



EXPERIMENTAL ANALYSIS AND MODELLING OF RAILWAY VEHICLE PASSING OVER TURNOUT FROG

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University of Pardubice

Jan Perner Transport Faculty

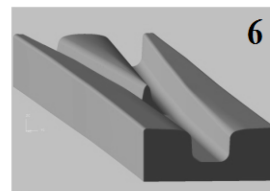
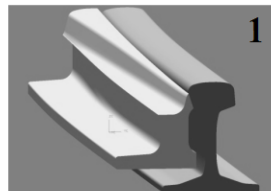
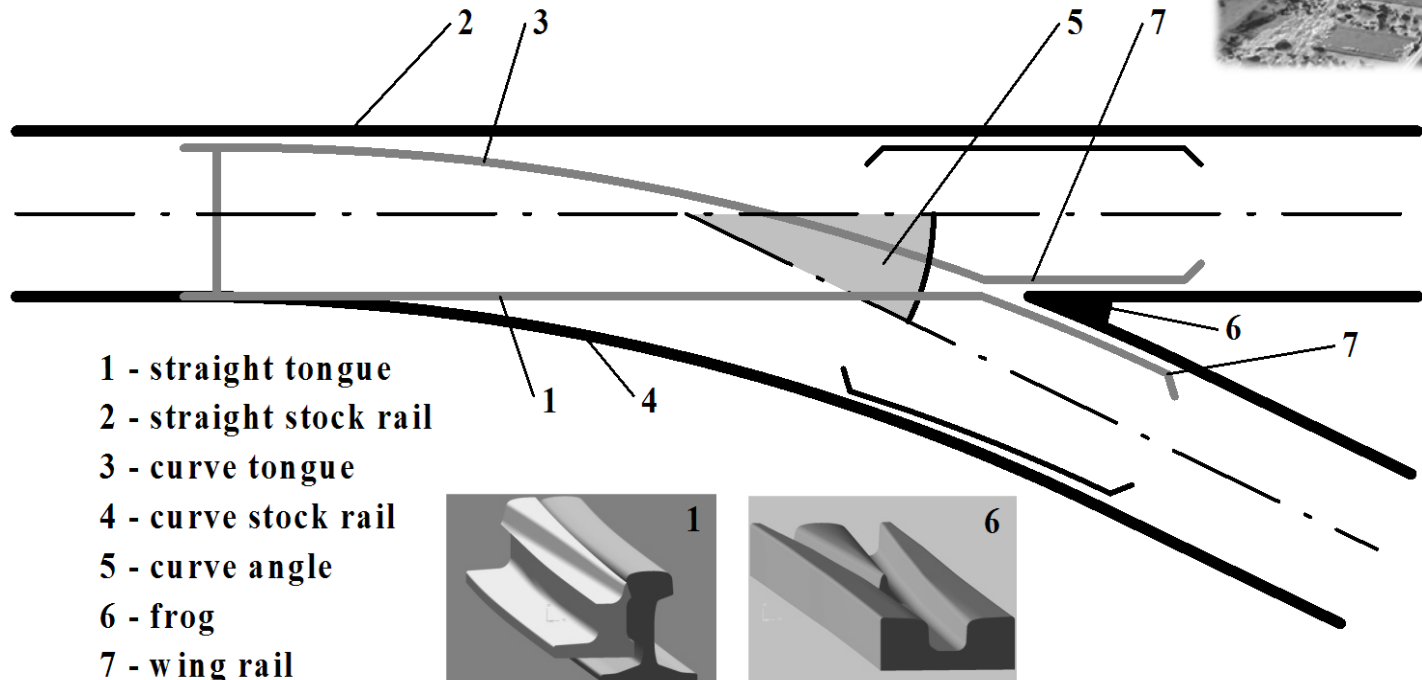
Department of Transport Means and Diagnostics

Rail Vehicles Section

Detached Branch in Česká Třebová

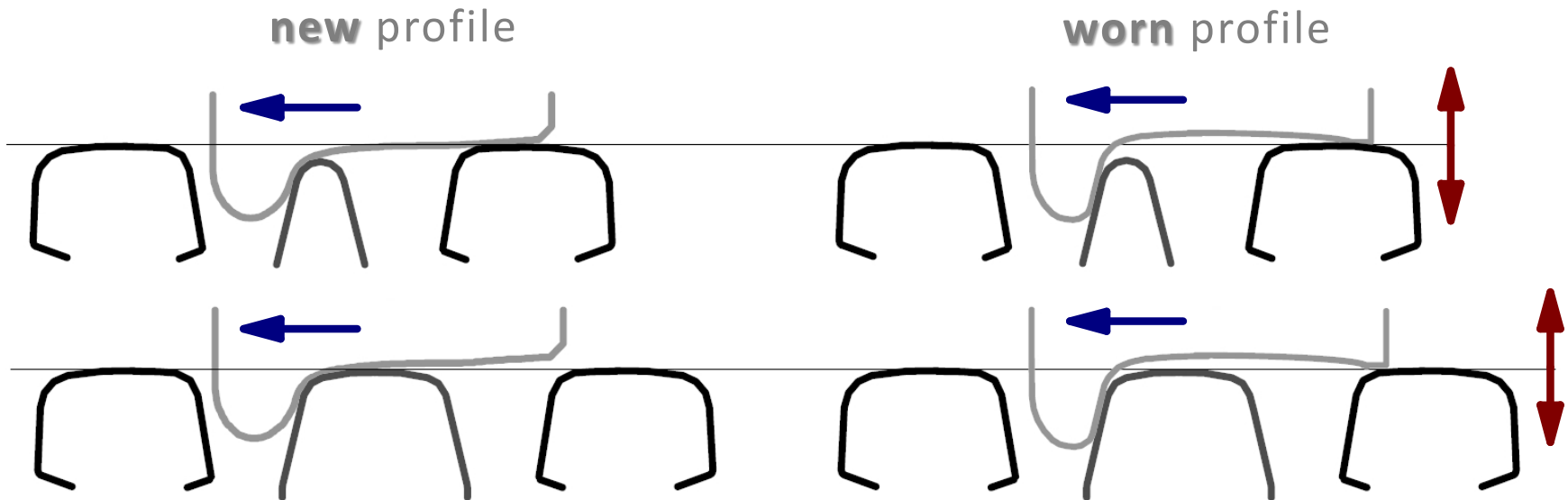
PASSING OF WHEELSET OVER TURNOUT

- increased **noise** and **vibration**,
- high **loading** in wheel-rail contact,
- **maintenance** and **repair** costs.



PASSING OF WHEELSET OVER FROG AREA

- have to be **continuous**,
- **without** lateral or vertical **impact**,
- depends on - **wheel** profiles.
- frog **rail** profiles.





EXPERIMENTAL ANALYSIS - FIRST EXPERIENCE

1st CORRIDOR – Czech republic

Břeclav – Brno – Česká Třebová – Praha - Děčín



681 001-4

PODIVÍN - VRANOVICE

15-19th November 2004

ZÁMRSK - PARDUBICE

10-13th October 2005

Testing speed

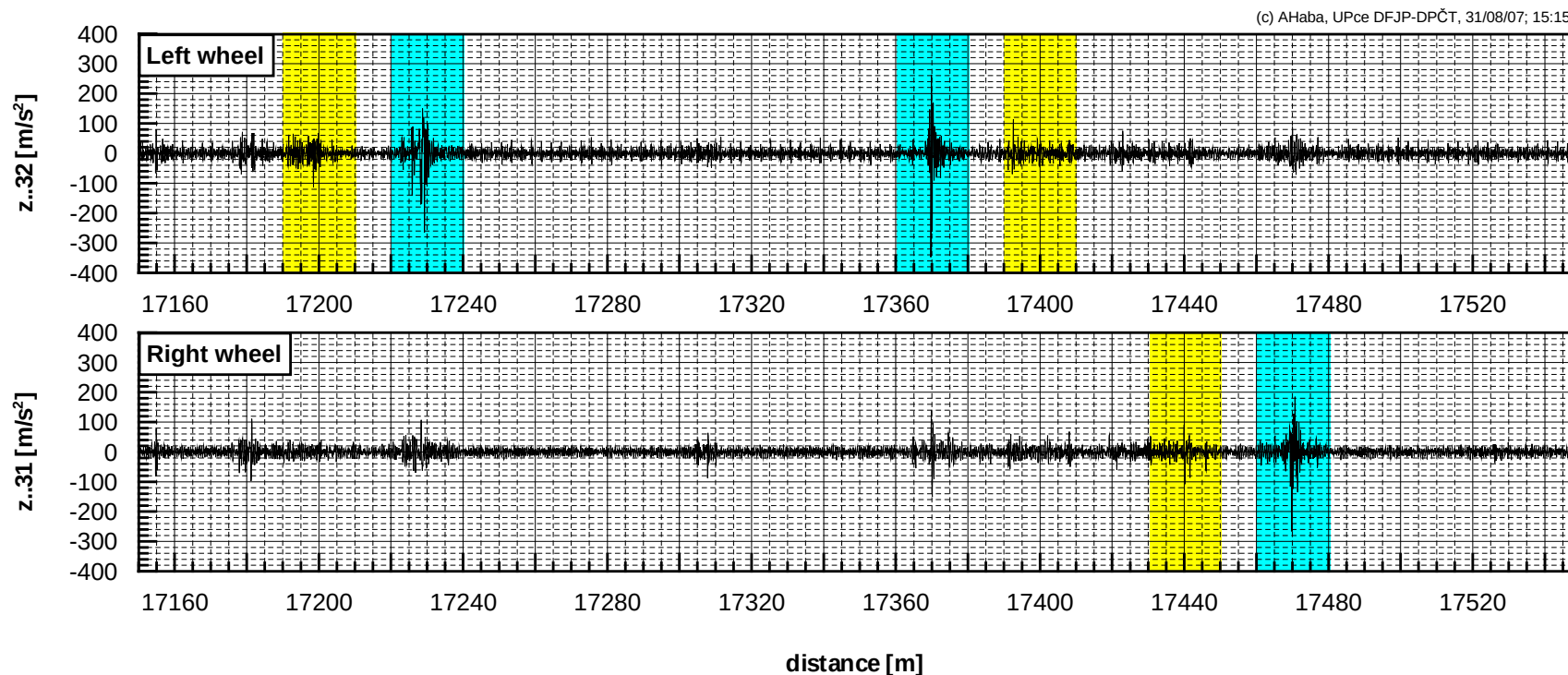
160 - 230 kmph



ACCELERATION SIGNAL RECORD

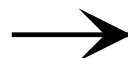
Station: KOSTĚNICE	Date: 10.10.2005
Track: 2	Vehicle: 681 001-4
Throat: Zámorsk's	Speed: 160 km/h
Direction: Pardubice	Measuring No.: M 02

→	No. 1	No. 5	No. 6
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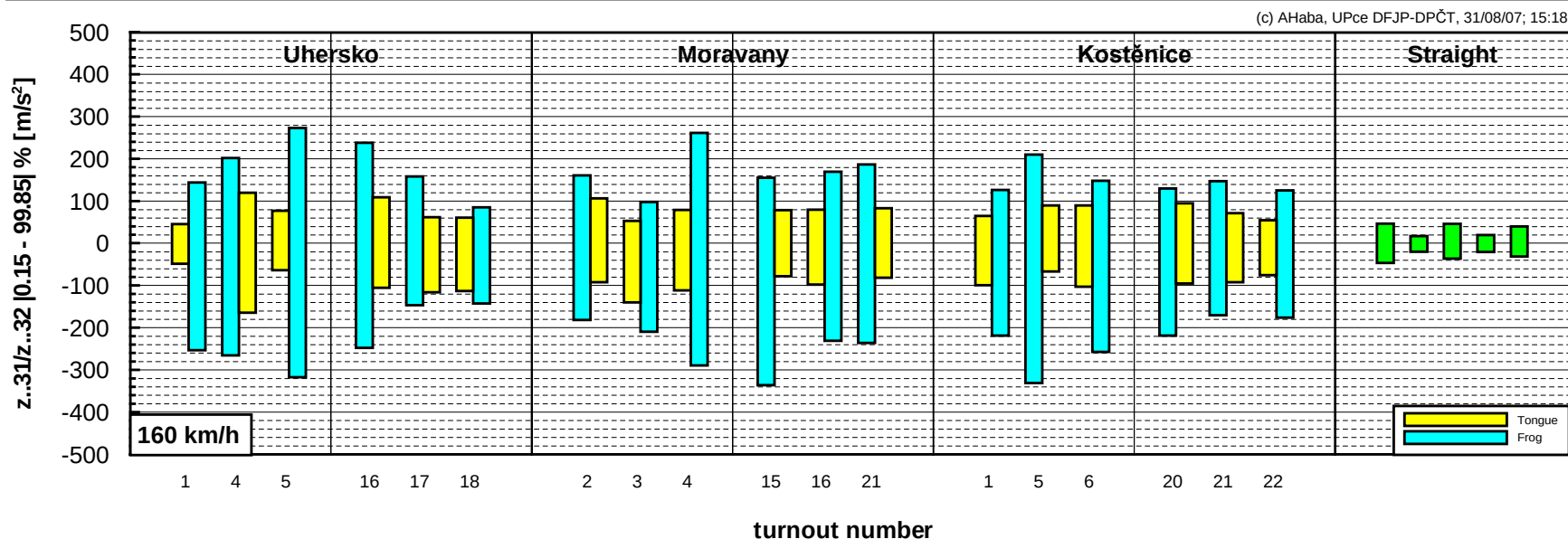


ACCELERATION SIGNAL ASSESMENT

Track section: **Zámorsk - Pardubice**
Track No.: **2.**
Running direction: **Pardubice**



Vehicle: **681 001-4**
Date: **10.-13.10.2005**
Quantity: **z..31/z..32**



TOP = 0.15% Percentile

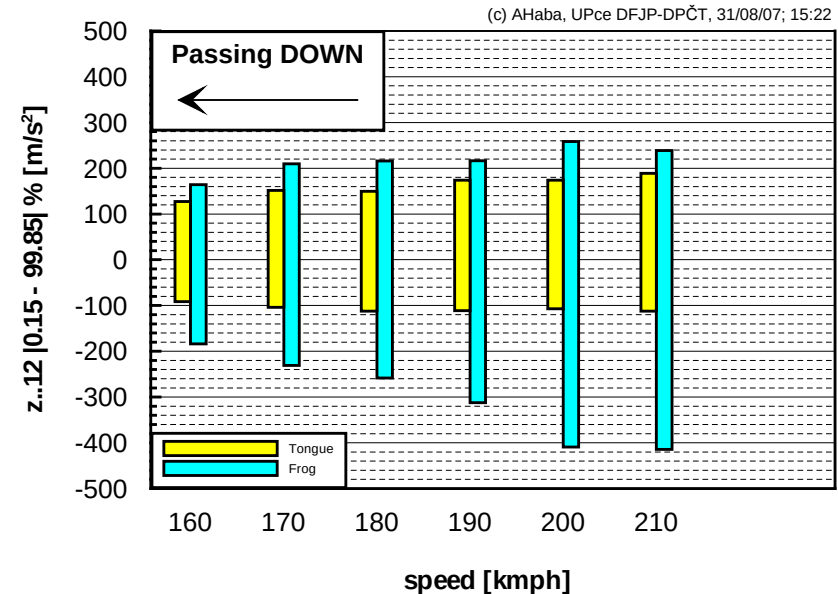
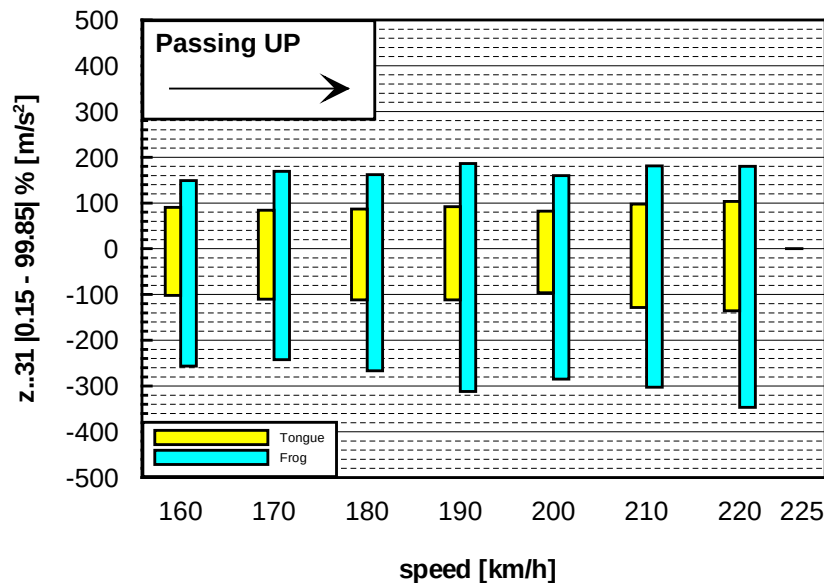
BOTTOM = 99.85% Percentile

ACCELERATION SIGNAL ASSESMENT

Track section: **Zámorsk - Pardubice**
Track No.: **2.**
Station: **KOSTĚNICE**
Turnout No.: **6**



Vehicle: **681 001-4**
Date: **10.+13.10.2005**



TOP = 0.15% Quantil

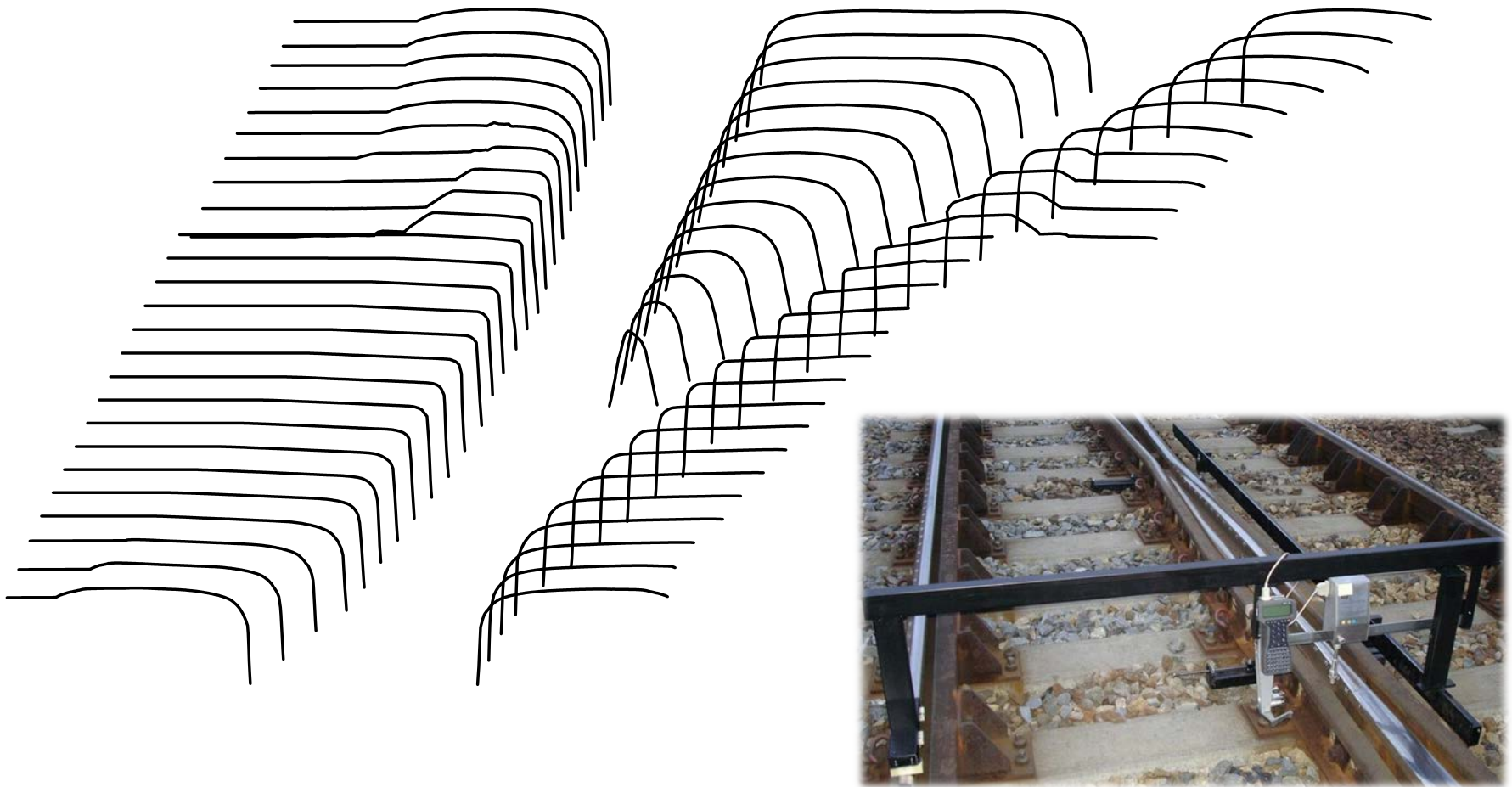
BOTTOM = 99.85% Quantil



IDENTIFICATION OF TURNOUT FROG STATE

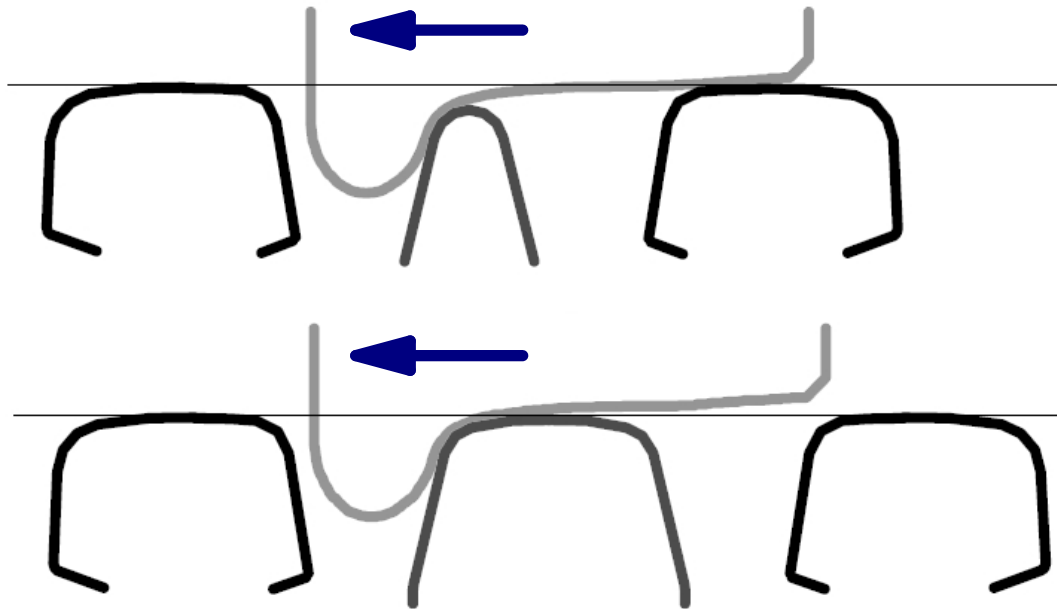


IDENTIFICATION OF TURNOUT FROG STATE

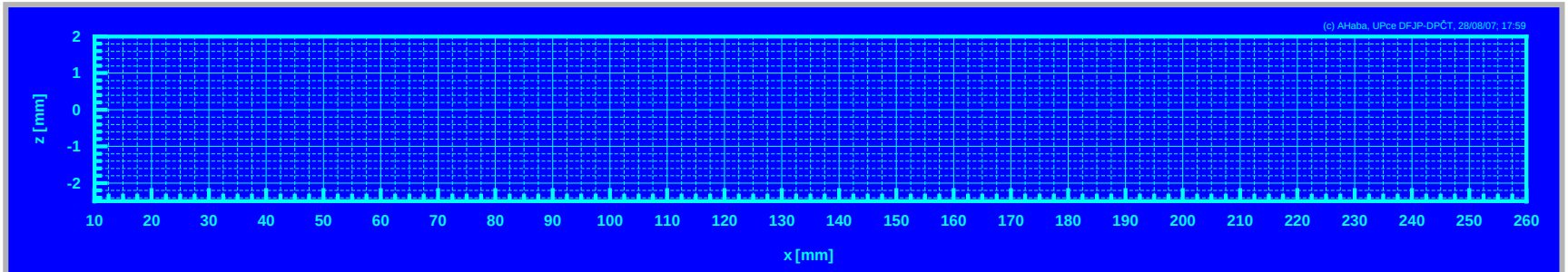
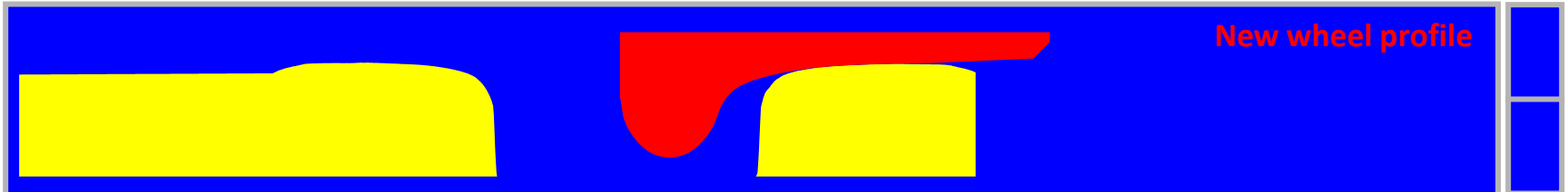
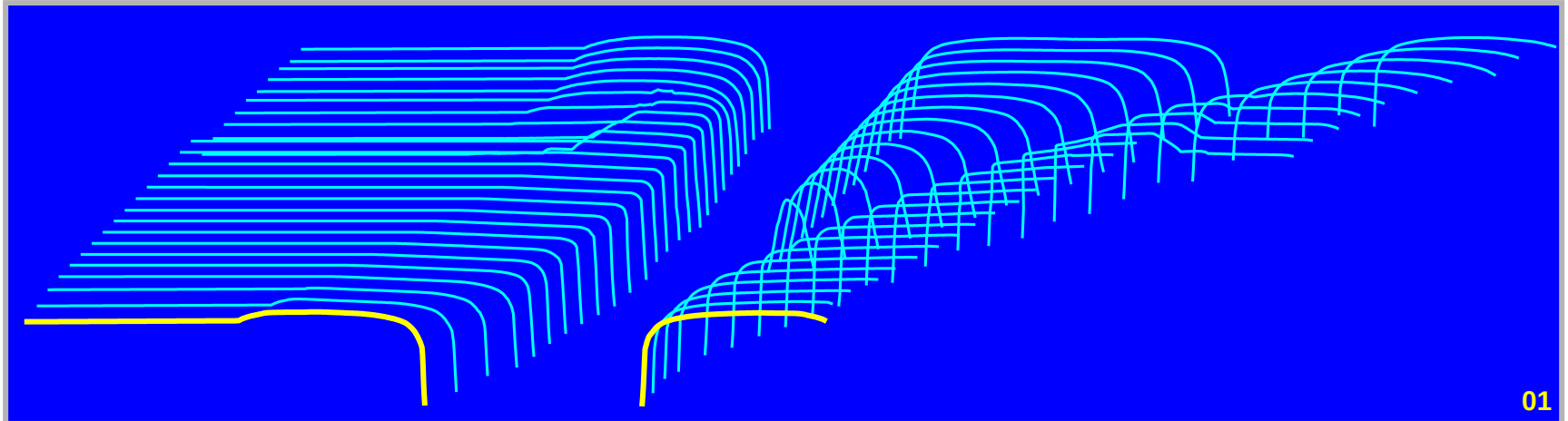


