 meter distance are possible up to 280 km/h
- Reduction is smaller compared with the simpler model in GENSYS

Benchmark

Partners

Benchmark av programvara
för analys av dynamisk
interaktion mellan
kontaktledning och
strömvägtagare

- Politecnico di Milano
- KTH Stockholm
- Instituto Superior Tecnico Lisboa
- Universidad Pontificia Comillas de Madrid
- Universitat Tecnica Valencia
- Southwest Jiaotong University Chengdu
- DB Systemtechnik GmbH
- Société nationale des chemins de fer français SNCF
- Korea Railroad Research Institute
- Railway Technical Research Institute Japan

Benchmark

System

Arbetet organiseras i 2 steg:

Steg 1: Analys av ett fiktivt idealt system

- 1. non linear static configuration of the catenary (3D catenary model);
- 2a. dynamic interaction of the catenary with a single pantograph (2D catenary model);
- 2b. dynamic interaction of the catenary with a single pantograph (3D catenary model);
- 3. dynamic interaction of the catenary with multiple pantographs (2D catenary model).

Steg 2: Jämförelse med mätningar för ett verkligt system

Benchmark

System i steg 1

Systemet inspererat av
Franska LN2 och Italienska C270
systemen

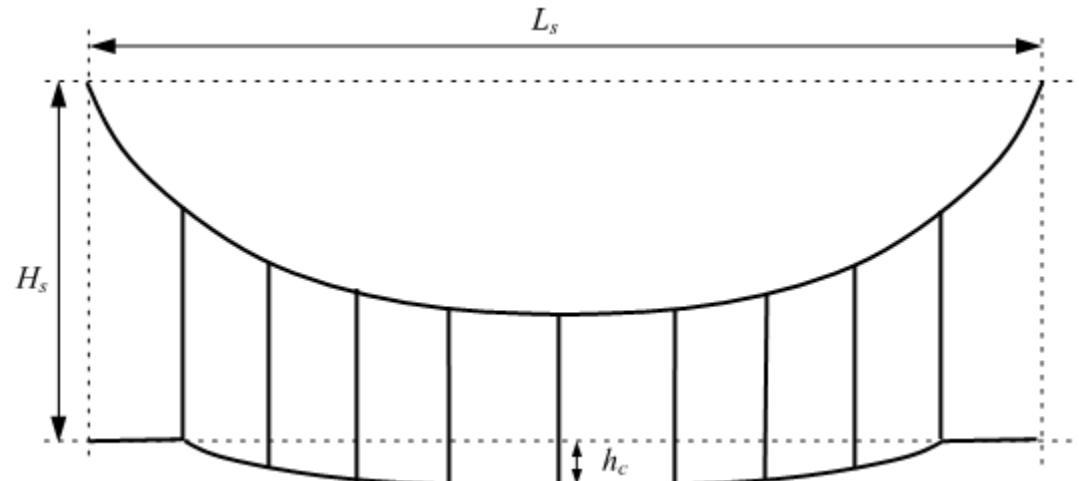
$$L = 55 \text{ [m]}$$

$$H_s = 1.2 \text{ [m]}$$

$$h_c = 55 \text{ [mm]} \text{ (1:1000 av } L)$$

$$S_c = 22 \text{ [kN]}$$

$$S_m = 16 \text{ [kN]}$$

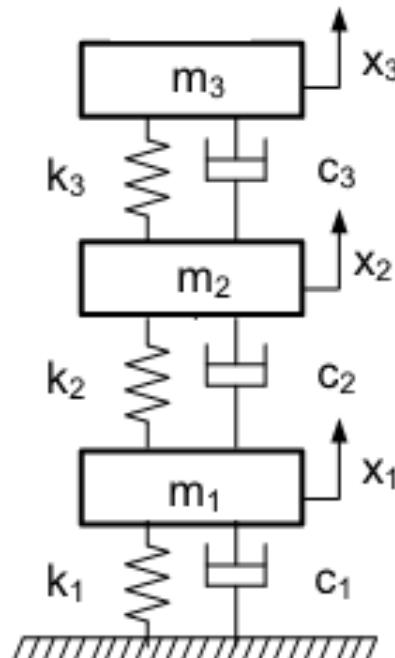


Benchmark

System i steg 1

Data inspererat av
en höghastighets strömväxtagare

Speed	V/V_w	Mean contact force
10 km/h		100 N, 200 N
230 km/h	50%	121 N
275 km/h	60%	143 N
320 km/h	70%	169 N
365 km/h	80%	169 N



m_1	6.0 kg
m_2	9.0 kg
m_3	7.5 kg
c_1	100 Ns/m
c_2	0.1 Ns/m
c_3	45.0 Ns/m
k_1	160.0 N/m
k_2	15500.0 N/m
k_3	7000.0 N/m