PASSING OF WHEELSET OVER FROG AREA

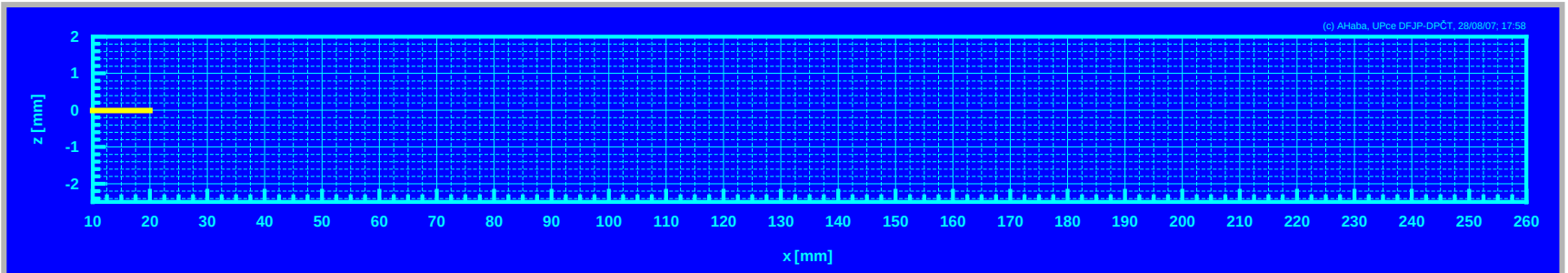
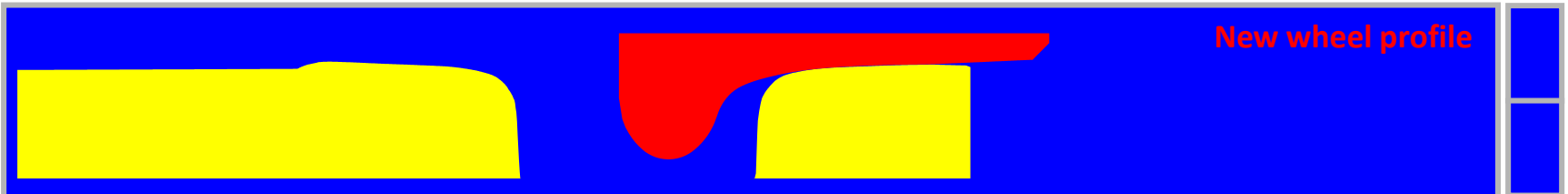
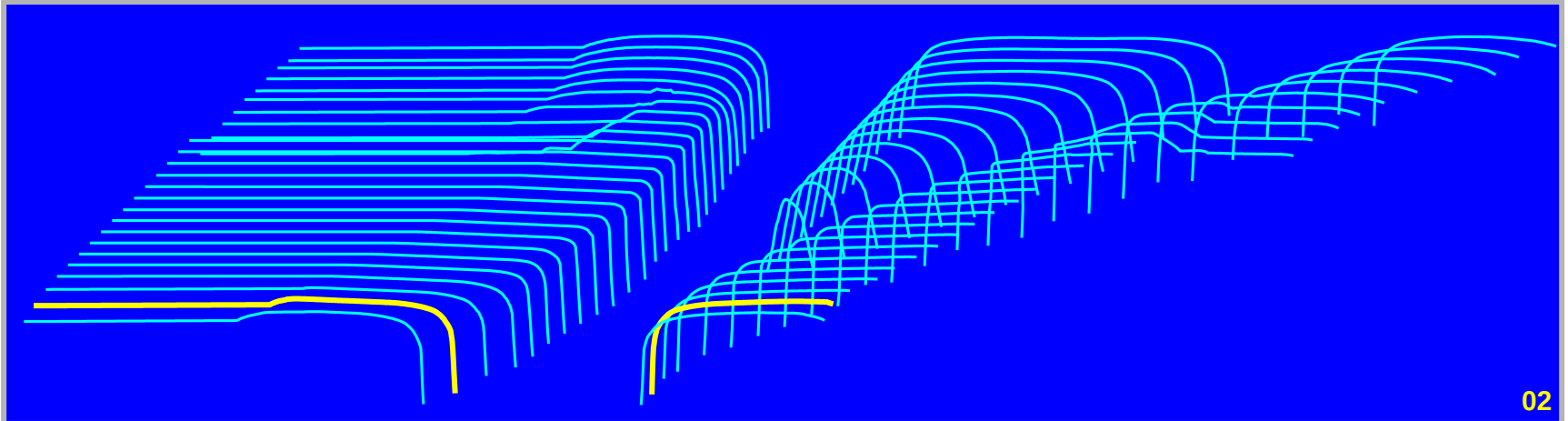
- **new** wheel profile -



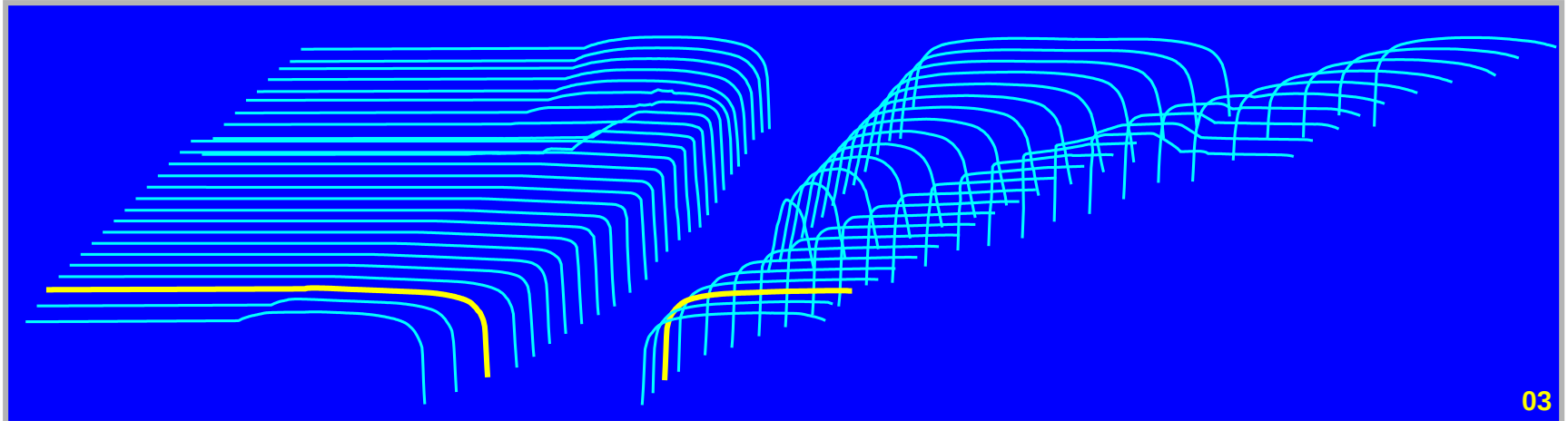
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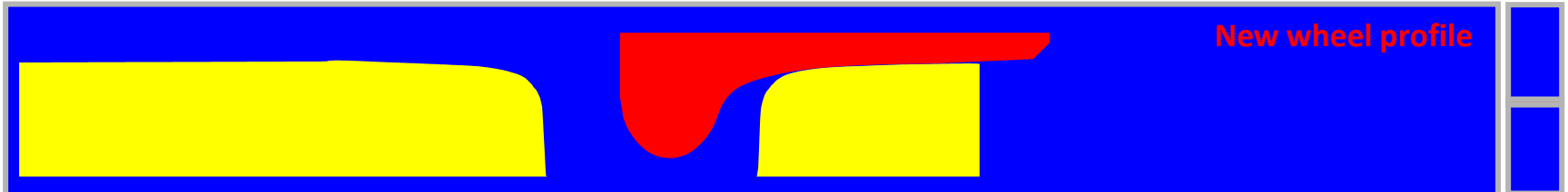
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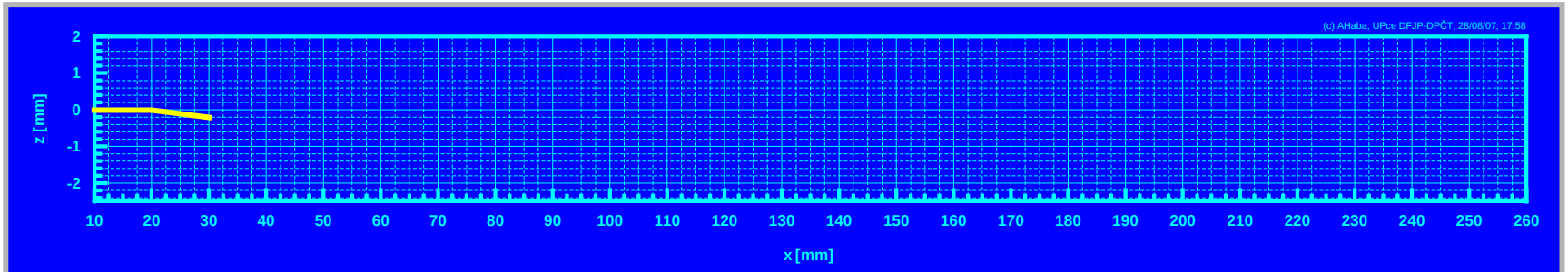
PASSING OF WHEELSET OVER FROG AREA



03

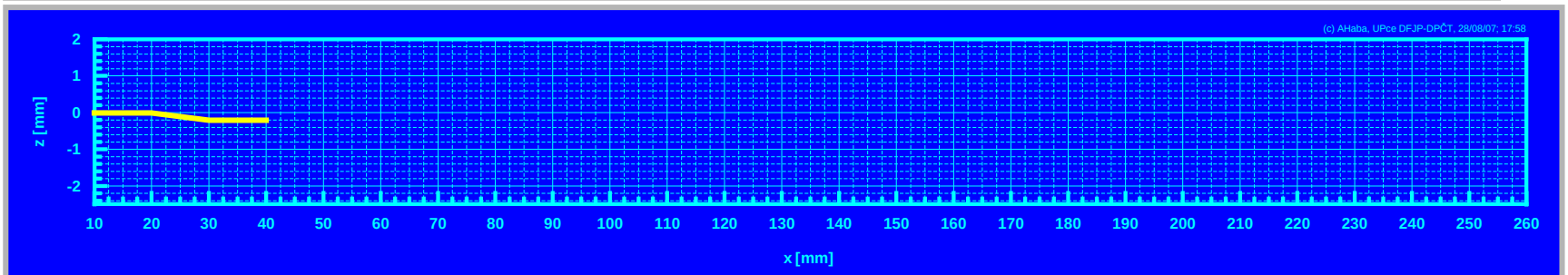
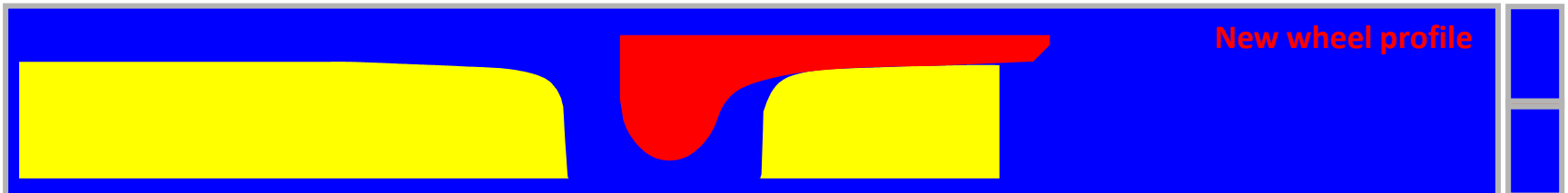
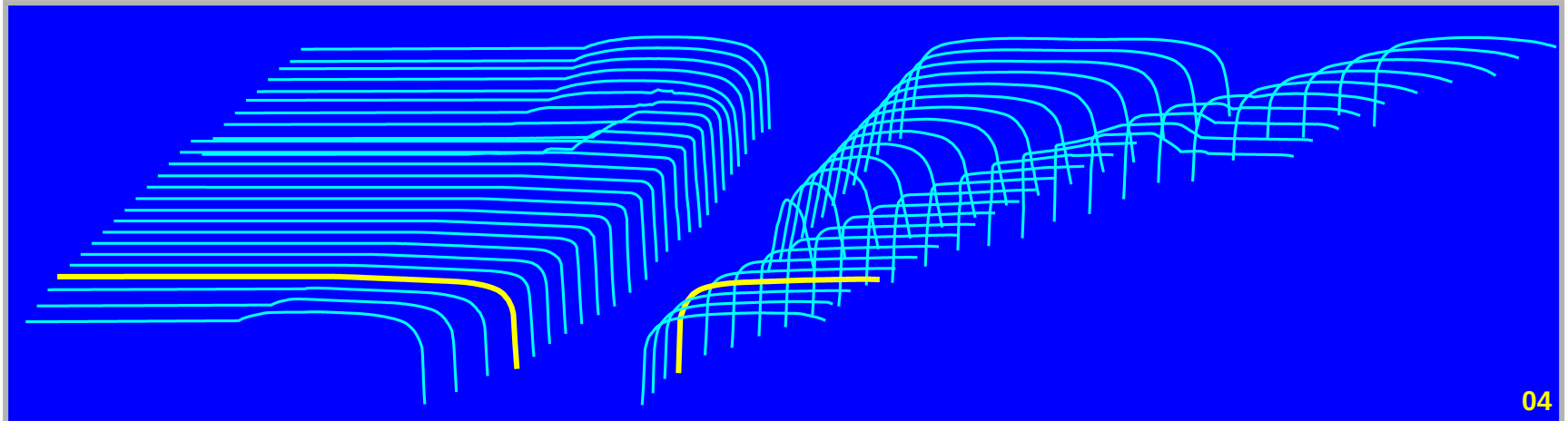


New wheel profile

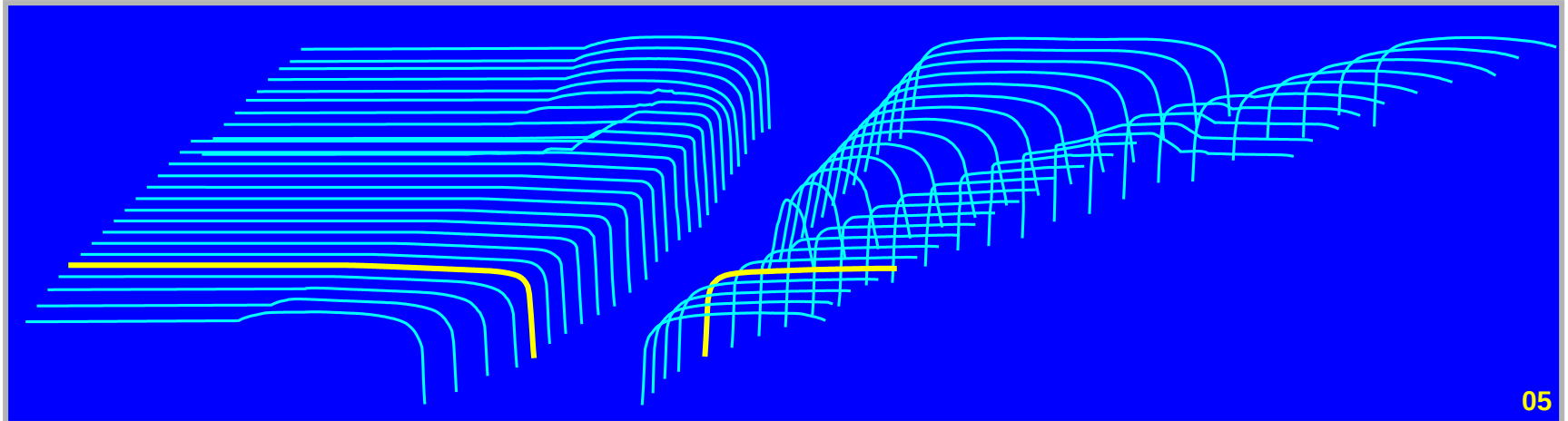


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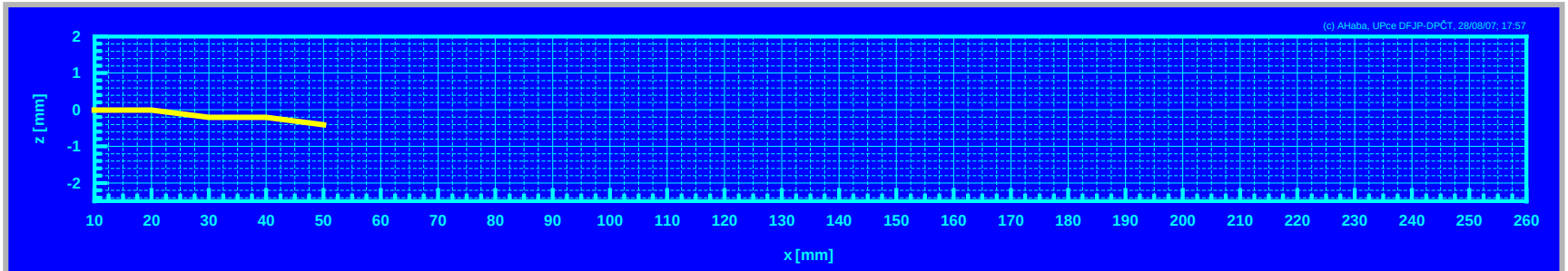
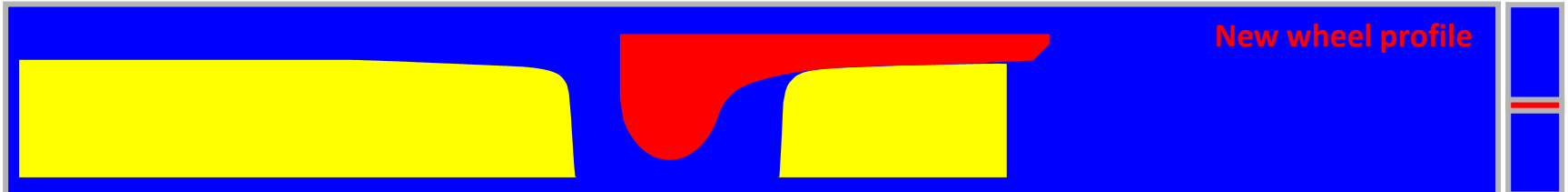
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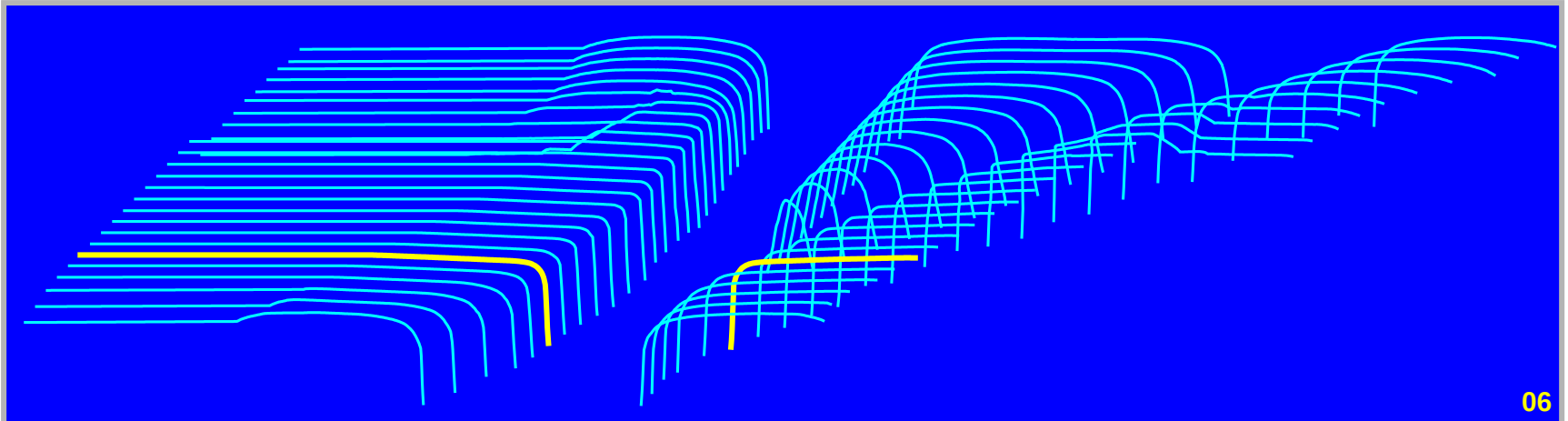
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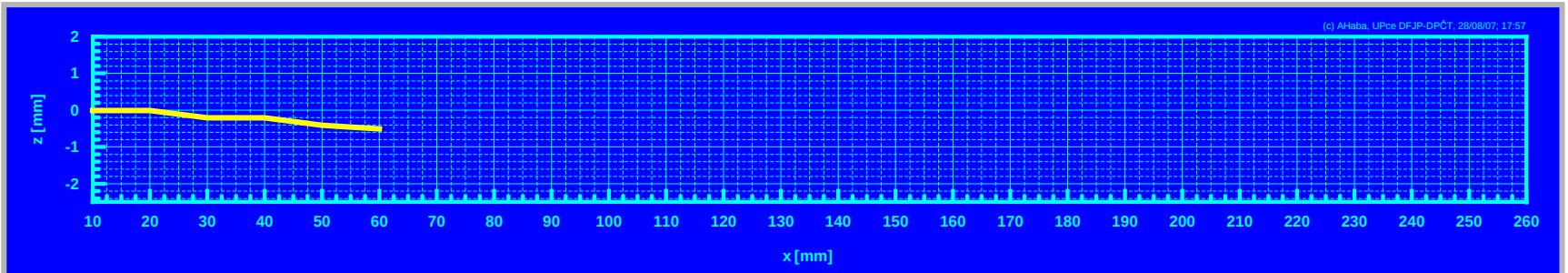
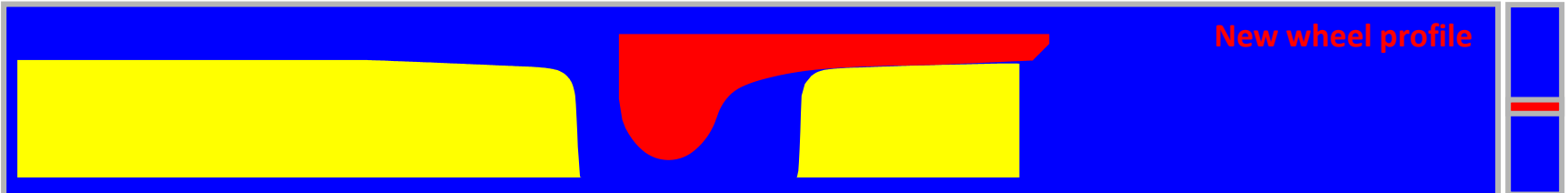
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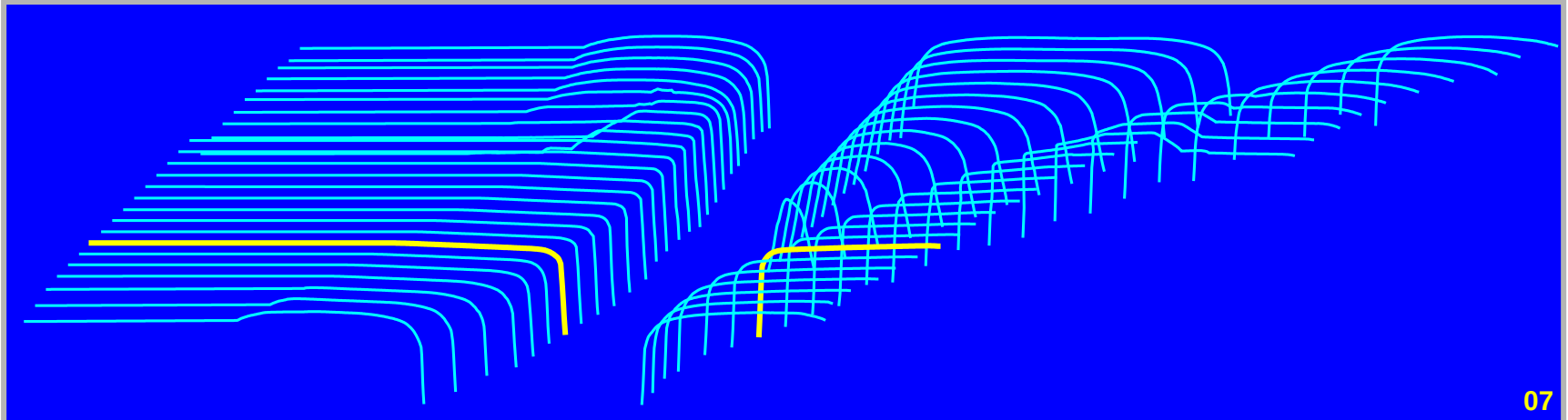
PASSING OF WHEELSET OVER FROG AREA



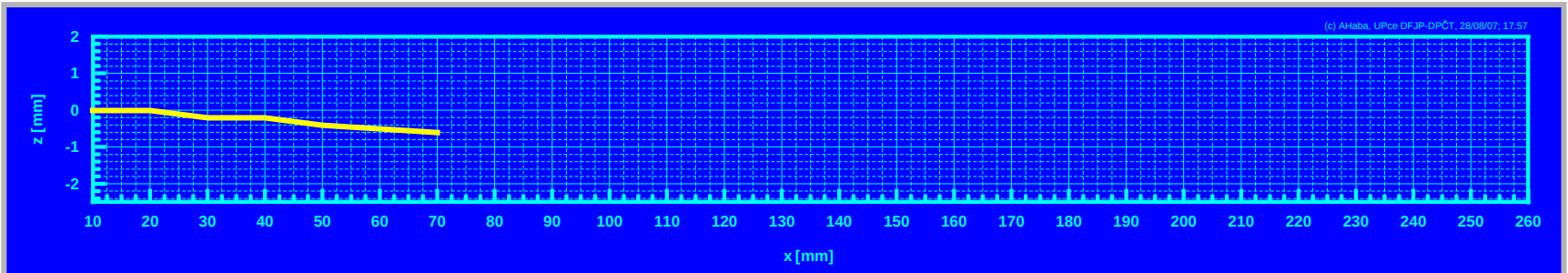
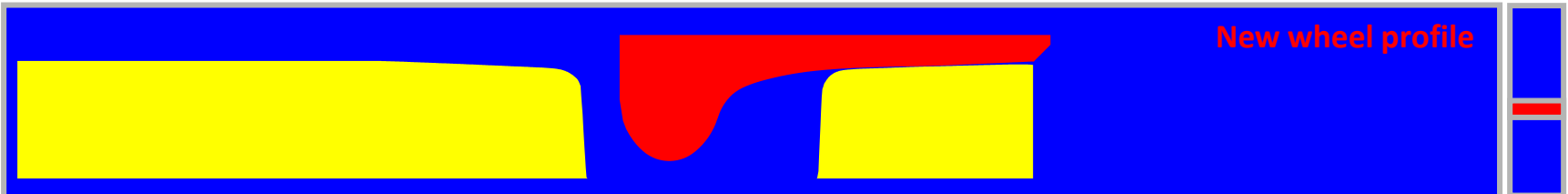
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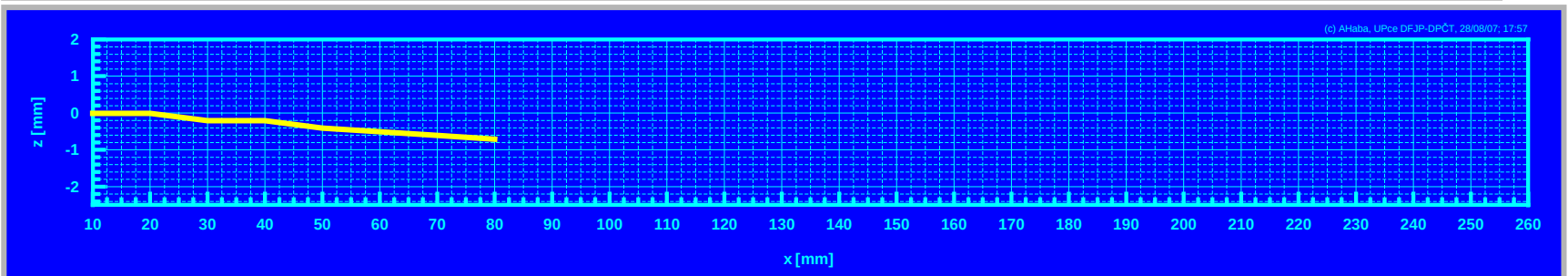
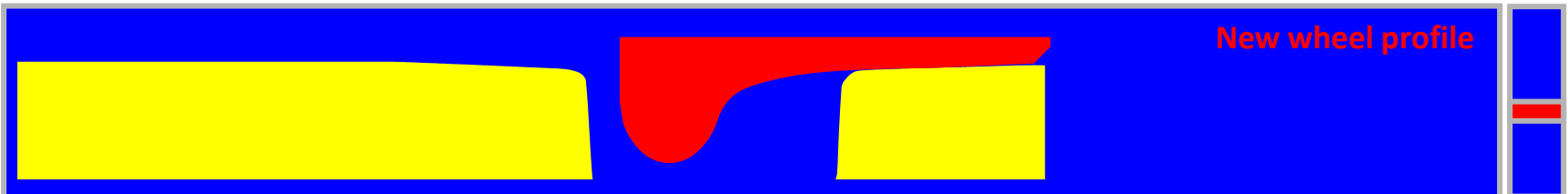
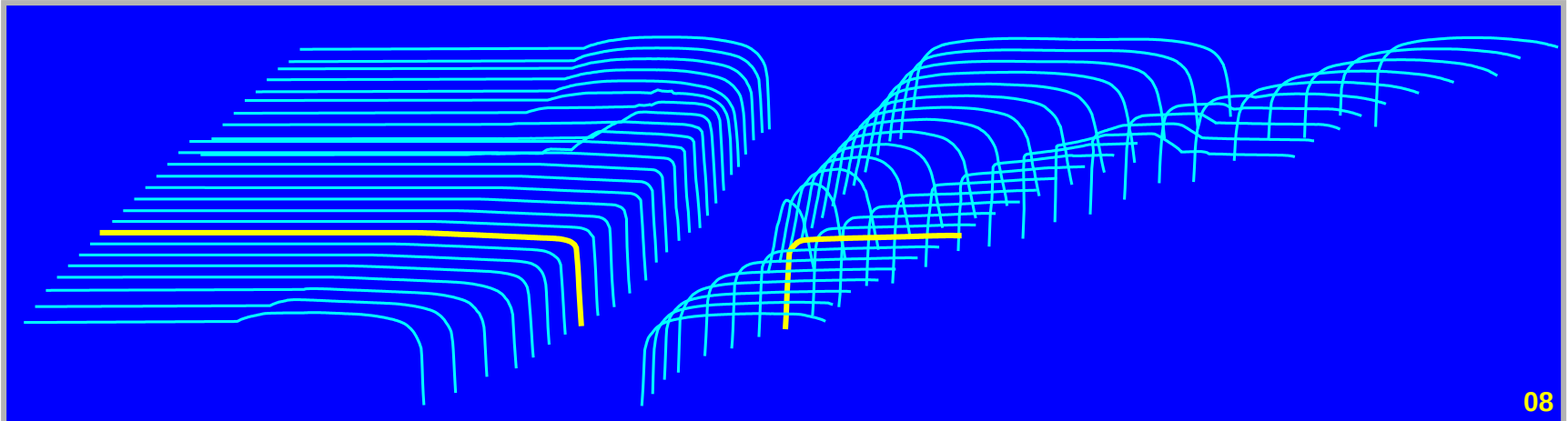
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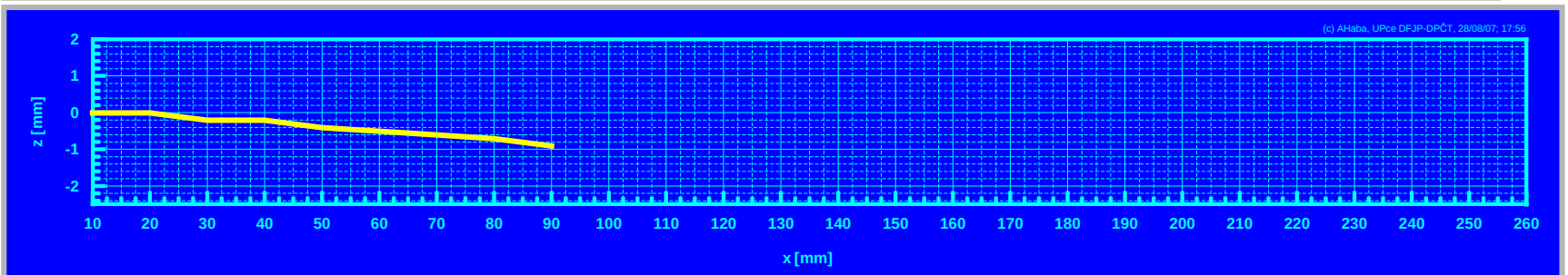
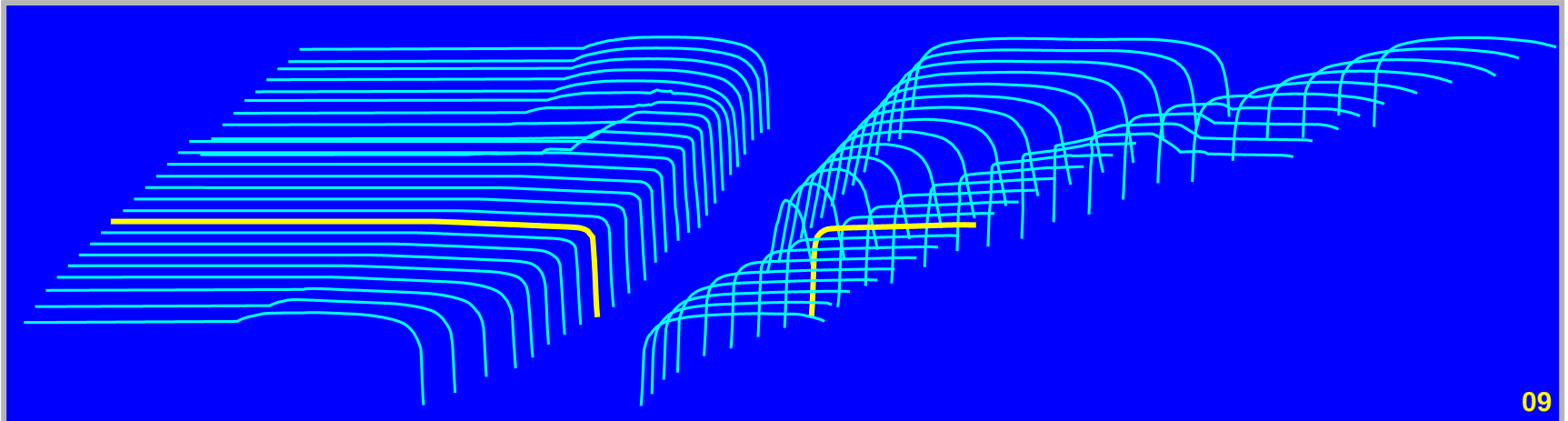
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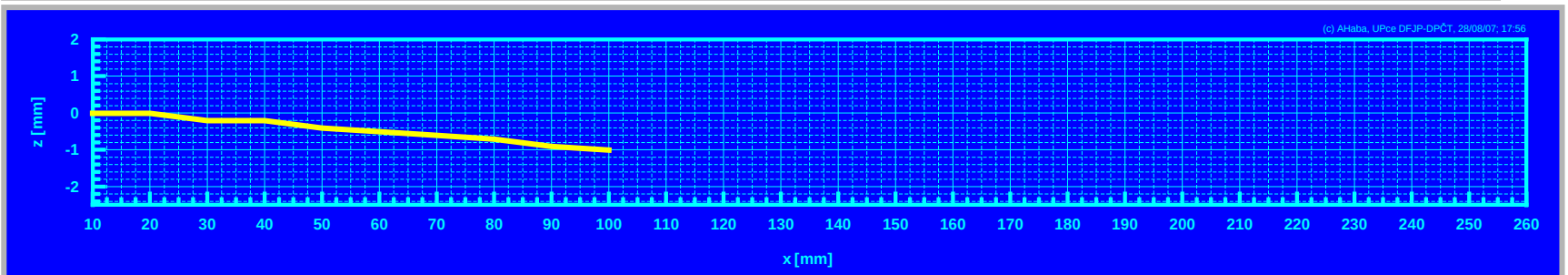
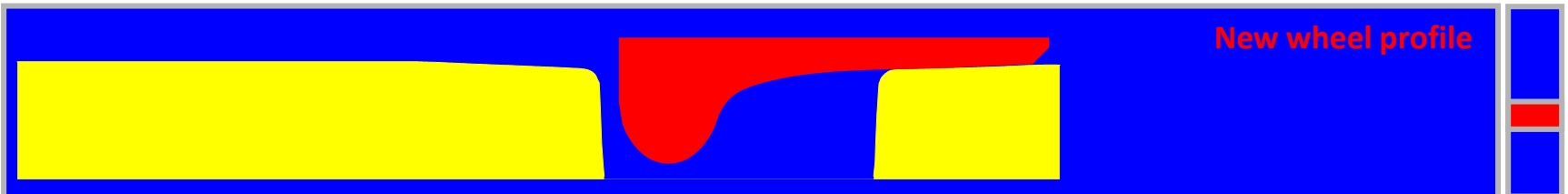
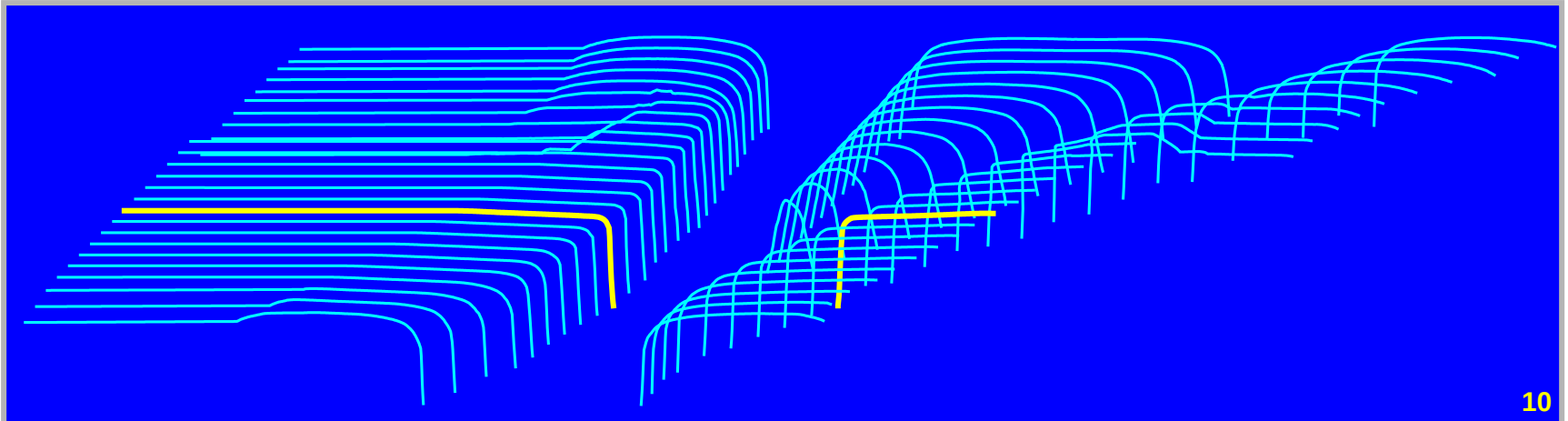
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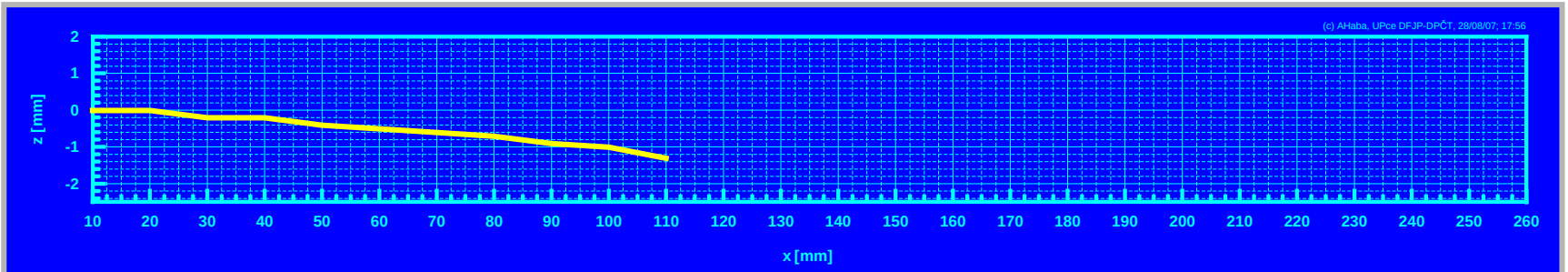
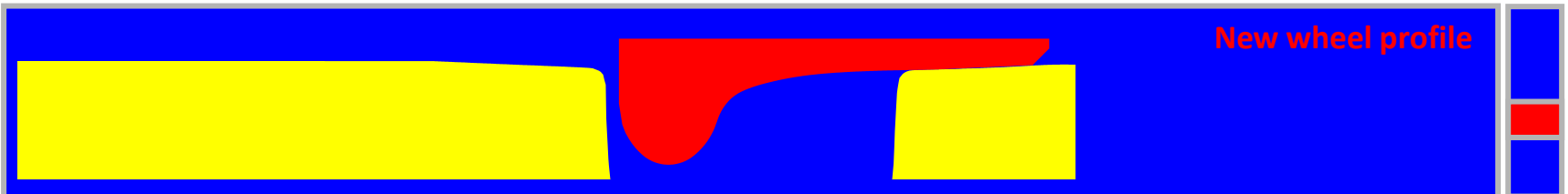
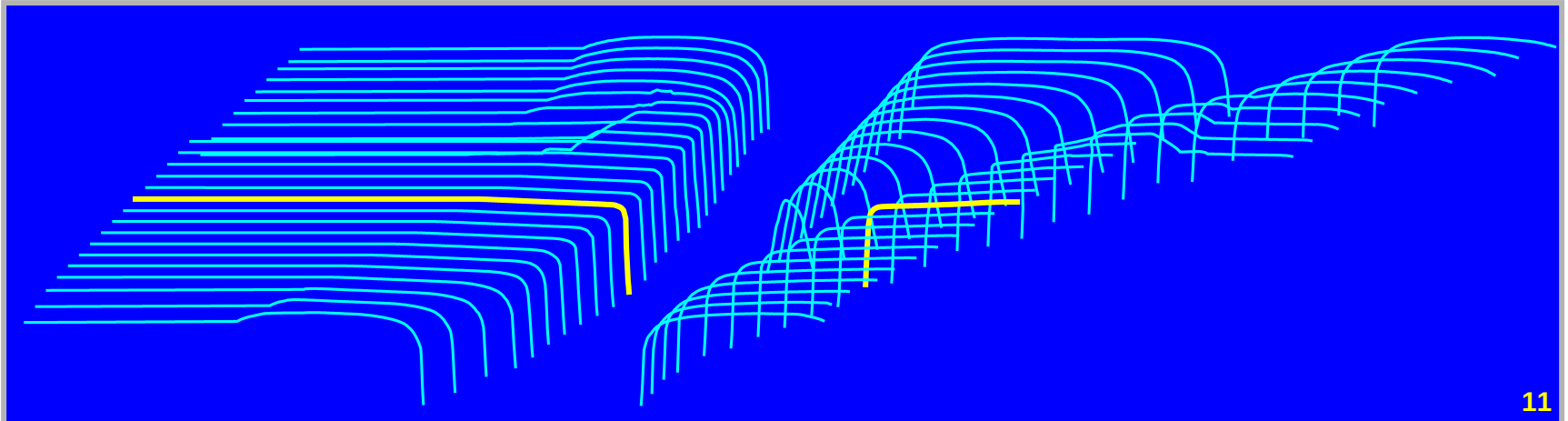
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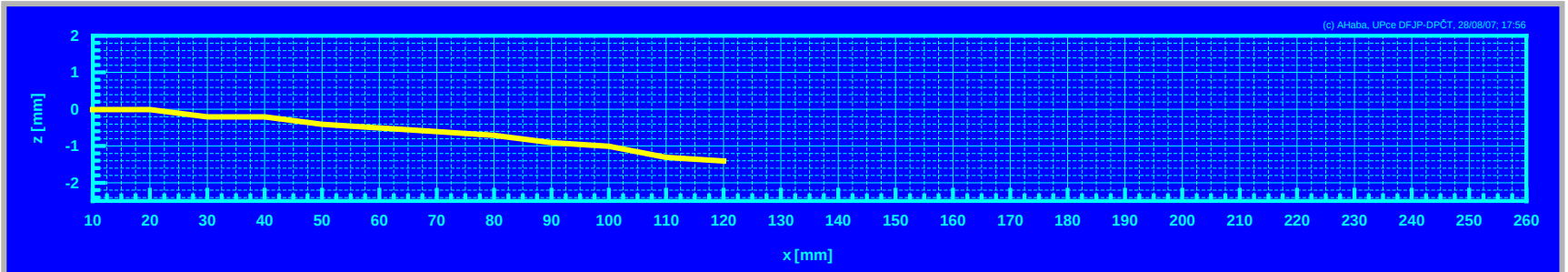
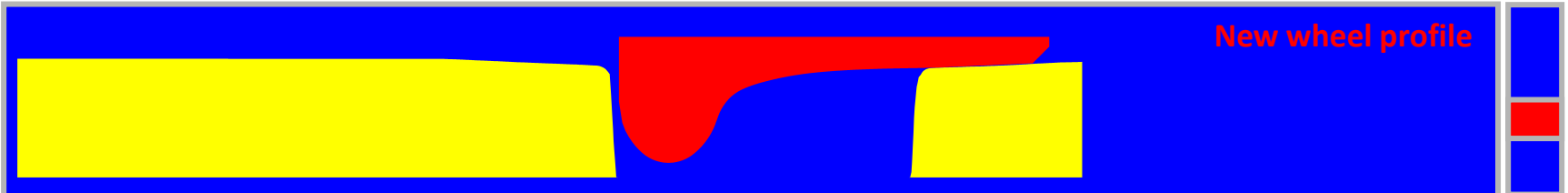
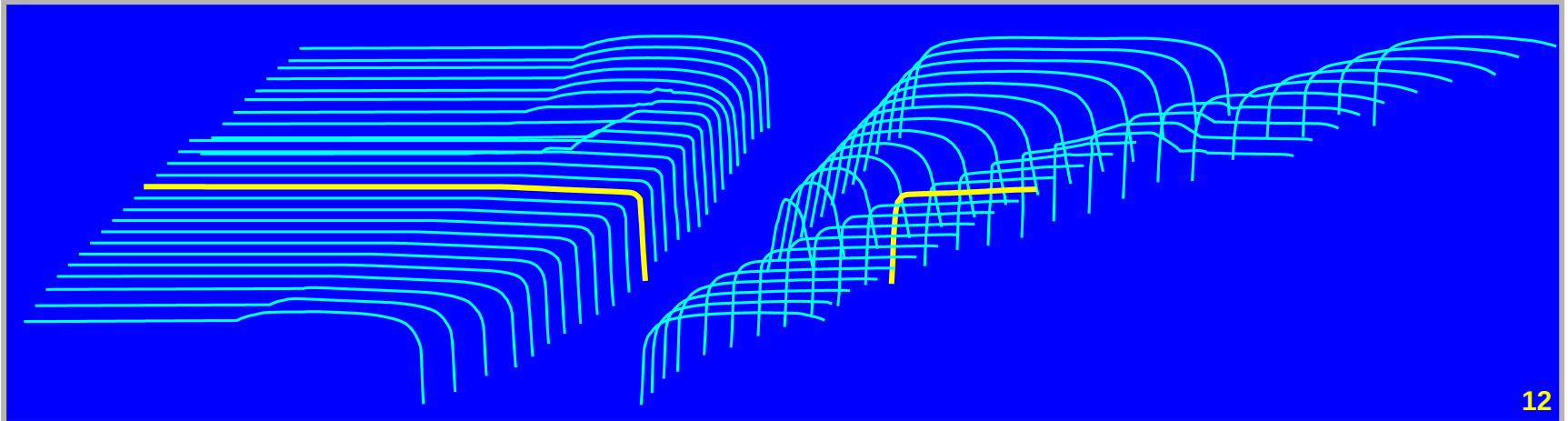
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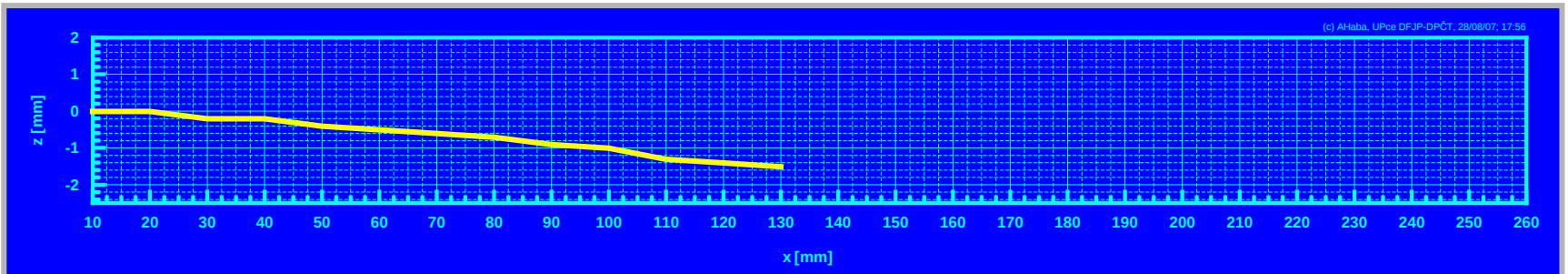
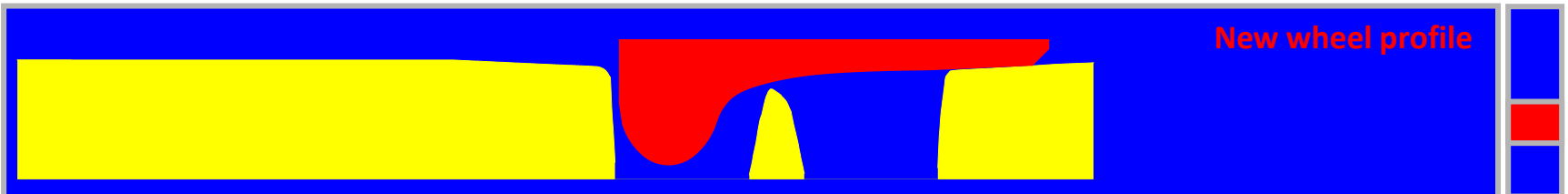
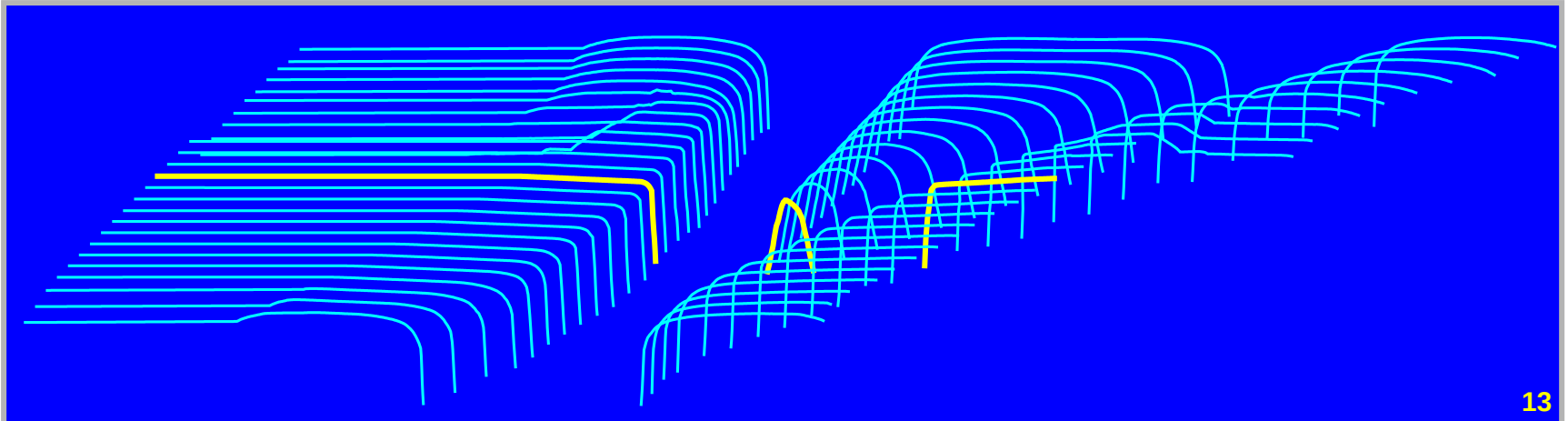
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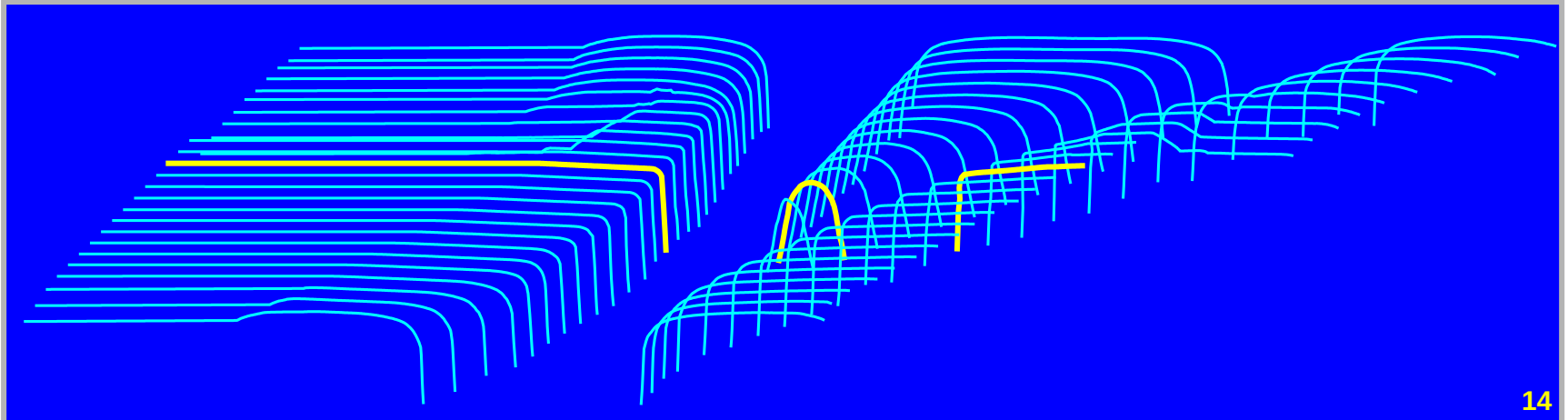
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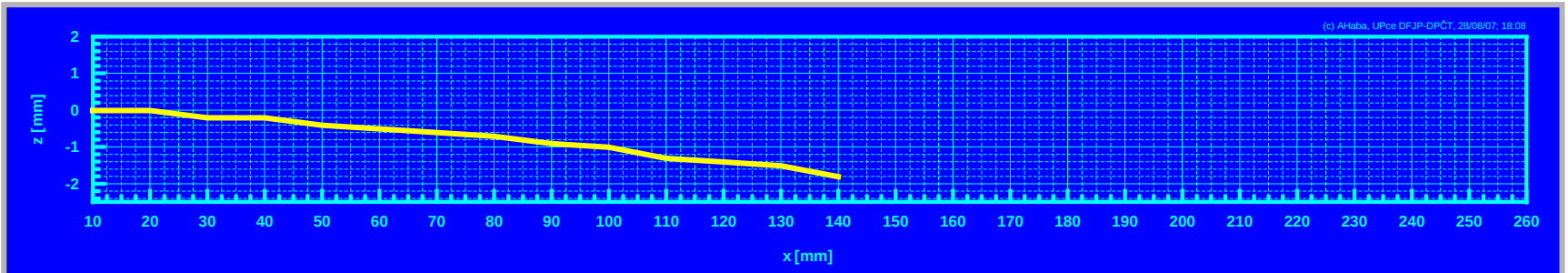
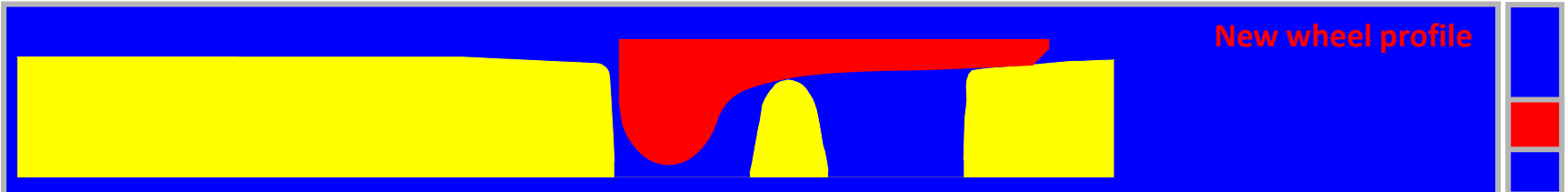
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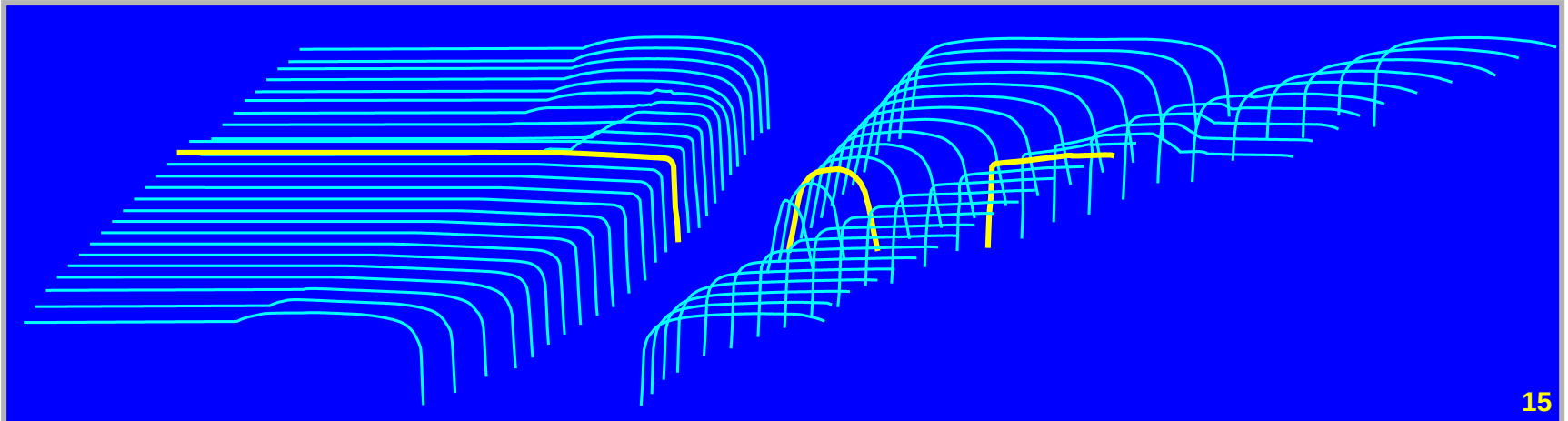
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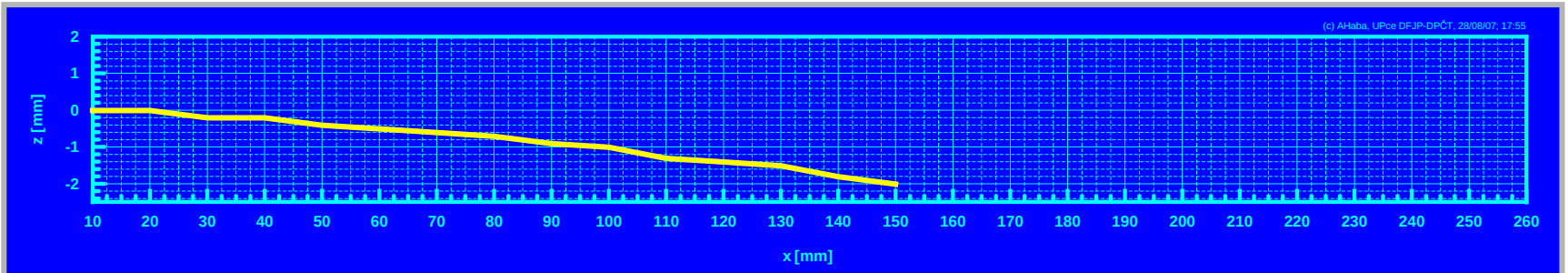
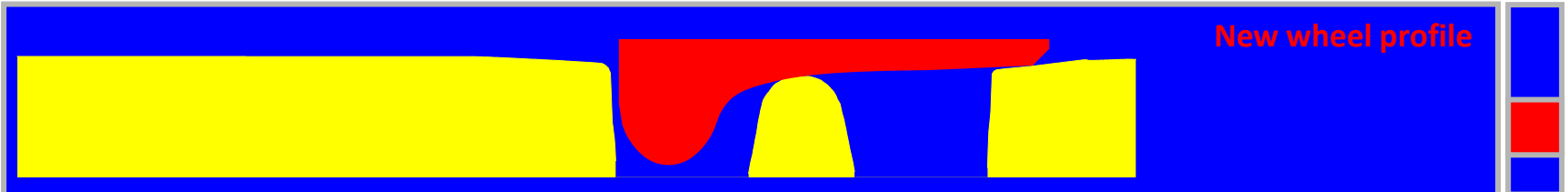
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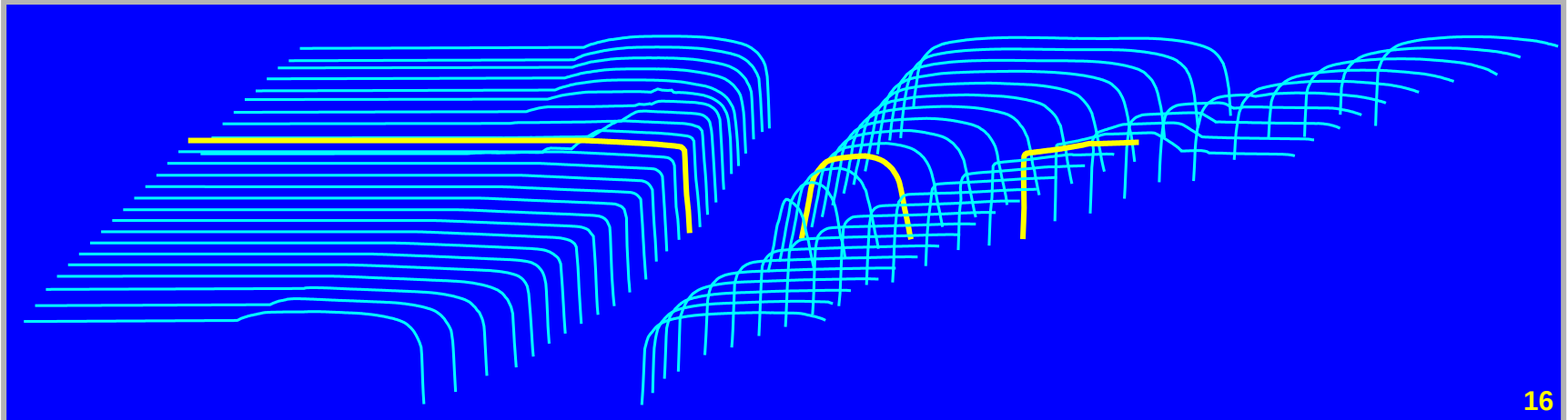
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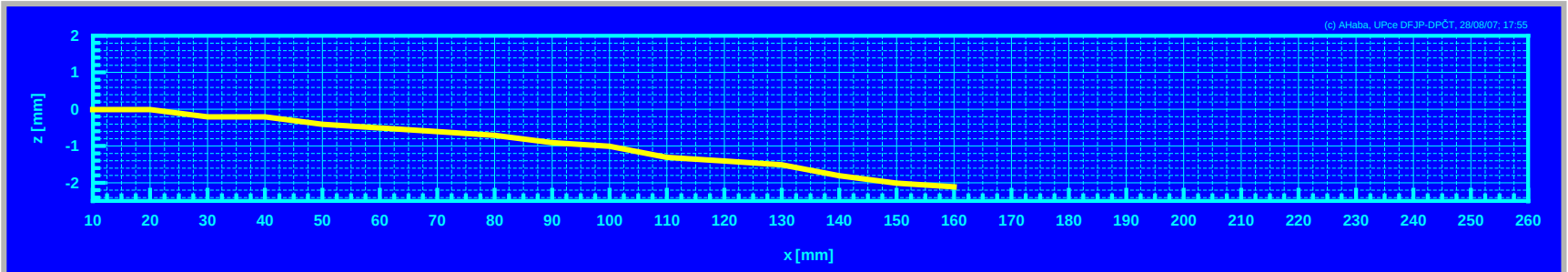
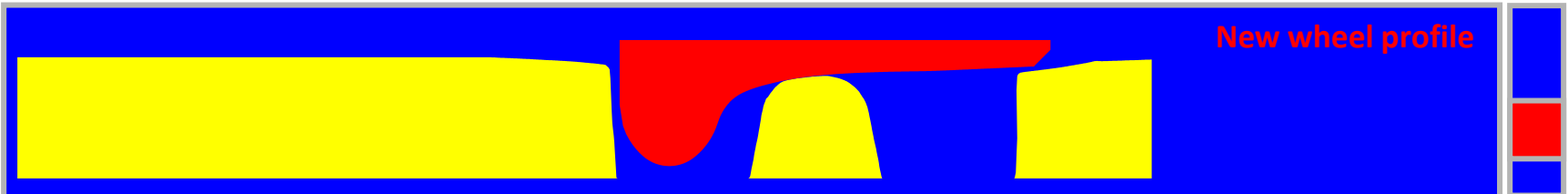
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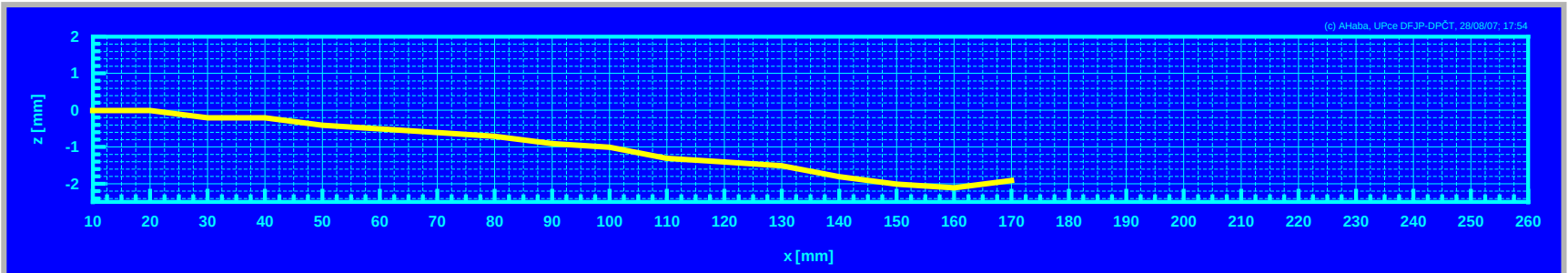
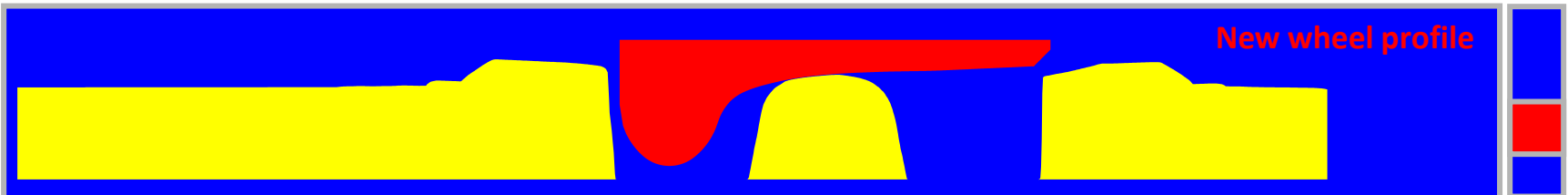