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Benchmark

General		Catenary						Pantograph			Sliding contact		Numerical integration	
Institution	sw name	FEM/FD	2D/3D	Element types	Droppers	Registration arms	Damping	Lumped Mass	Flexibility contact strips	Multi-Body	Multiple pantos	Penalty method	Constraint	Method
DB	PROSA	FD	2D	beams, strings	piecewise linear with slackening	Linear spring-mass system	Velocity-proportional	Yes	Yes*	Yes*	Yes	No	Yes	Catenary: explicit 2-step method, pantograph trapezoidal rule integration or 2-step backward difference (BDF)
IST	PantoCat	FEM	3D	Euler-Bernoulli-Timoshenko Beams	Beam elements with slackening	beam elements	Proportional	Yes	Yes	Yes	Yes	Yes	No	Catenary: Newmark, pantograph: Gear (in co-simulation)
KRRI	SPOPS	FEM	2D (**)	Euler-Bernoulli Beams	mass-spring-damper with slackening	mass-spring	Velocity-proportional	Yes	No (Rolling considered)	No	Yes	Yes	Yes	Alpha method
KTH	CaPaSIM	FEM	3D	Euler-Bernoulli beams, bar elements	bar elements with slackening	mass+stiffness / bar element	Proportional	Yes	Yes	No	Yes	Yes	No	Newmark method
POLIMI	PCaDA	FEM	3D	Euler-Bernoulli Beams	non-linear visco-elastic with slackening	mass-spring / FEM	Proportional	Yes	Yes	No	Yes	Yes	No	Newmark method
RTRI	Gasen-do FB	FEM	3D	Euler-Bernoulli Beams	Bar Elements with Slackening	Bar Element	Proportional	Yes	No	No	Yes	Yes	No	Implicit Newmark + Newton Raphson
SNCF	OSCAR	FEM	3D	Euler-Bernoulli Beams	Non-linear with slackening	beam elements	Proportional or Rayleigh or modal	Yes	Yes	Yes	Yes	Yes	No	Implicit Newmark
SWJTU	PCRUN	FEM	3D	Beams	Spring Element	Linear spring-mass system	Modal	Yes	No	Yes	Yes	Yes	No	Newmark method
UPCo	CANDY	FEM	2D	Co-rotational beams and bars	bar elements with slackening	Linear spring-mass system for 2D	Rayleigh	Yes	No	No	Yes	Yes	No	Alpha method + Newton Rapshon
UPV	PACDIN	FEM(*)	3D	ANCF beams, bars	bar elements with slackening	Non-linear bar element	Proportional	Yes	No	No	Yes	Yes	No	Newmark, Alpha-method, 4th order RK
(*) Absolute Node Coordinate Formulation														
(**) Change of lateral position of the contact point due to stagger can be considered														

(*) Absolute Node Coordinate Formulation

(**) Change of lateral position of the contact point due to stagger can be considered

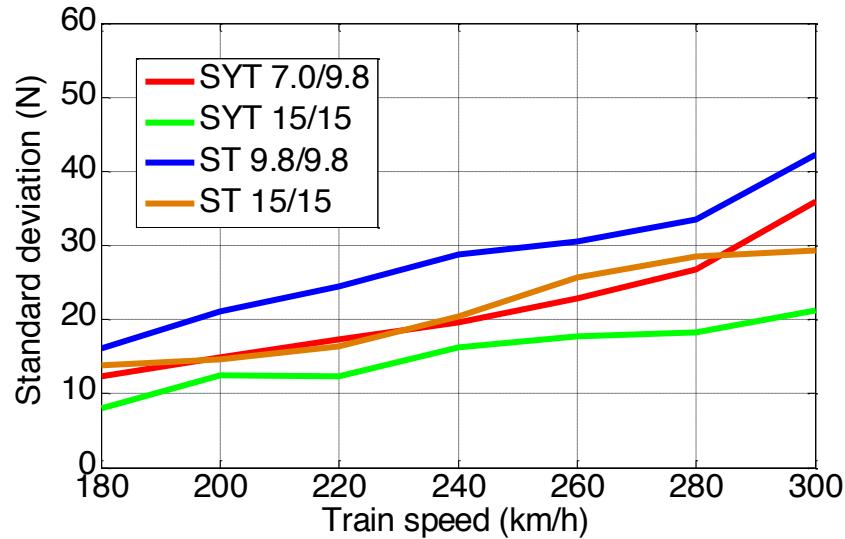
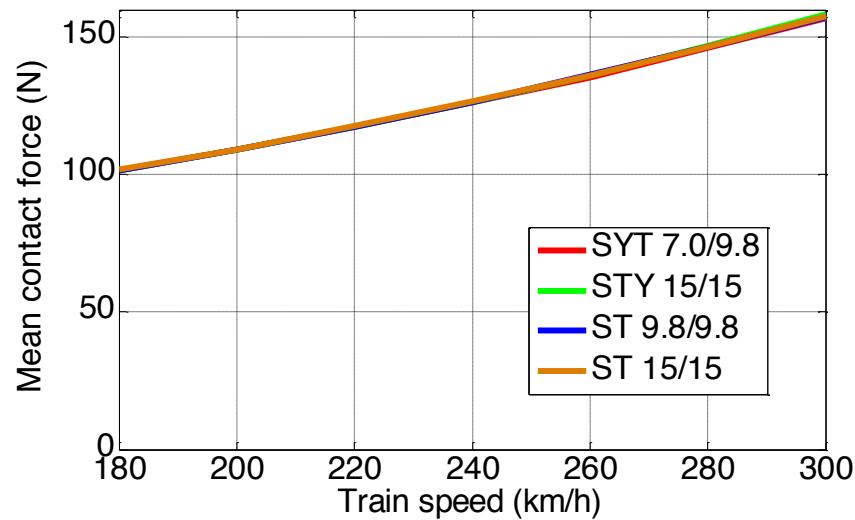
Parameter studies

The following parameters are investigated:

- Type of catenary (x4)
- Number of pantographs (x1, x2, x3)
- Running speed (150-300 km/h)
- Spacing distance between pantographs (60-80 m)
- Position of a pantograph in the whole system