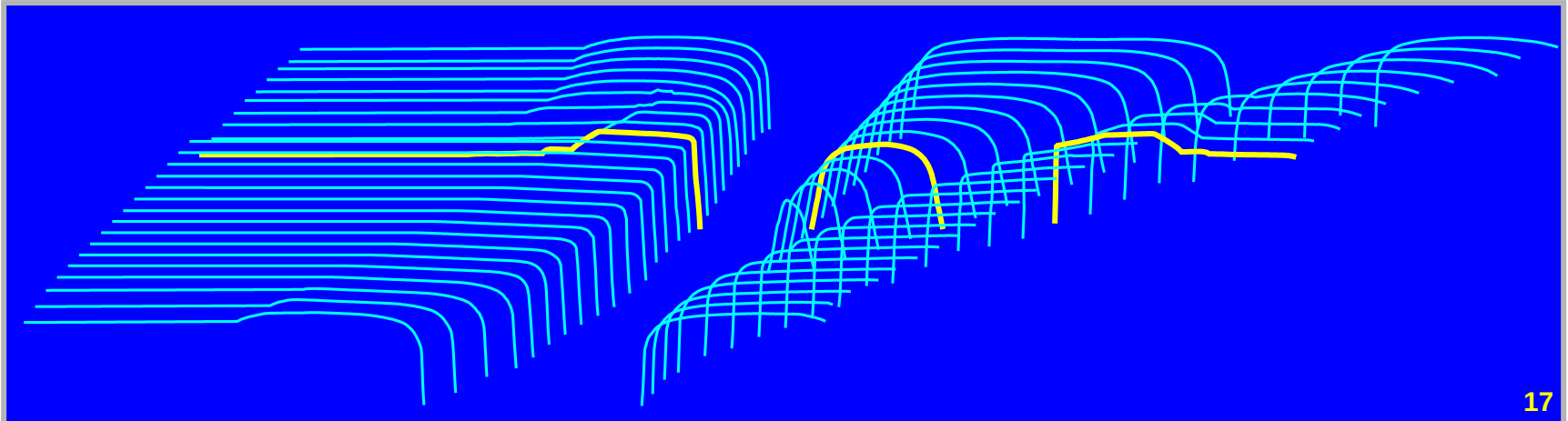
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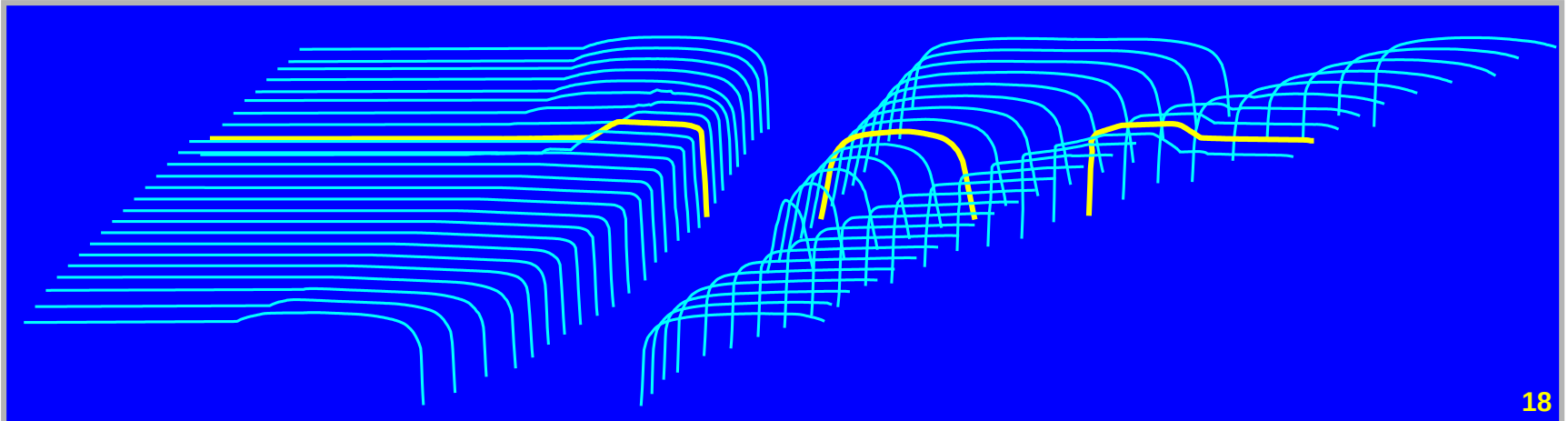
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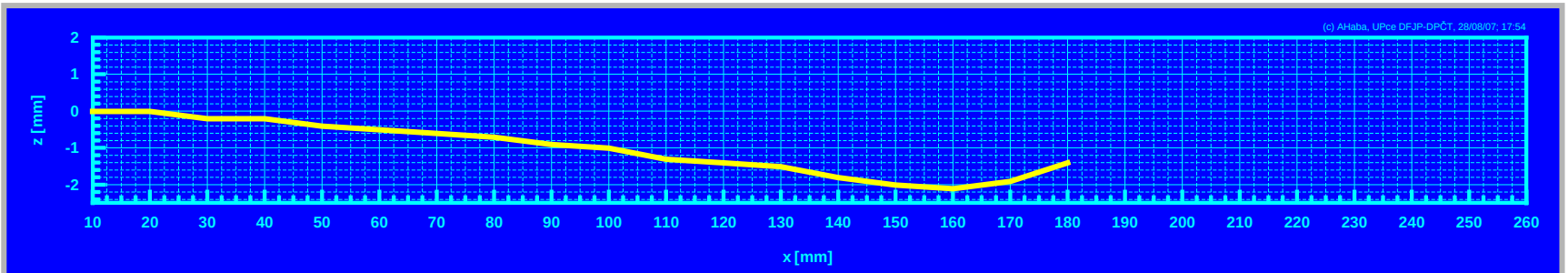
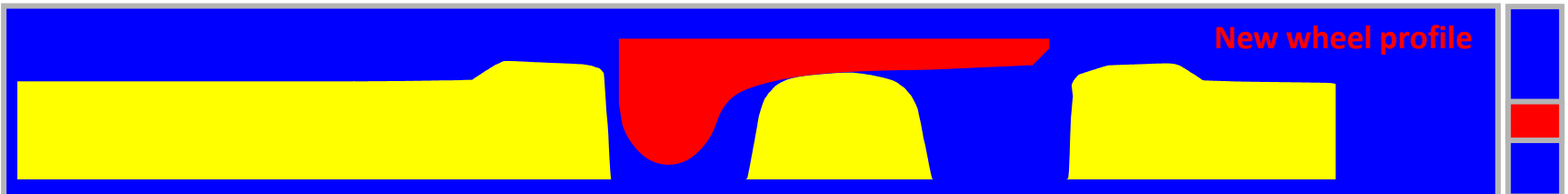
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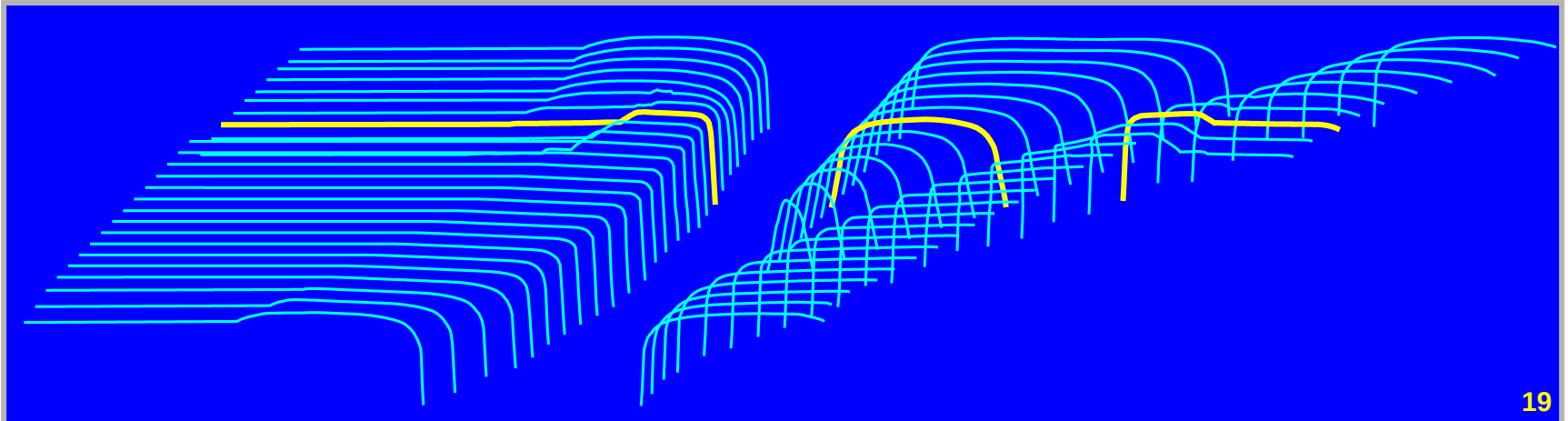
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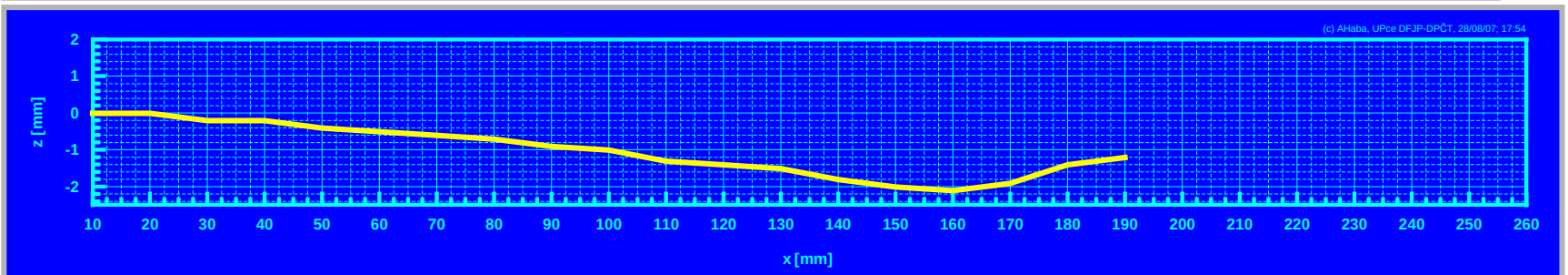
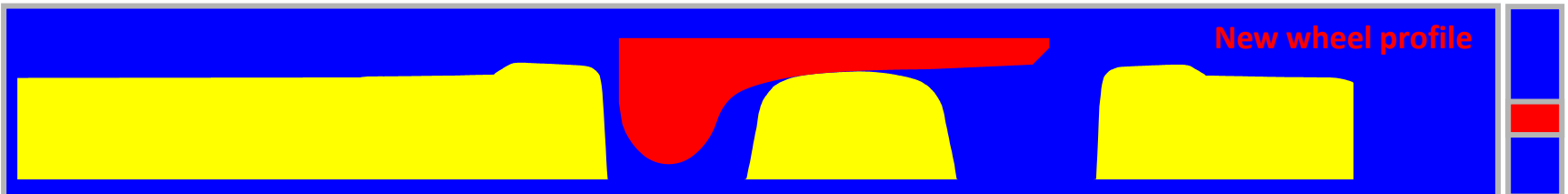
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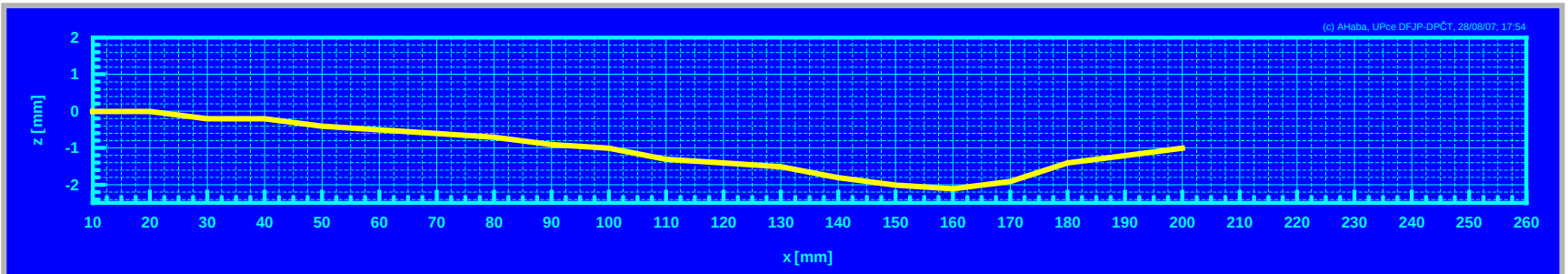
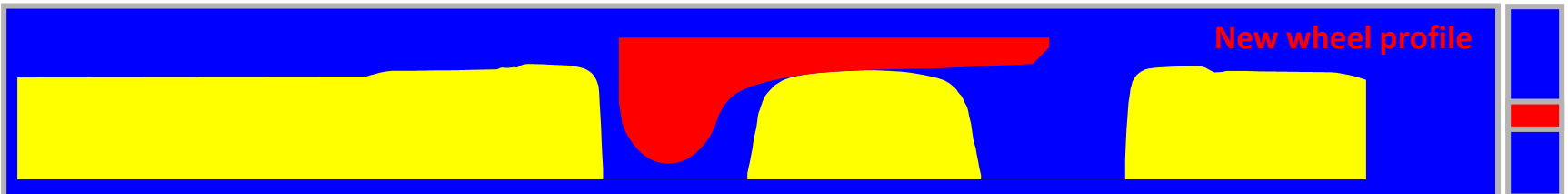
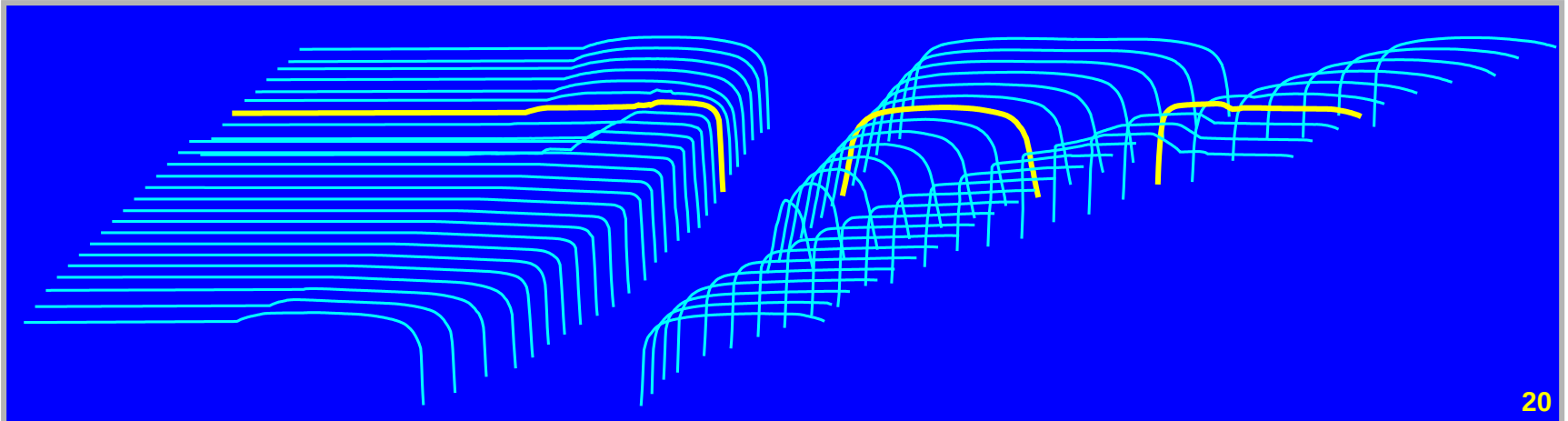
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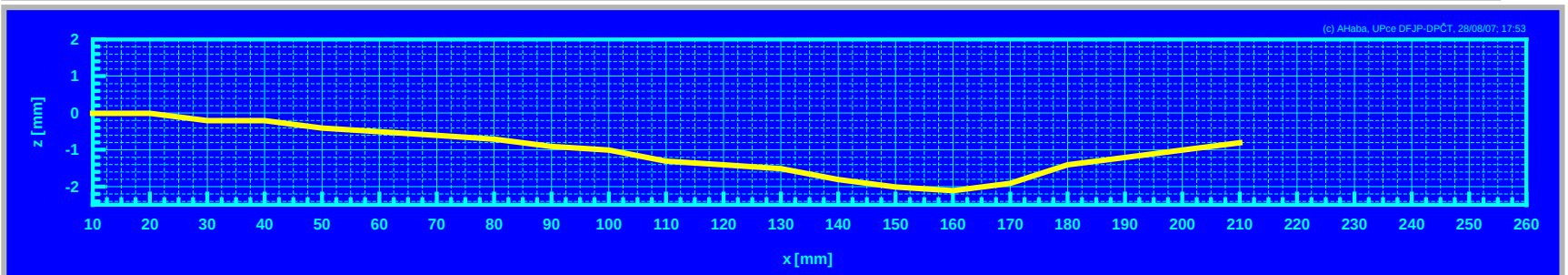
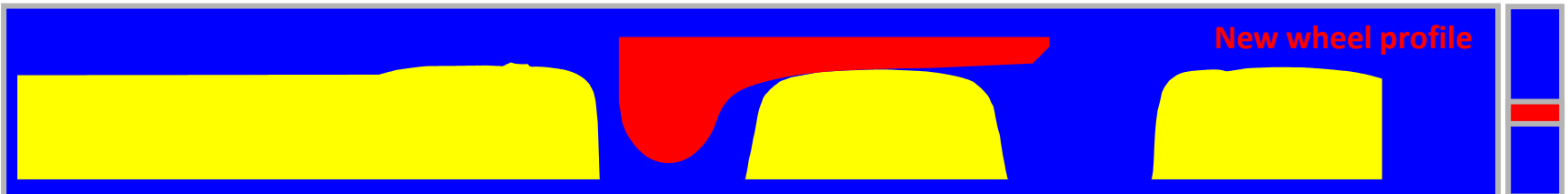
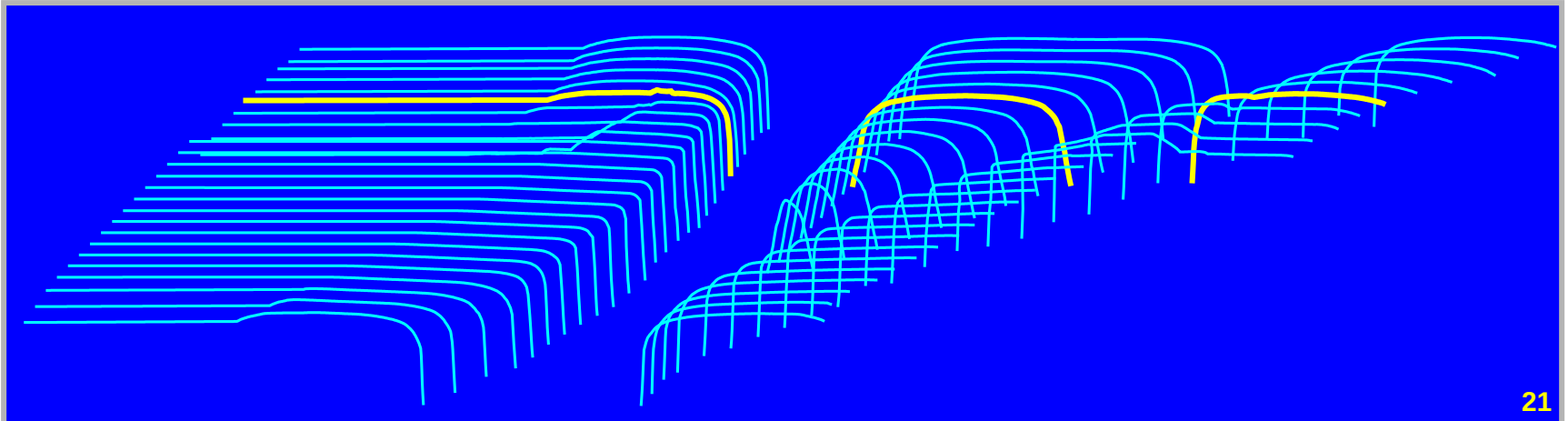
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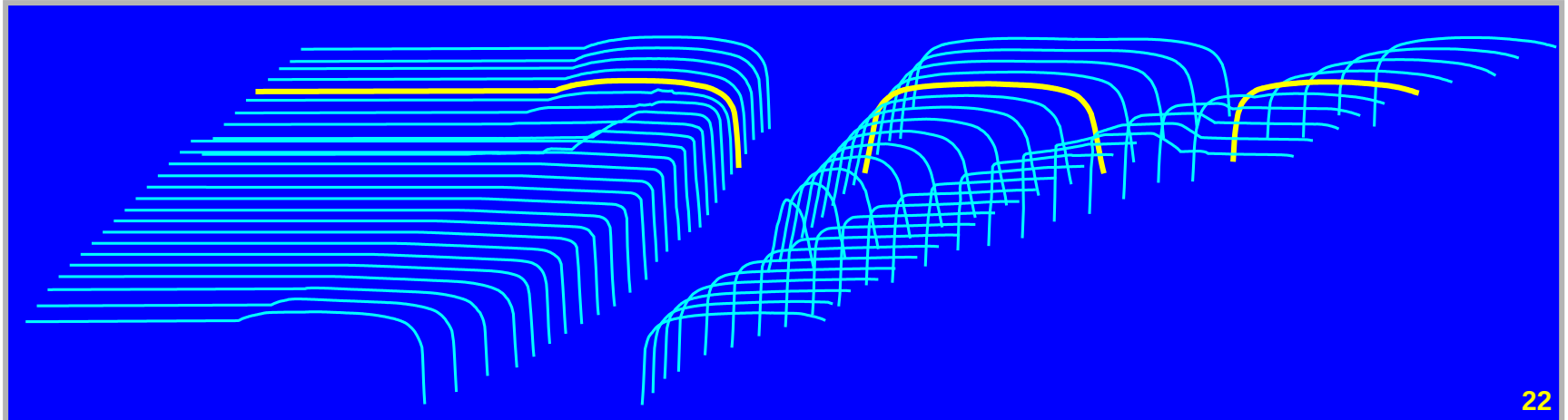
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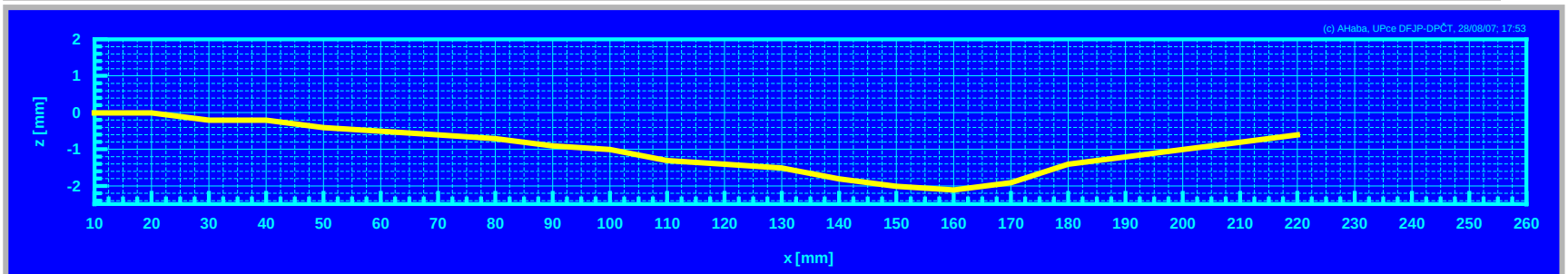
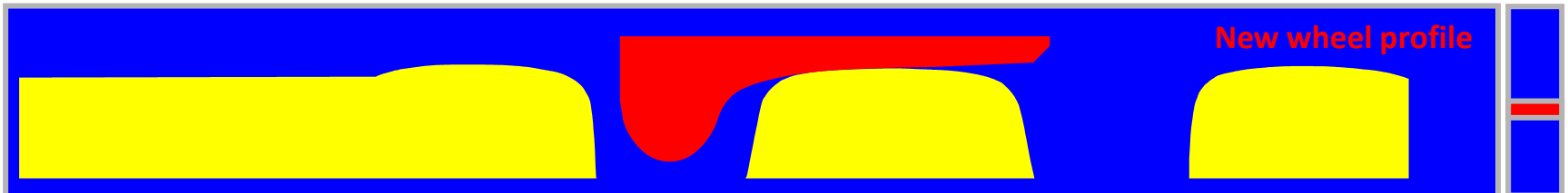
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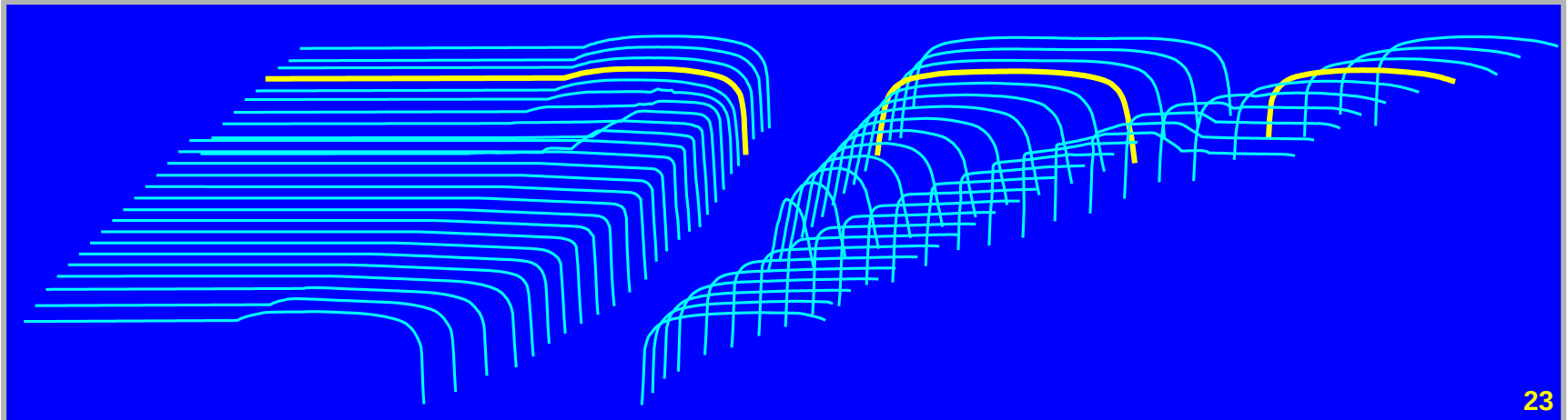
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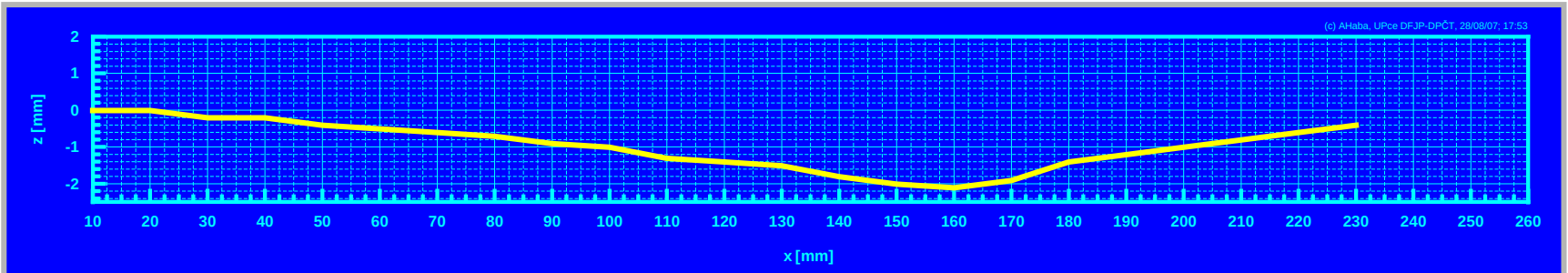
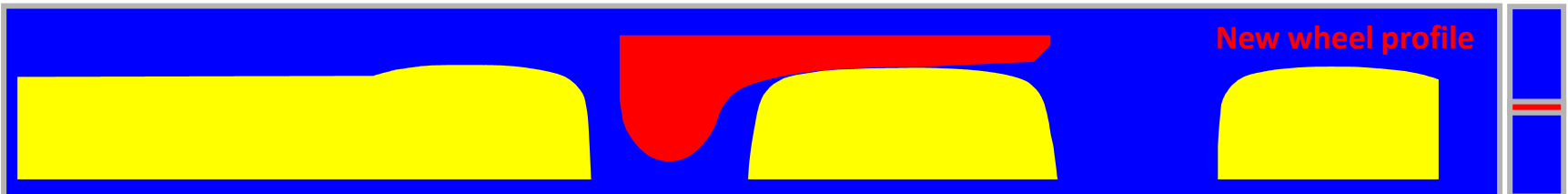
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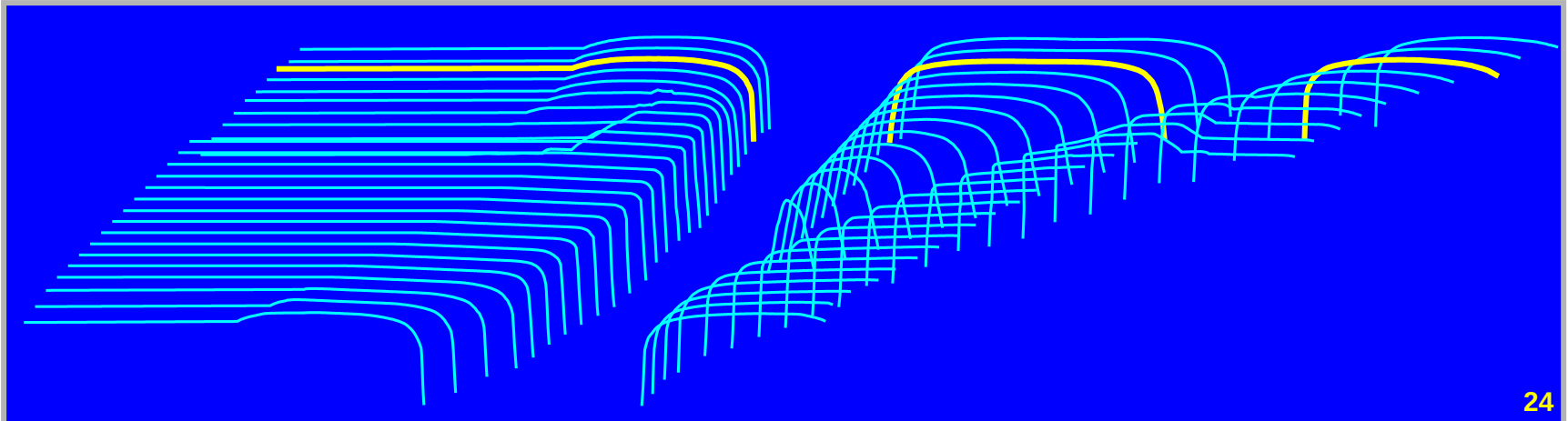
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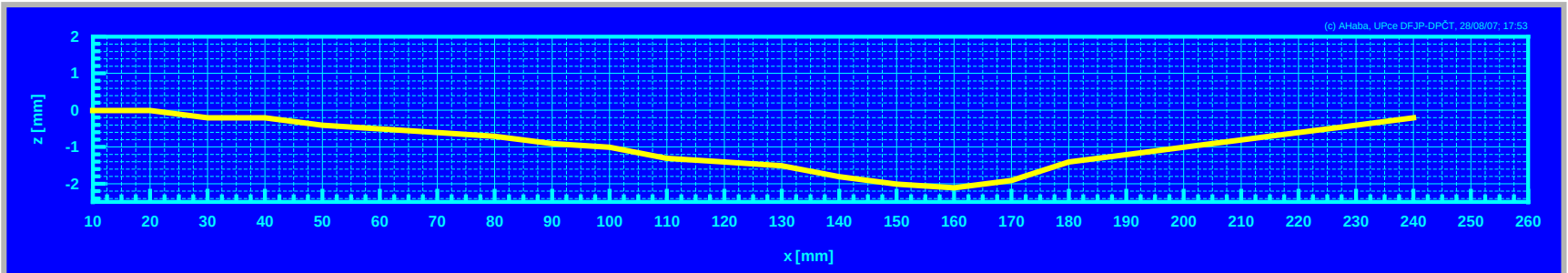
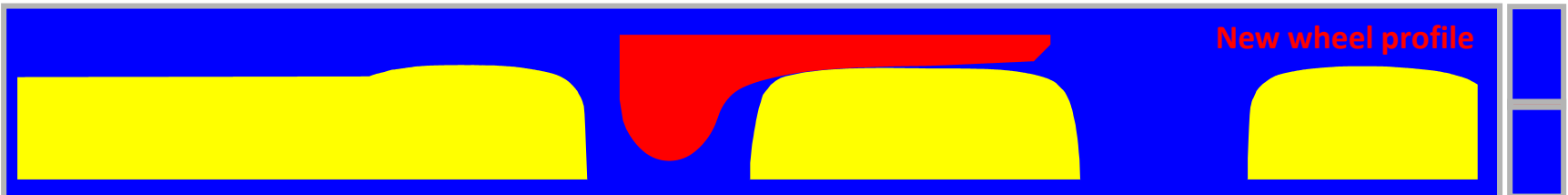
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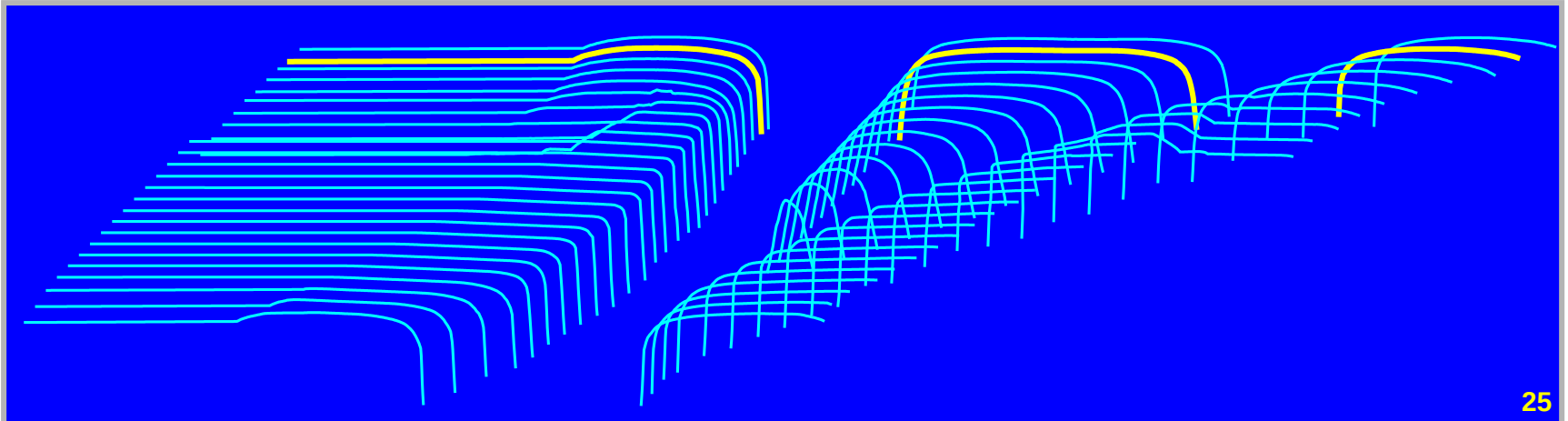
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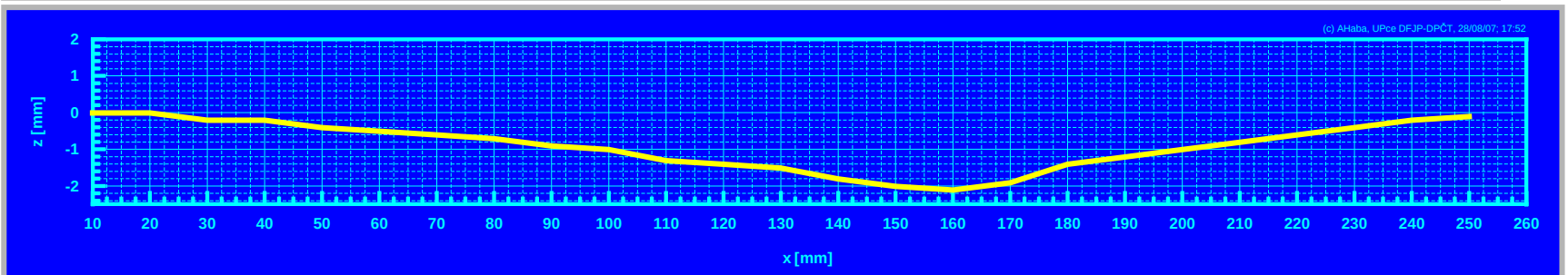
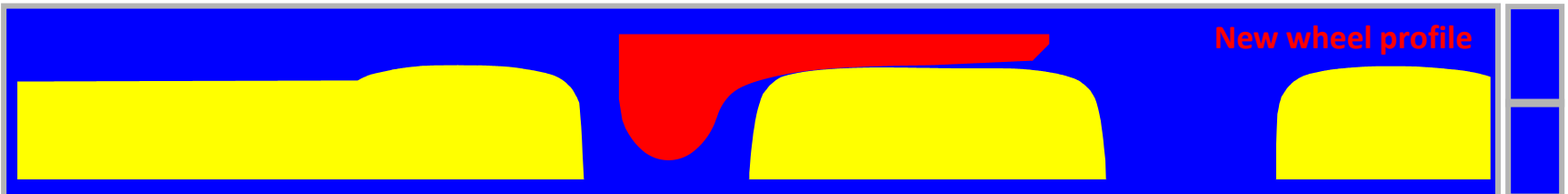
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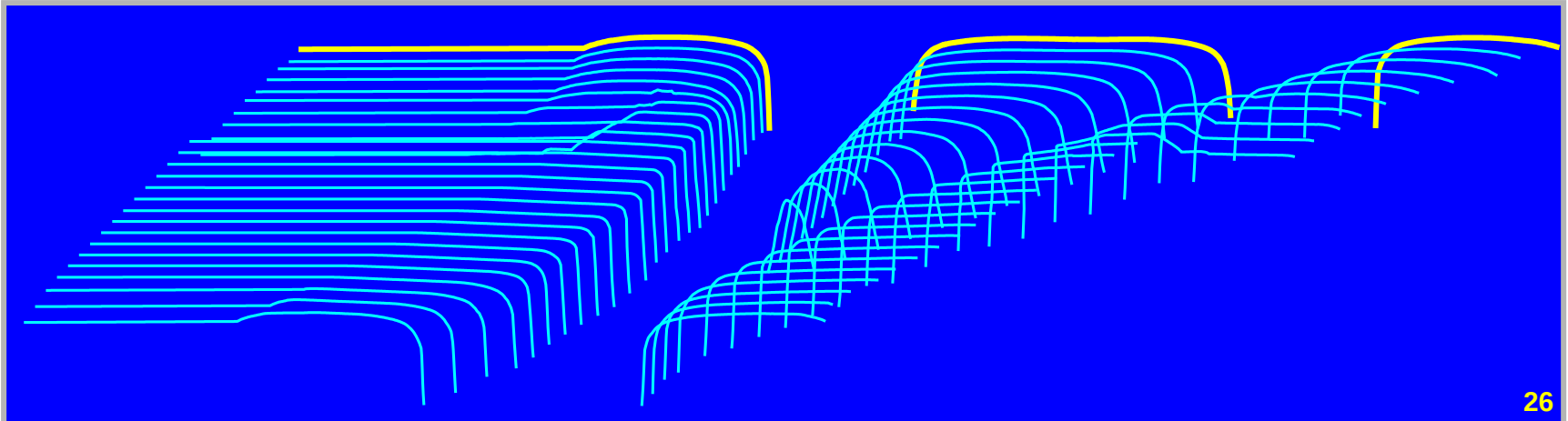
PASSING OF WHEELSET OVER FROG AREA