Parameter studies

Single pantograph operation with respect to different types of catenaries

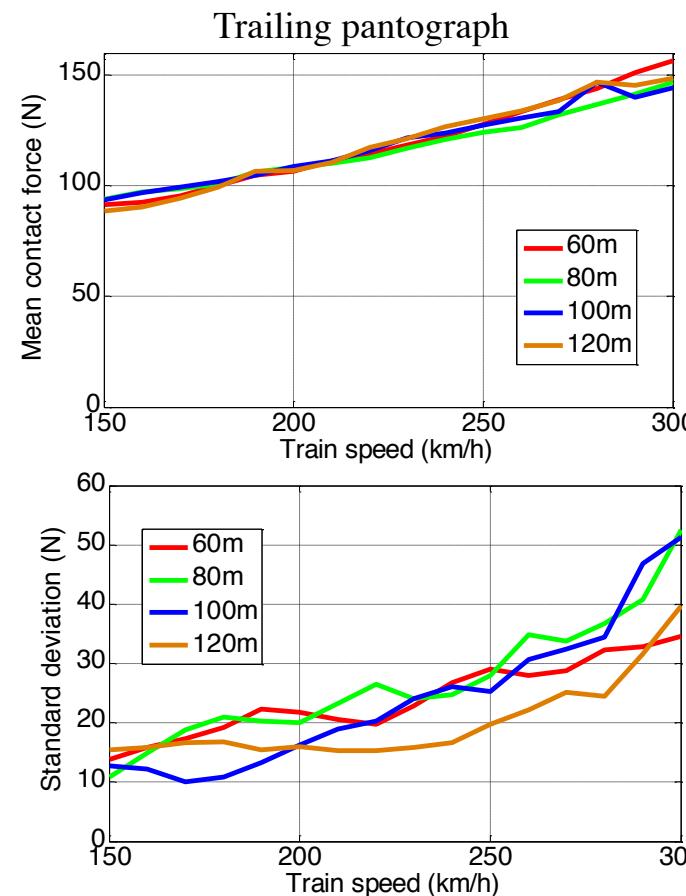
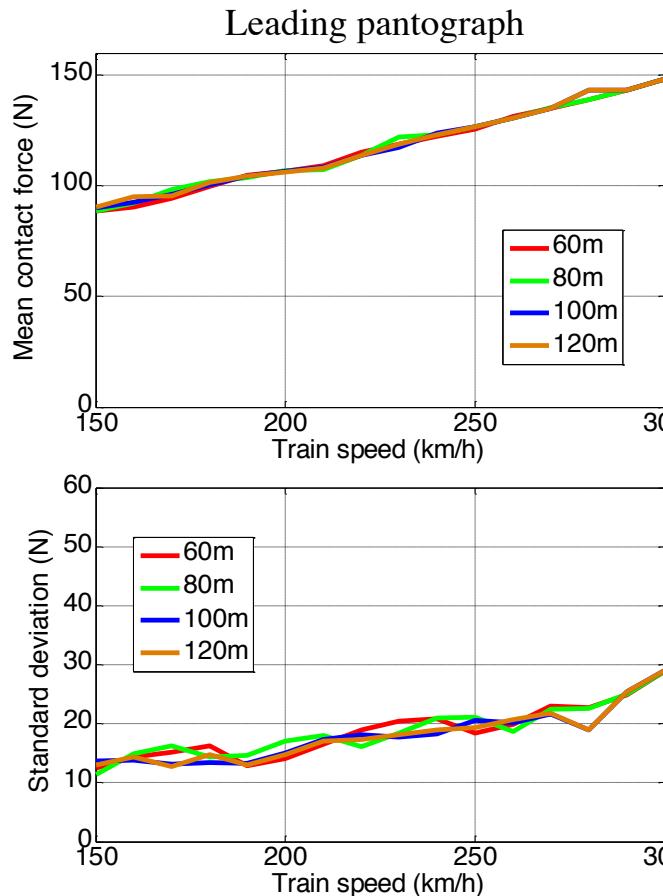


Comment: The catenary systems with stitch wires have less fluctuation of contact force than those without the stitch wire

With Pantograph SSS400

Parameter studies

Two pantographs operation with respect to pantographs at different spacing distances

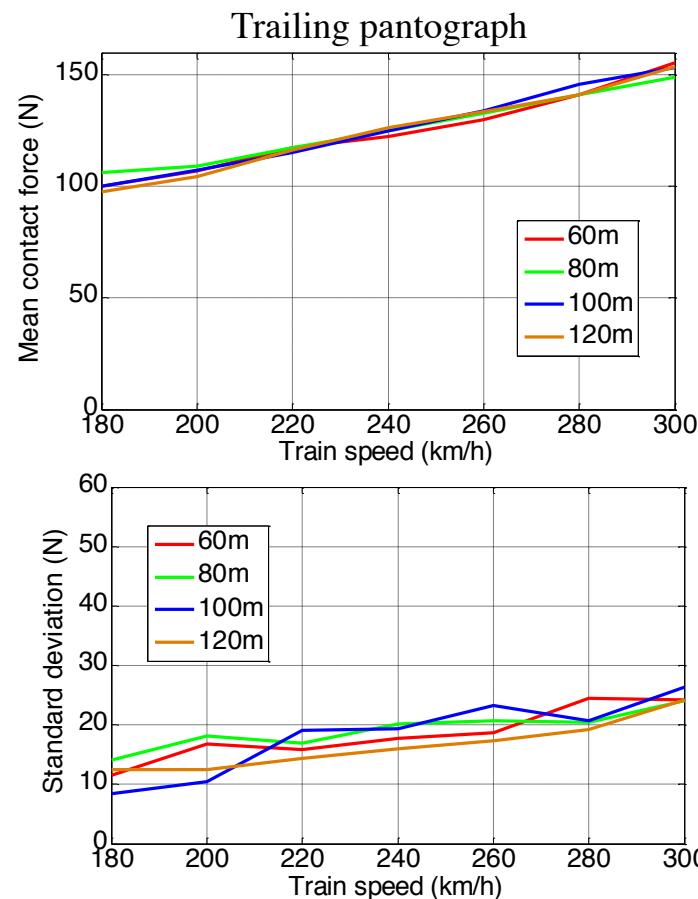
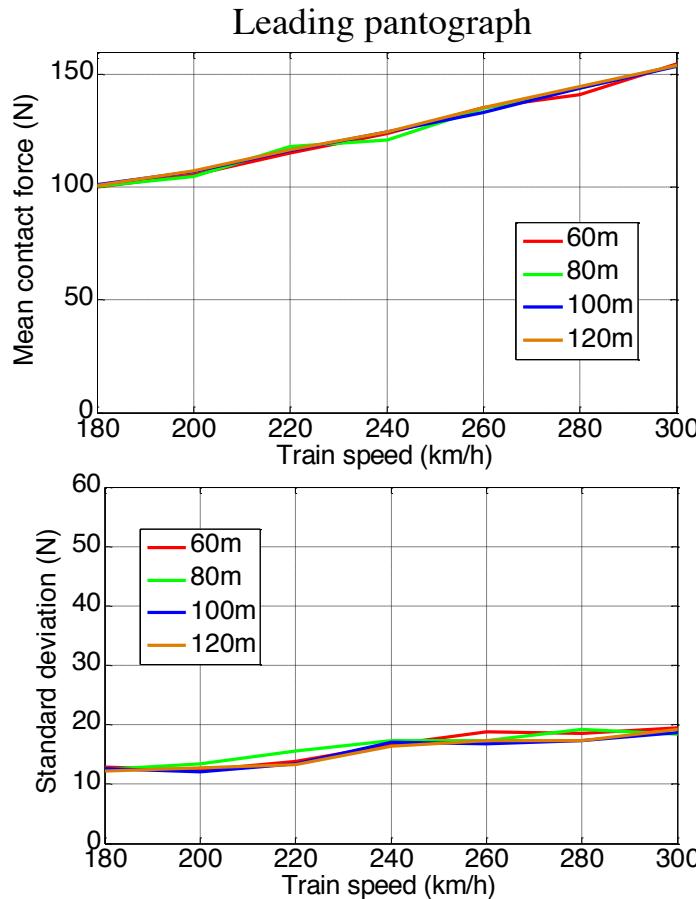


Comment: The mean contact forces is much less influenced by other pantographs. The standard deviation of the leading pantograph is less influenced by the trailing one, while the standard deviation of the trailing one is significantly influenced by the one ahead.

SYT 7.0/9.8
WBL 88

Parameter studies

Two pantographs operation with respect to different types of catenary



Comment: the performance on different systems varies a lot.