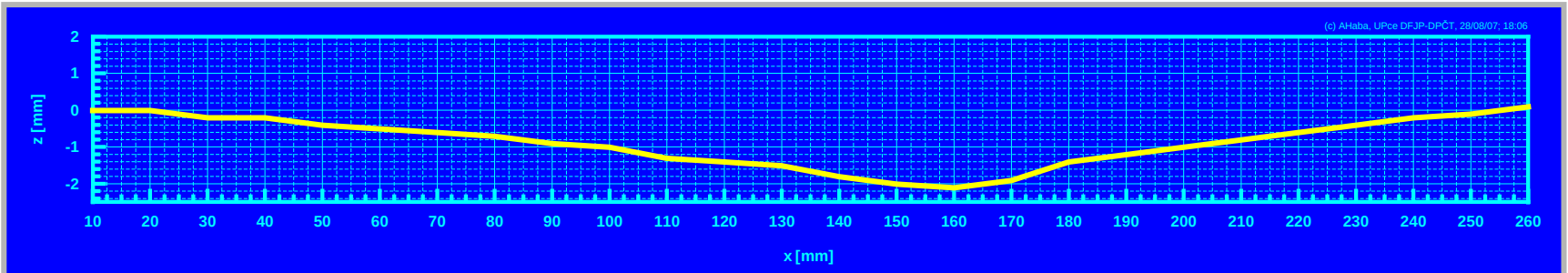
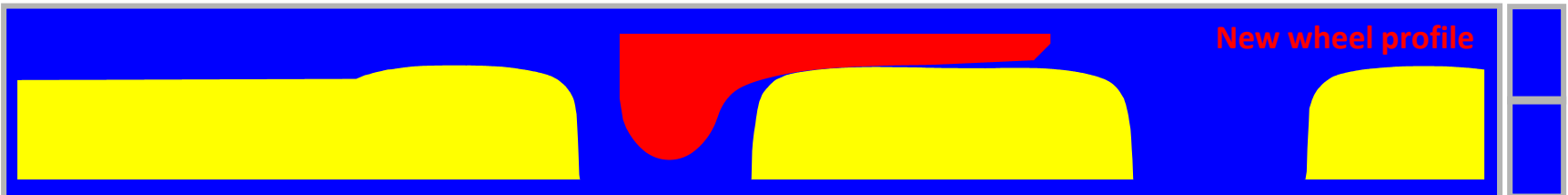
25