SYT 15/15
WBL 88

Parameter studies

$$F_{\text{min}} = F_{\text{mean}} - 3\sigma \geq 0 \text{ N}$$

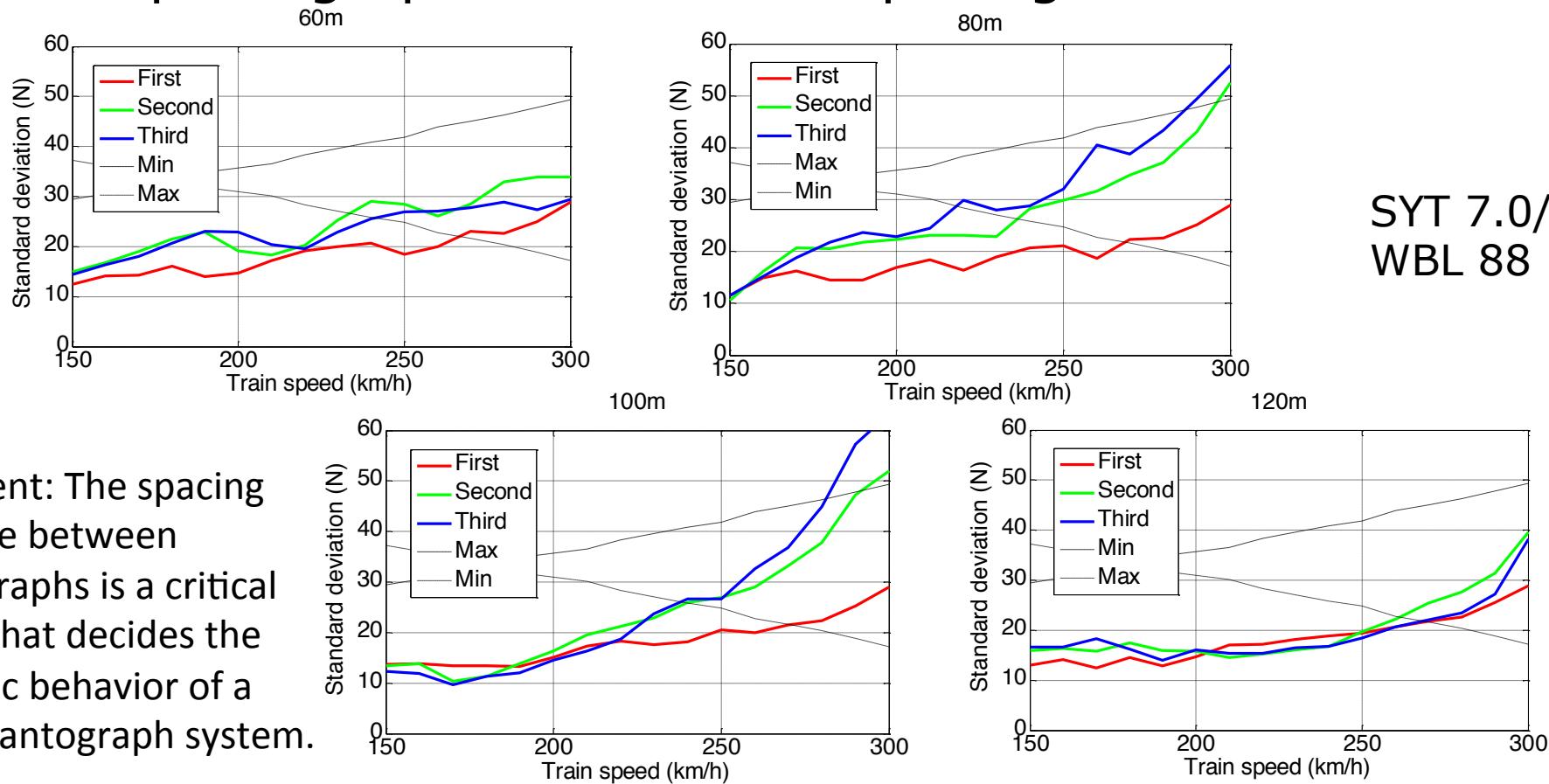
$$F_{\text{max}} = F_{\text{mean}} + 3\sigma \leq 200 \text{ N}$$

$$\sigma \leq \sigma_{\text{max}} = F_{\text{mean}} / 3$$

$$\sigma \leq \sigma_{\text{min}} = (200 - F_{\text{mean}}) / 3$$

BVS 543.330

Three pantographs operation with respect to pantographs at different spacing distances



Comment: The spacing distance between pantographs is a critical factor that decides the dynamic behavior of a multi-pantograph system.

Parameter studies

$$F_{\downarrow min} = F_{\downarrow mean} - 3\sigma \geq 0 \text{ N}$$

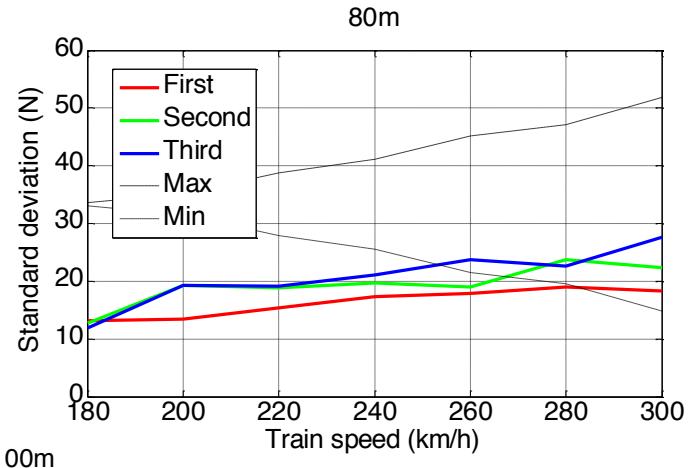
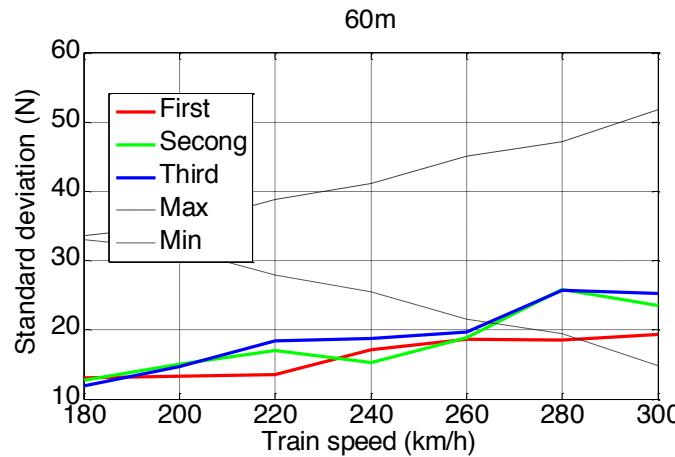
$$F_{\downarrow max} = F_{\downarrow mean} + 3\sigma \leq 200 \text{ N}$$

$$\sigma \leq \sigma_{\downarrow max} = F_{\downarrow mean} / 3$$

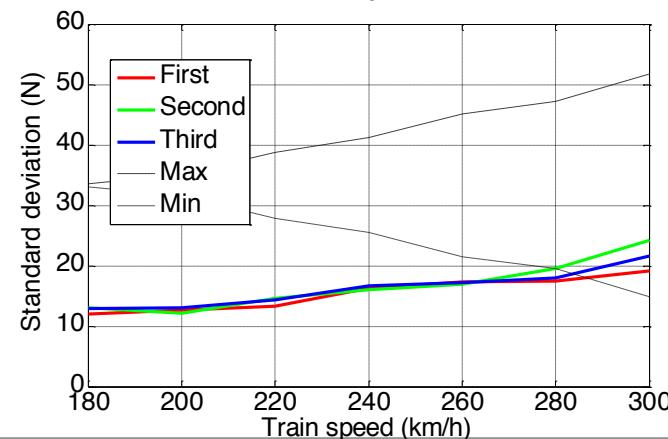
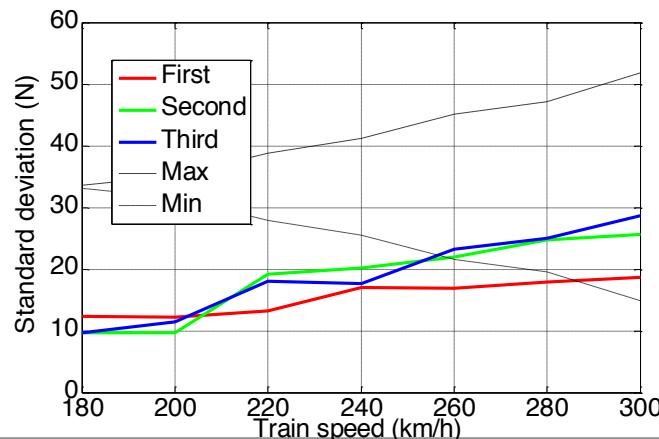
$$\sigma \leq \sigma_{\downarrow min} = (200 - F_{\downarrow mean}) / 3$$

BVS 543.330

Three pantographs operation with respect to pantographs at different spacing distances


 SYT 15/15
 WBL 88

Comment: The type of the catenary system is also a critical factor that influences the performance. The SYT 15/15 allows trains to run at a high speed



Parameter studies

Conclusions:

- The pantograph-catenary systems with the stitch wire have less fluctuation of contact force
- The mean contact forces are not sensitive to both the number of pantographs and their spacing distances
- A trailing pantograph is heavily influenced by all pantographs in front of it
- The dynamic behavior of the system does not always get worse with the number of pantographs increasing
- The spacing distance between pantographs and the type of catenary in use are critical factors in multi-pantograph operation

Framtida arbete

- Benchmark – Jämförelse med uppmätta resultat
- Vidareutveckla 3D modellen
- Kontaktledningssystem för framtida höghastighetsbanor i Sverige
- Aktiva strömväxtagare ev. tillsammans med POLIMI
- Testa aktiva strömväxtagare