PASSING OF WHEELSET OVER FROG AREA

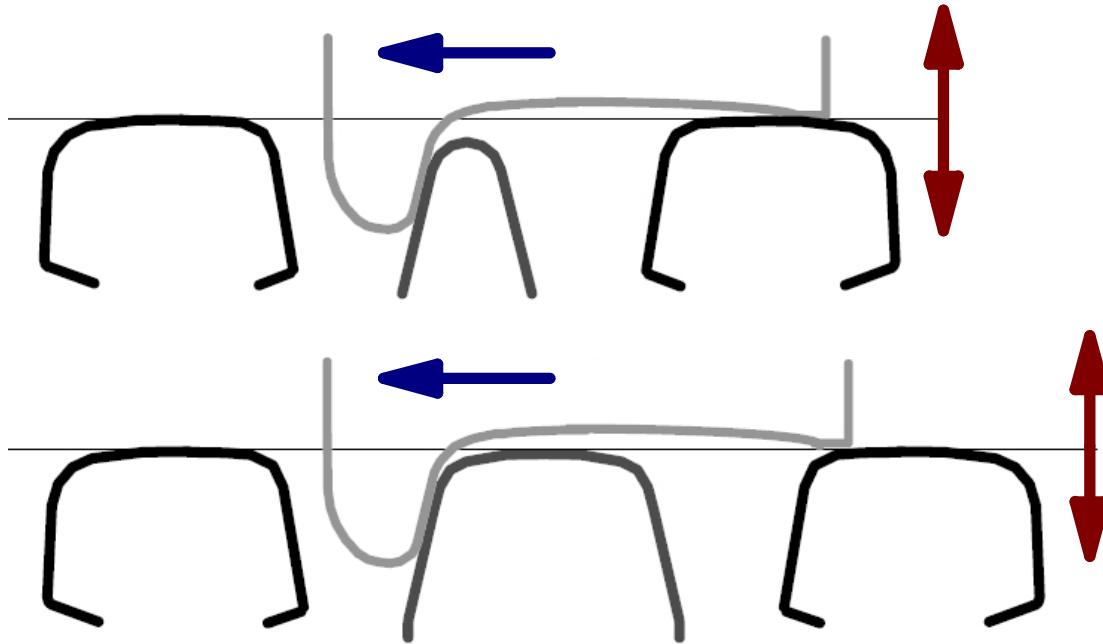


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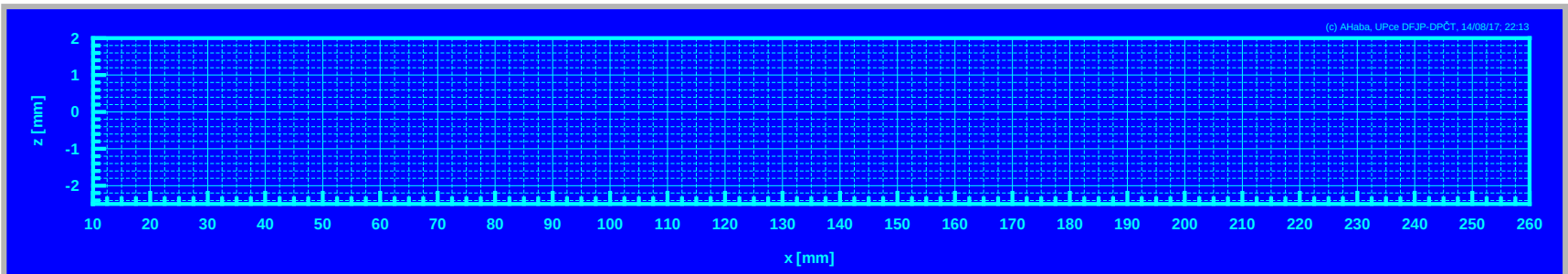
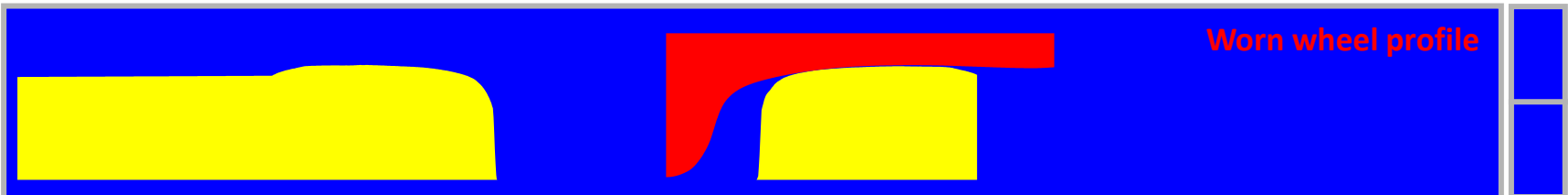
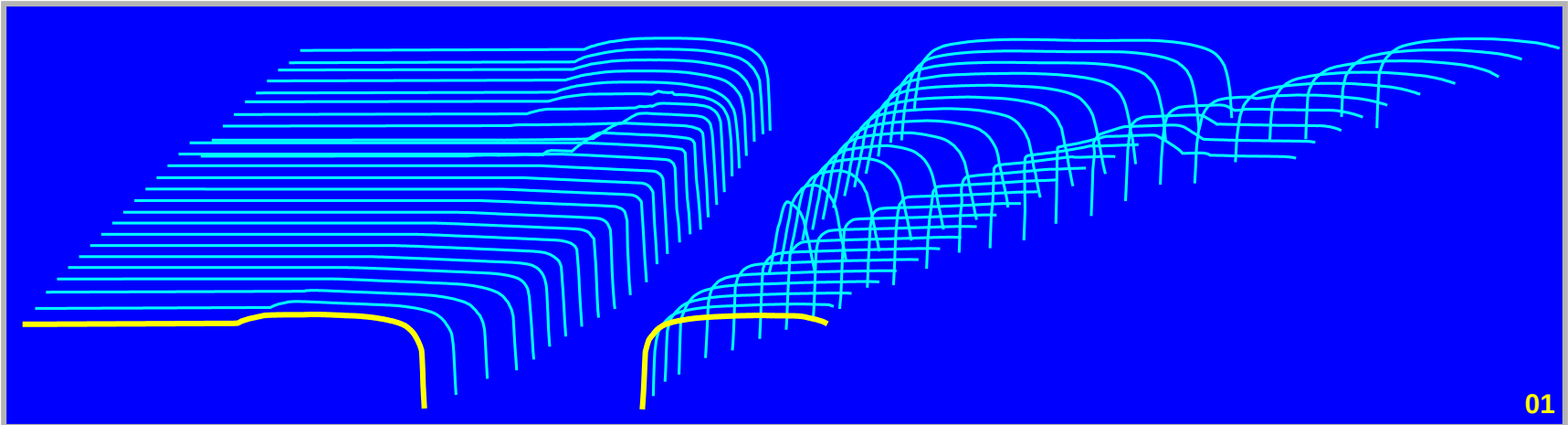


PASSING OF WHEELSET OVER FROG AREA

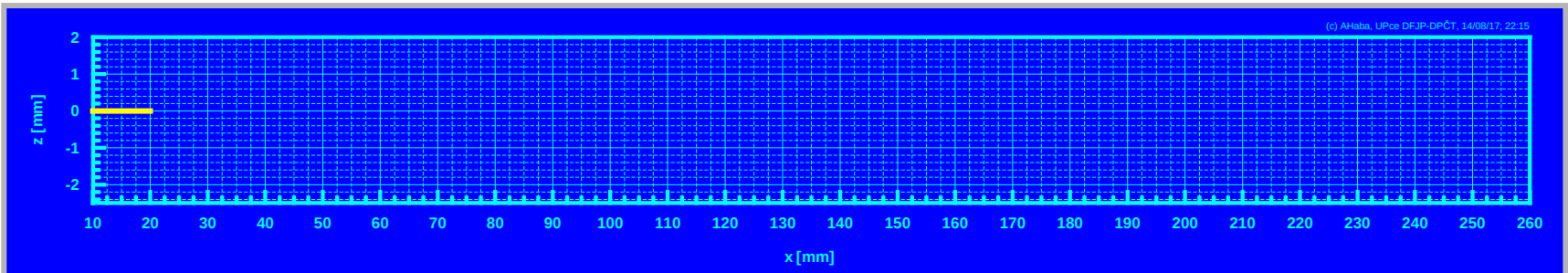
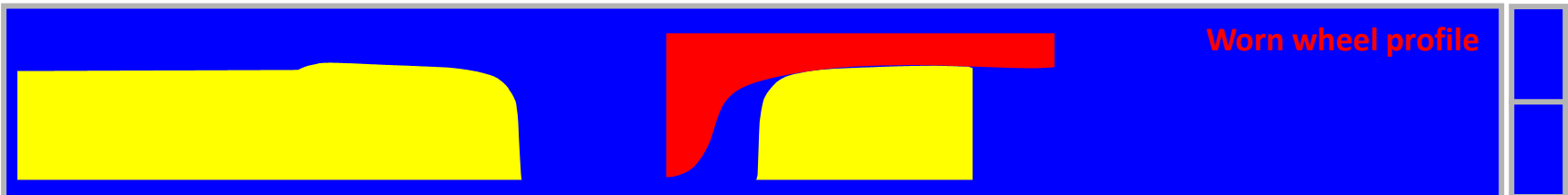
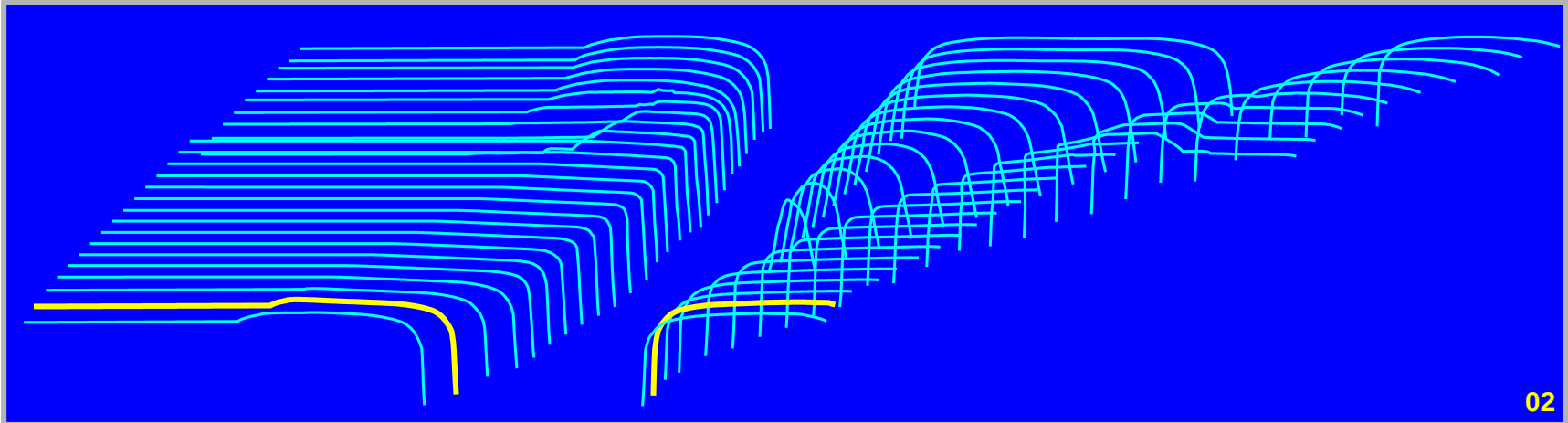
- **worn** wheel profile -



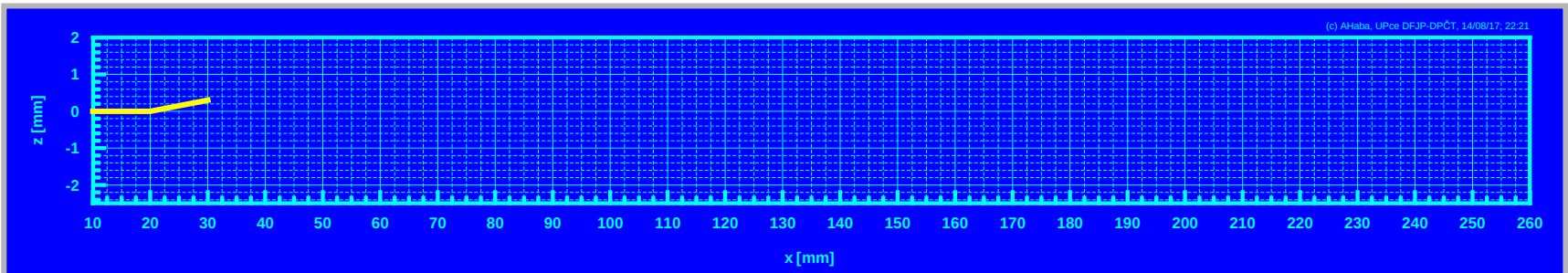
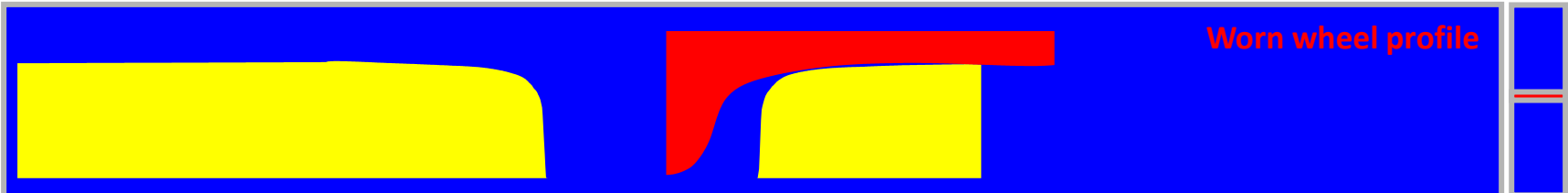
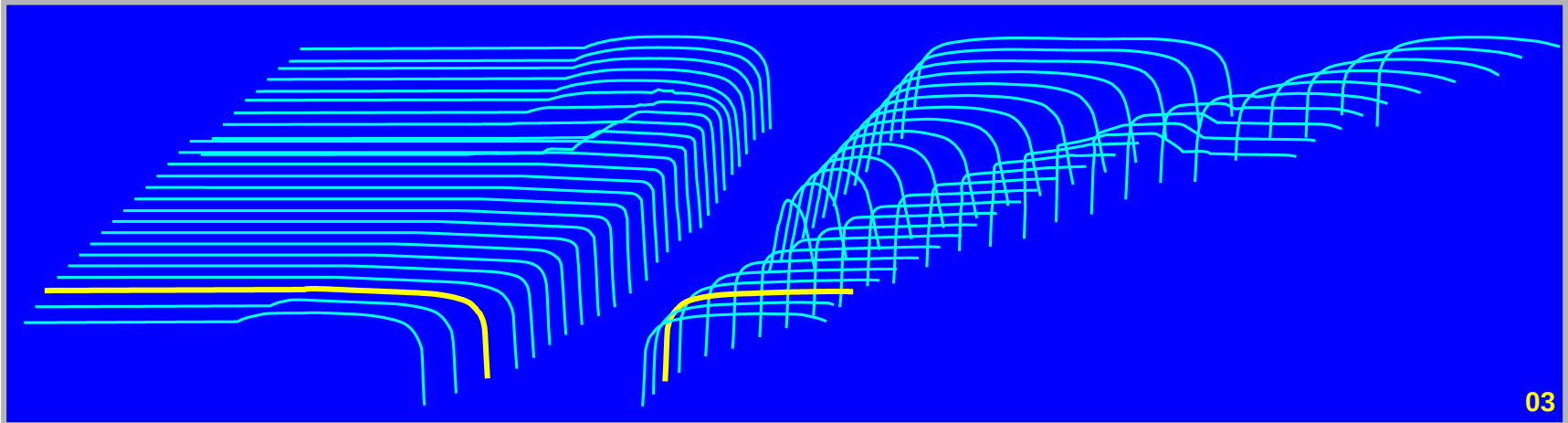
PASSING OF WHEELSET OVER FROG AREA



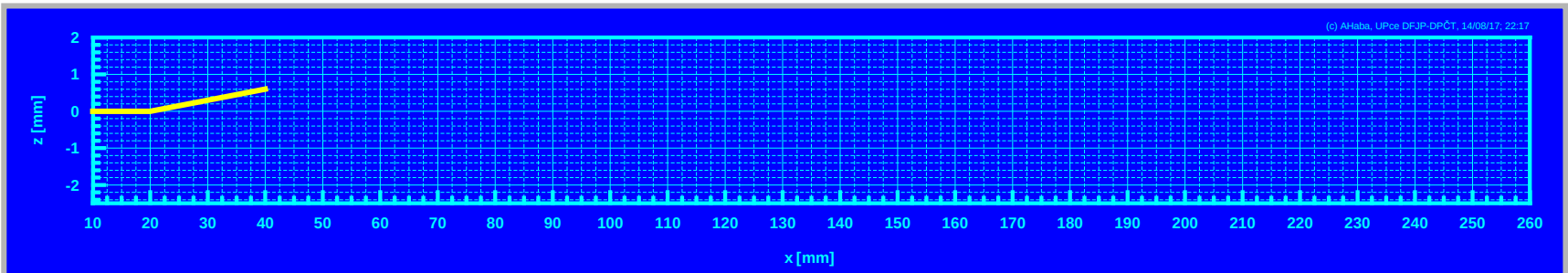
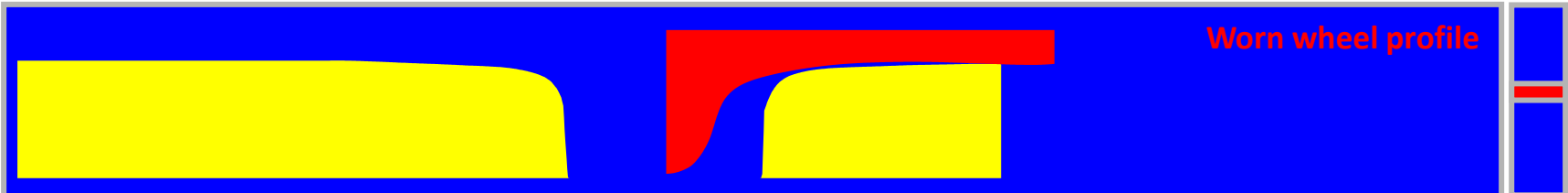
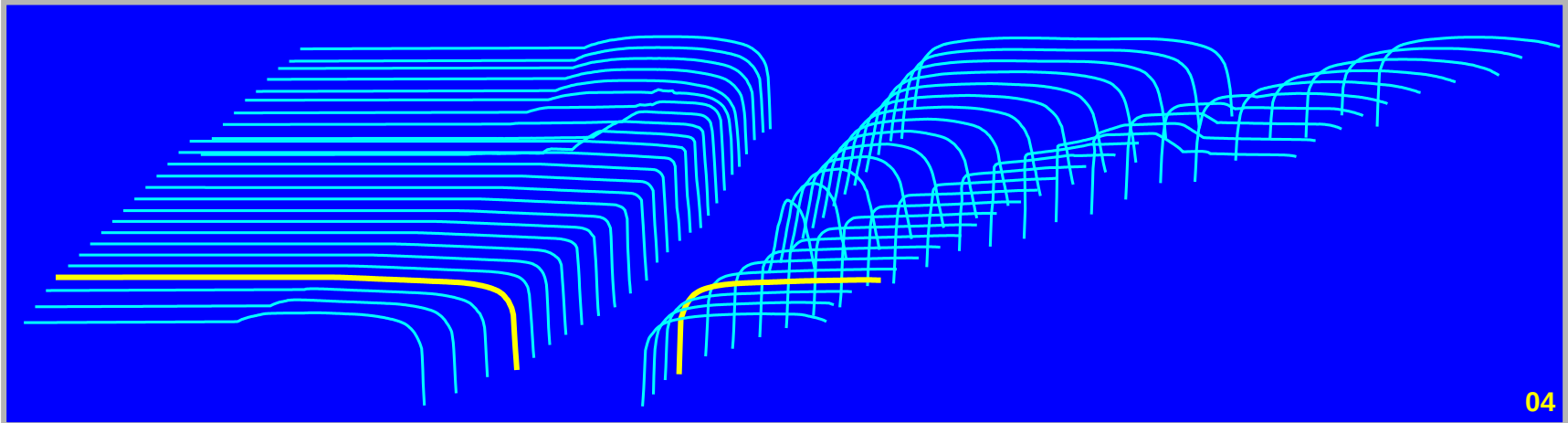
PASSING OF WHEELSET OVER FROG AREA



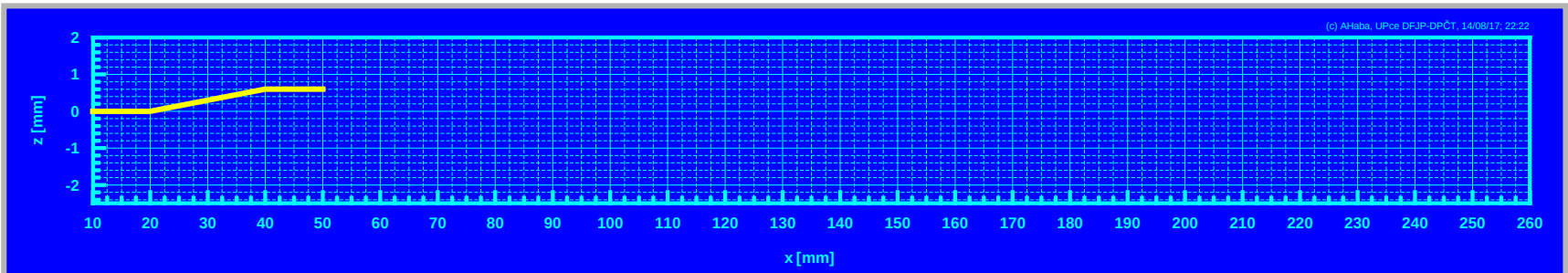
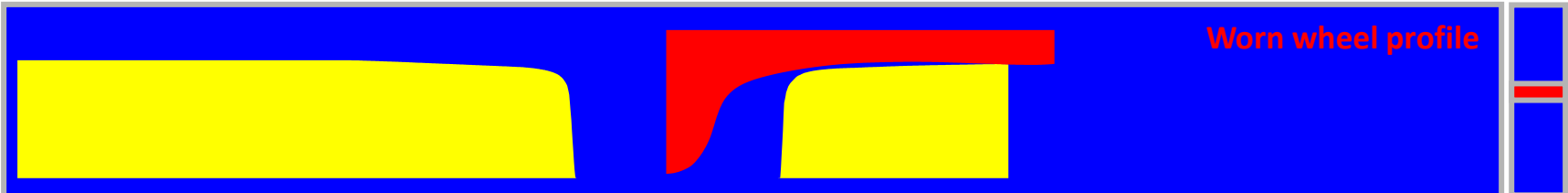
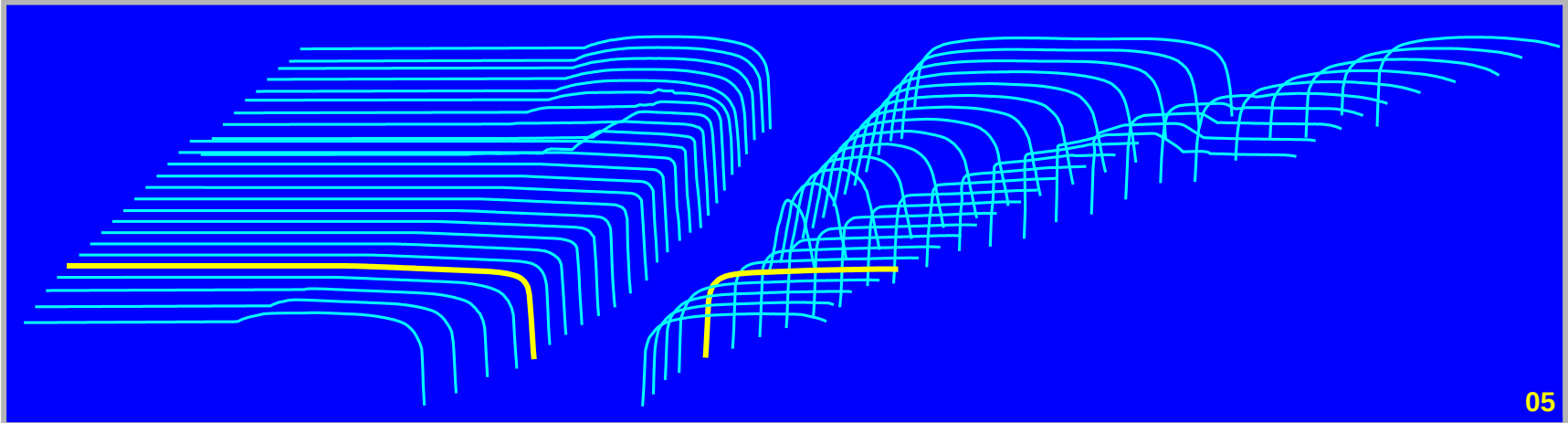
PASSING OF WHEELSET OVER FROG AREA



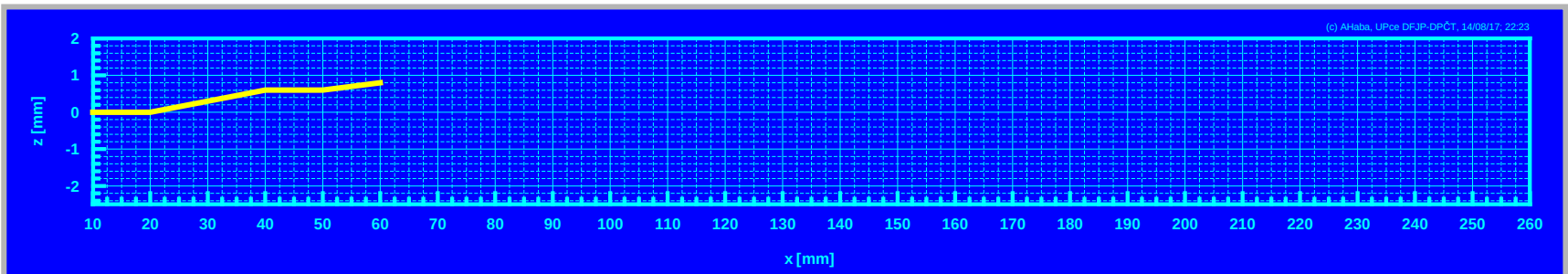
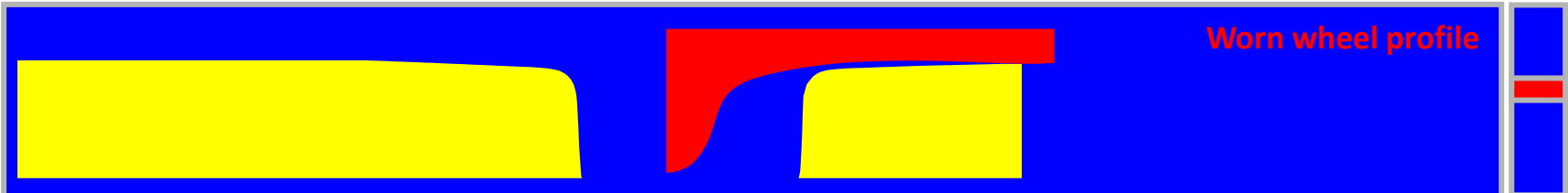
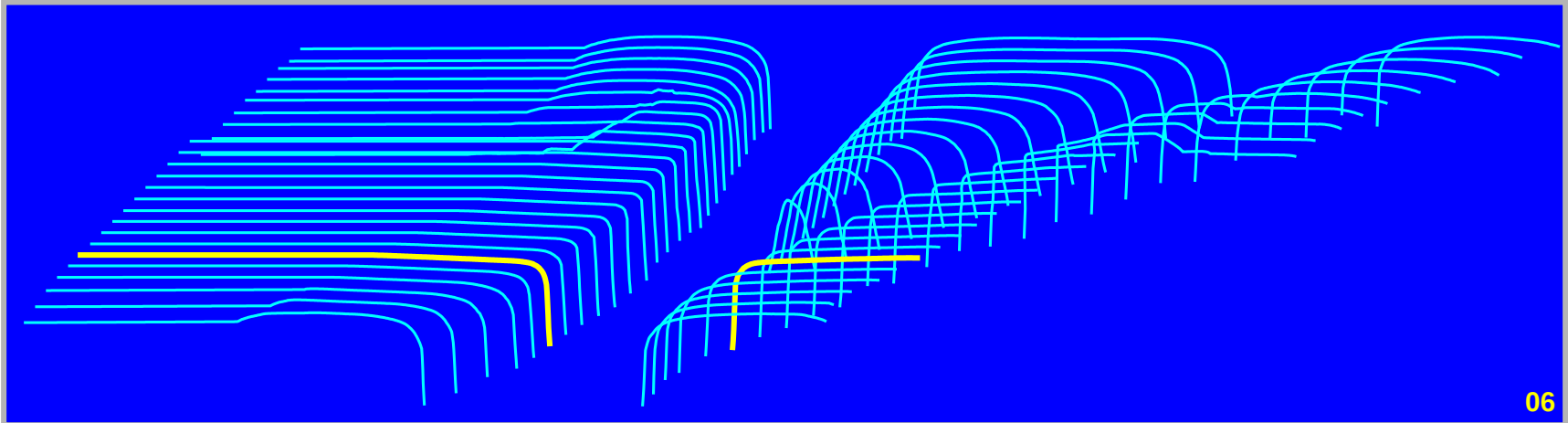
PASSING OF WHEELSET OVER FROG AREA



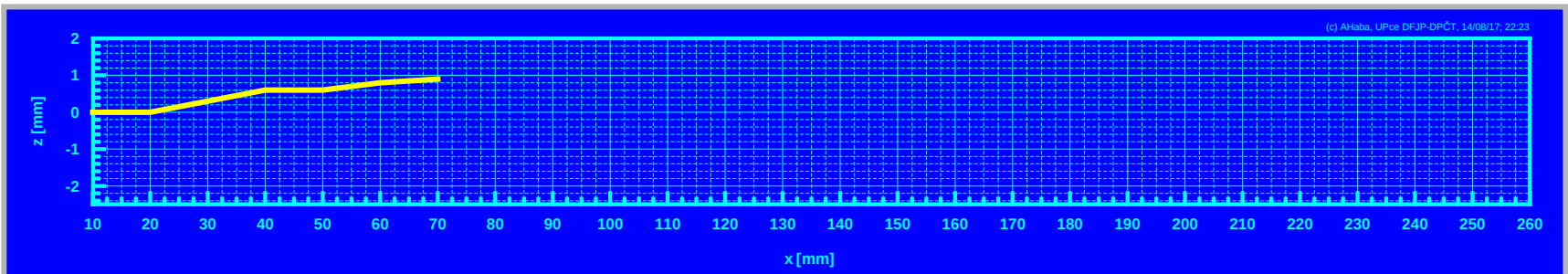
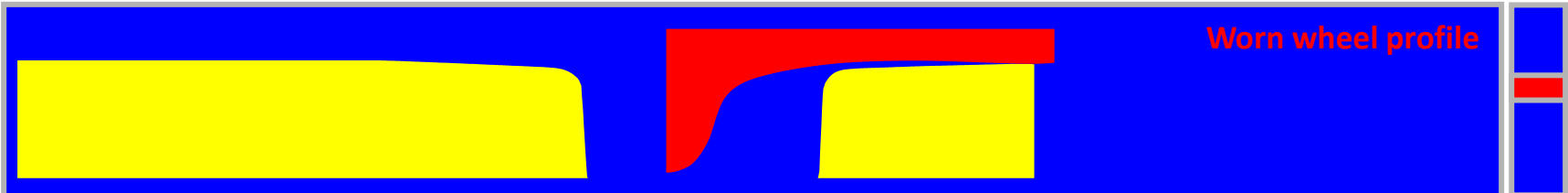
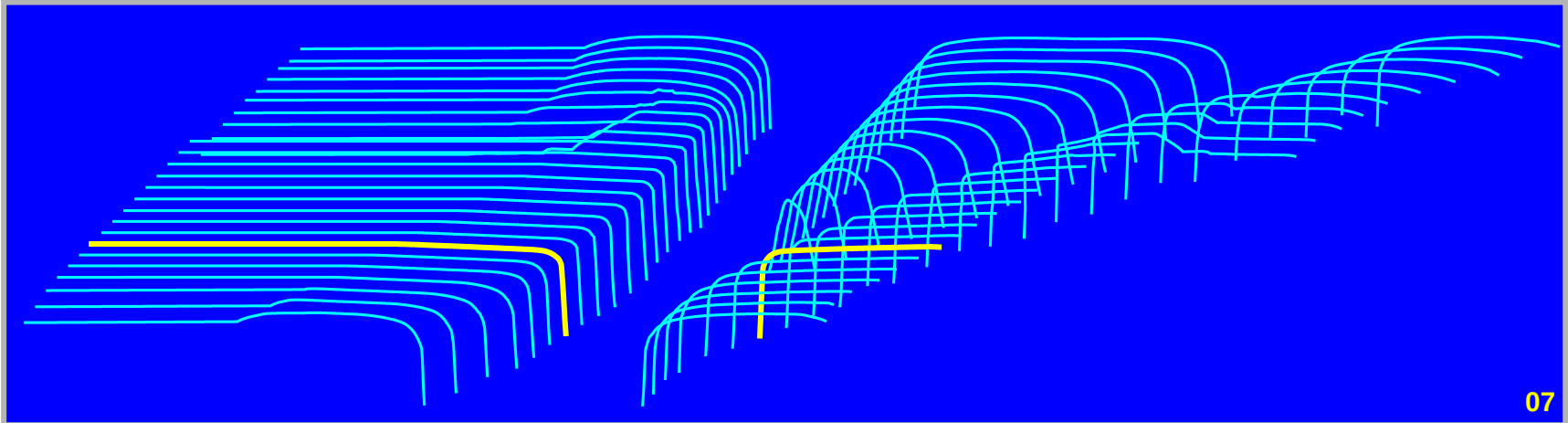
PASSING OF WHEELSET OVER FROG AREA



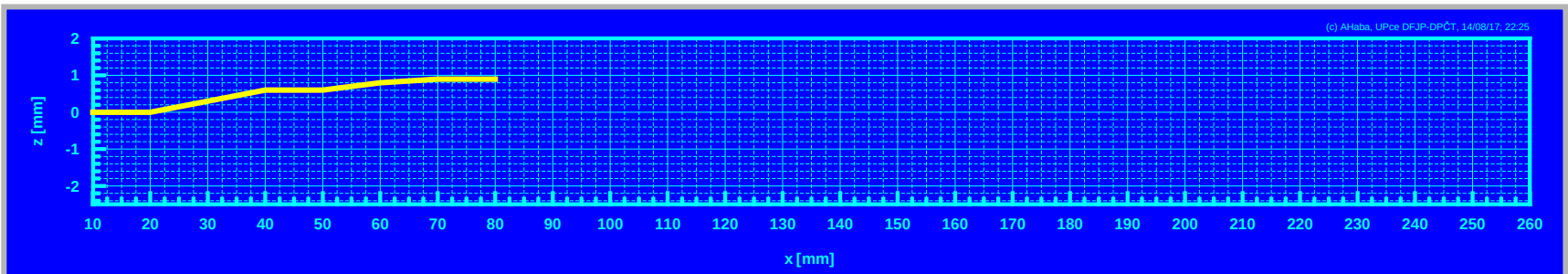
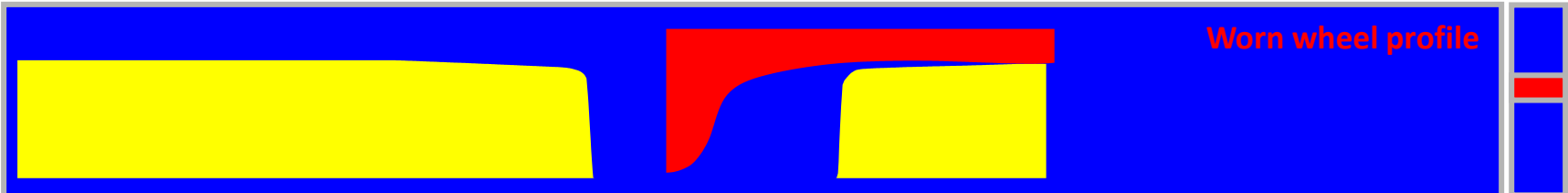
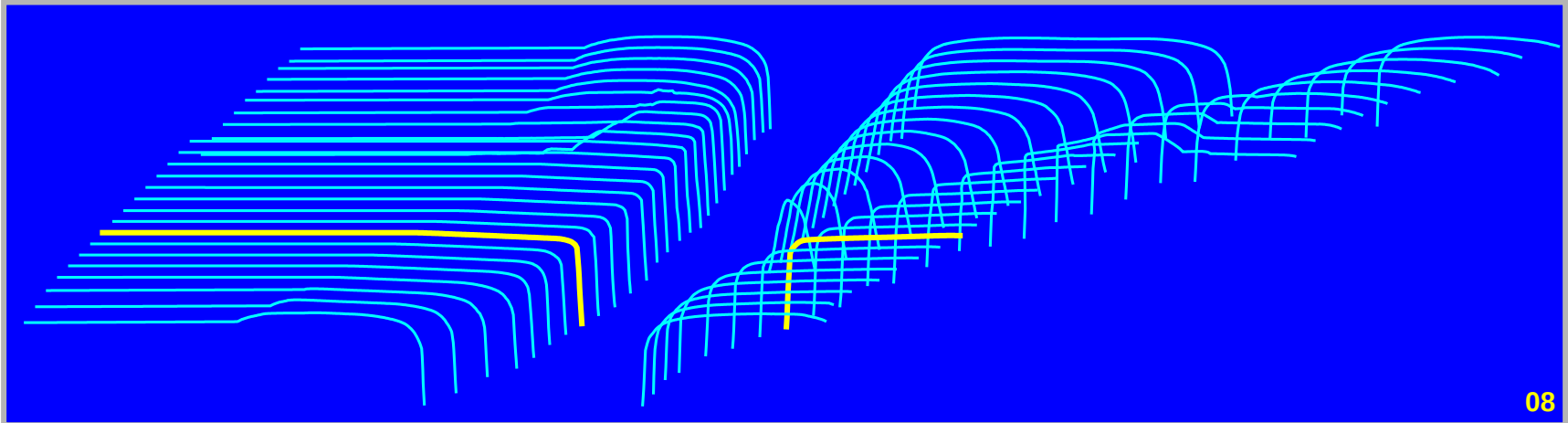
PASSING OF WHEELSET OVER FROG AREA



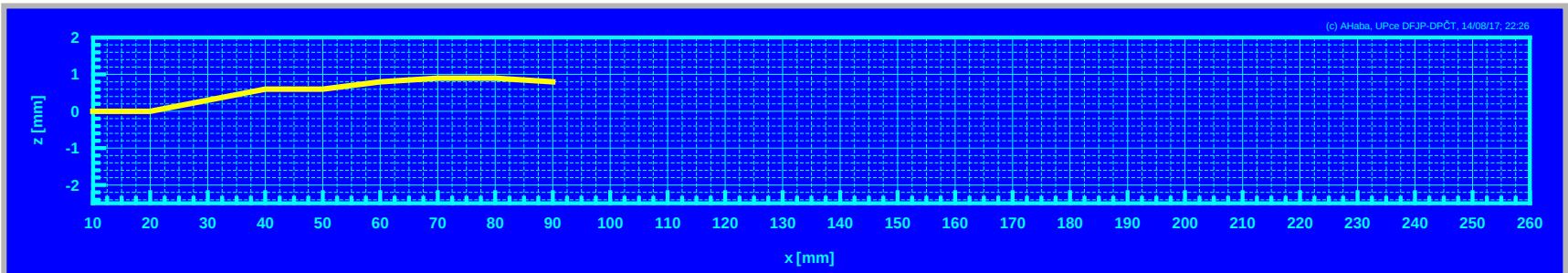
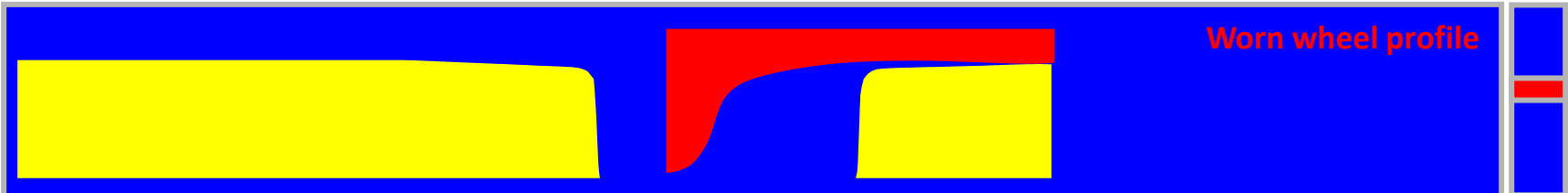
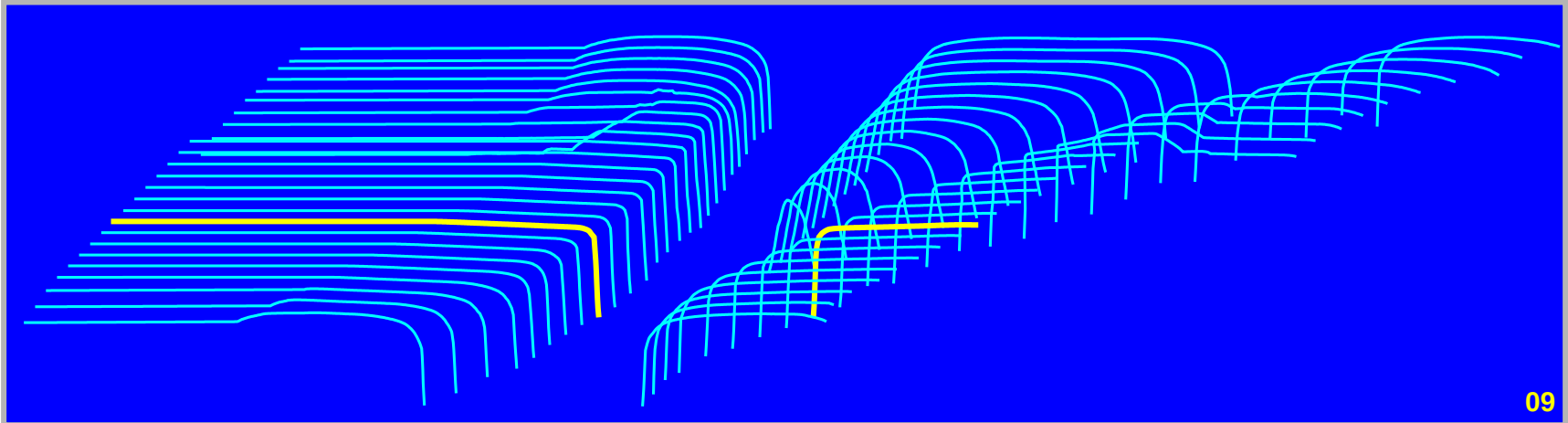
PASSING OF WHEELSET OVER FROG AREA



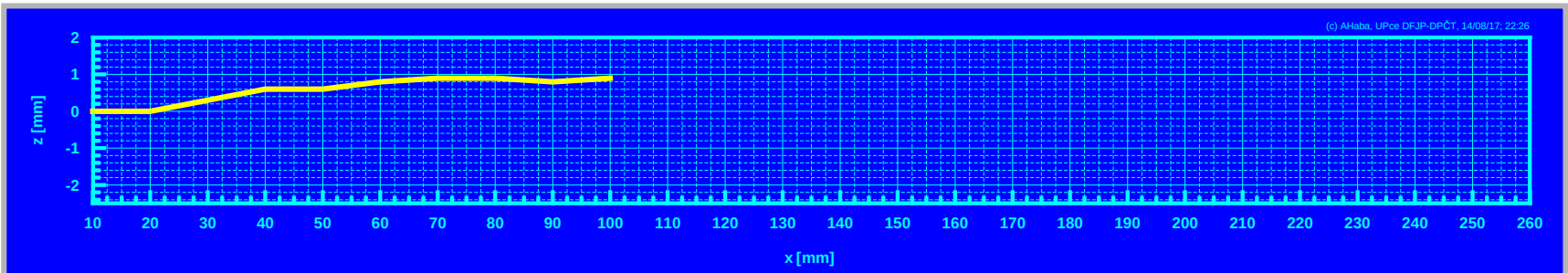
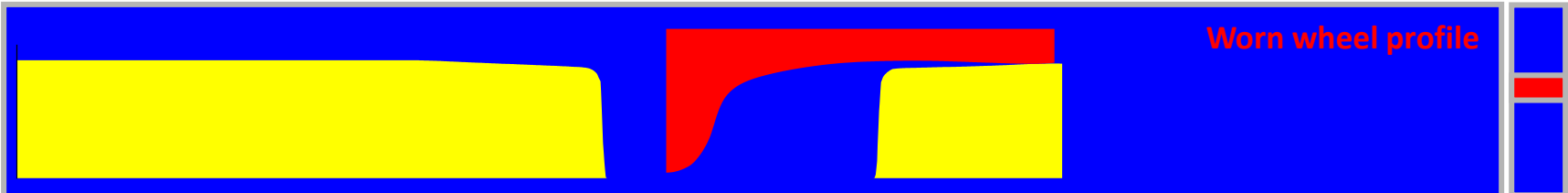
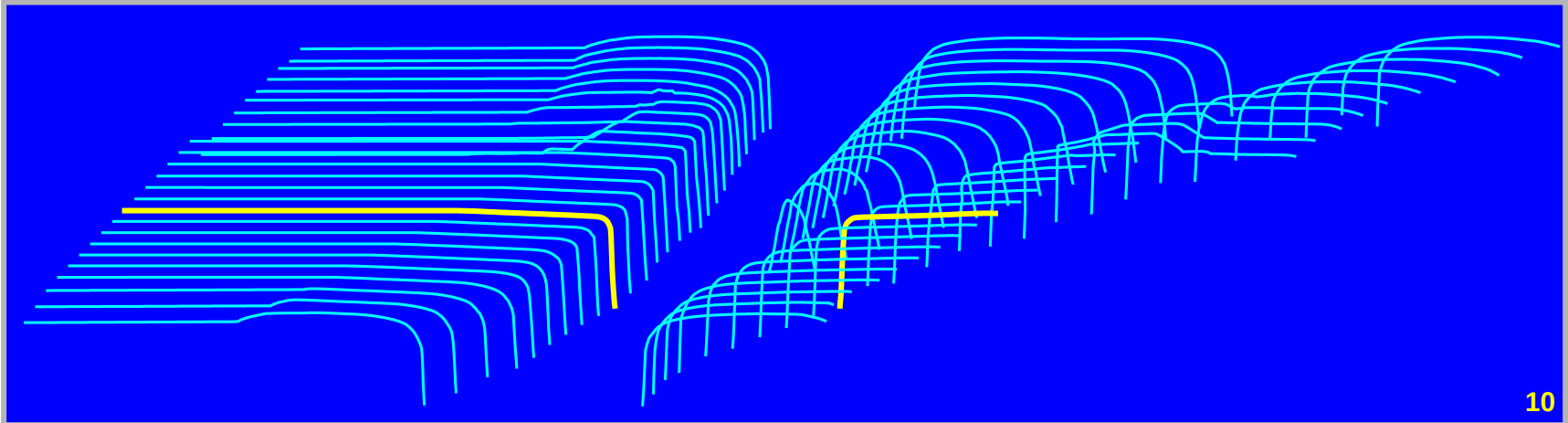
PASSING OF WHEELSET OVER FROG AREA



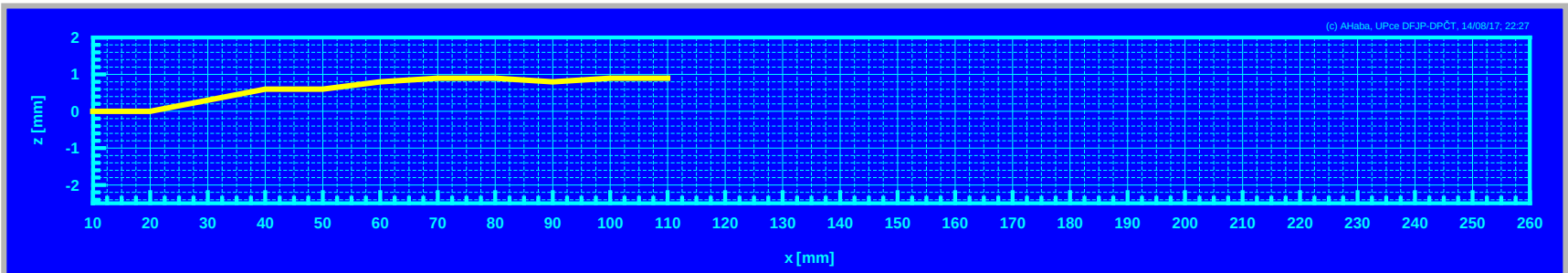
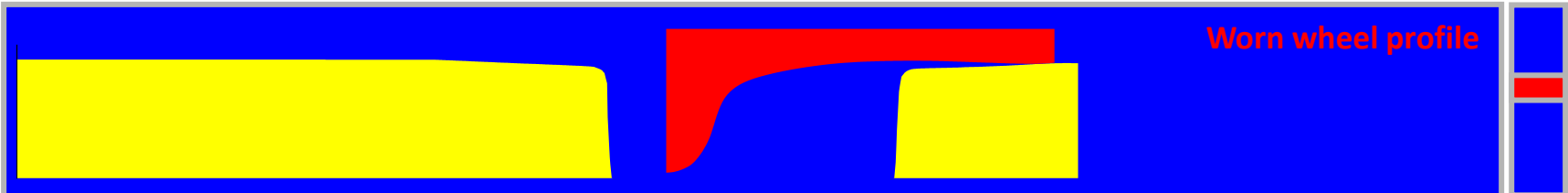
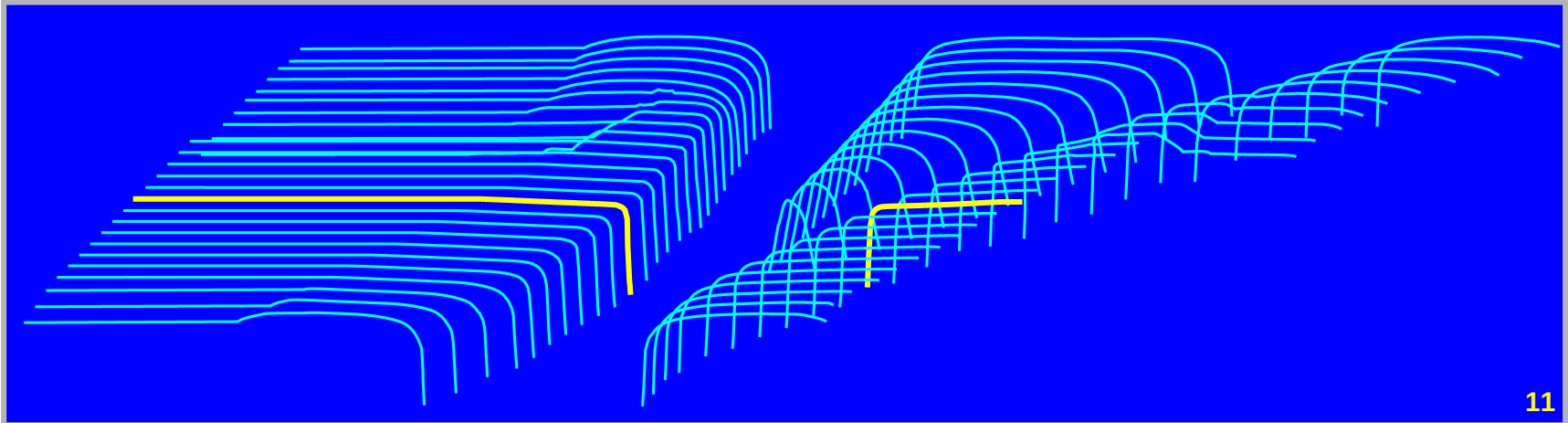
PASSING OF WHEELSET OVER FROG AREA



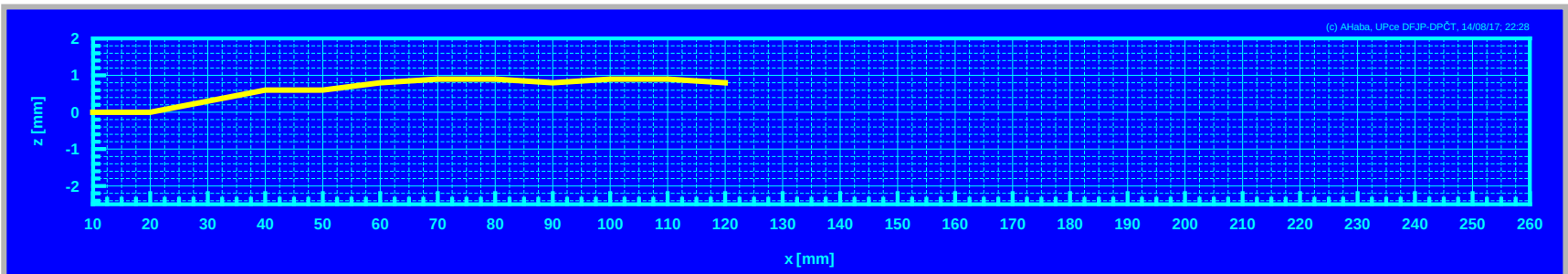
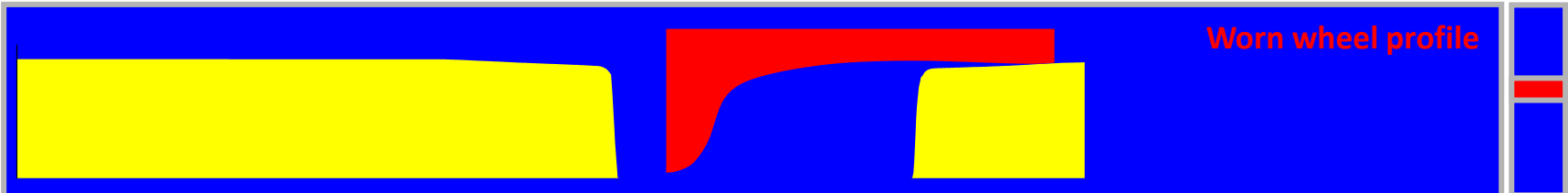
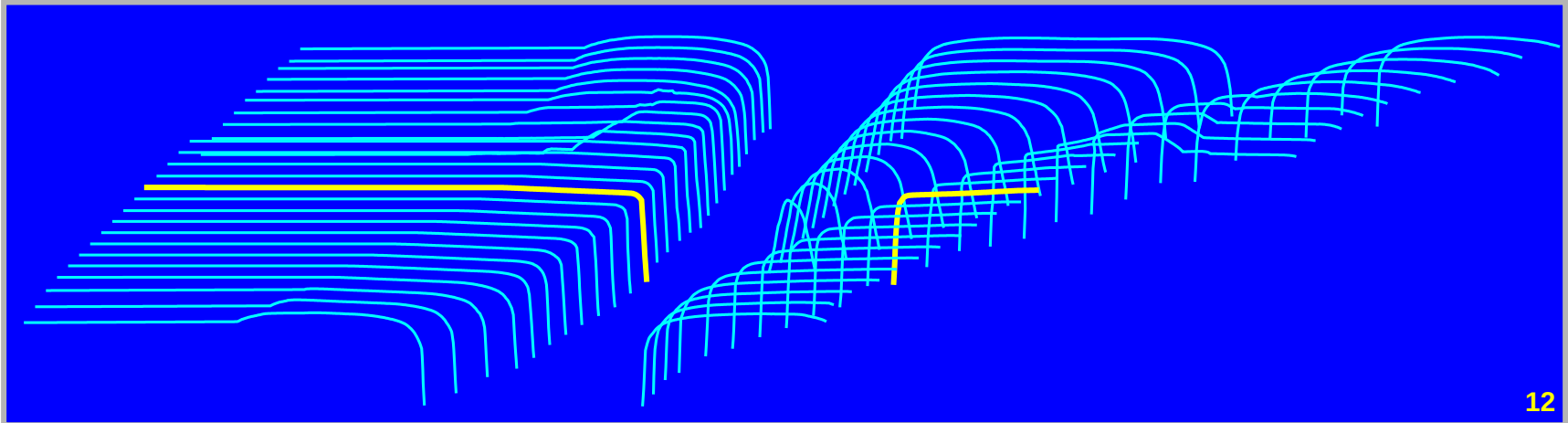
PASSING OF WHEELSET OVER FROG AREA



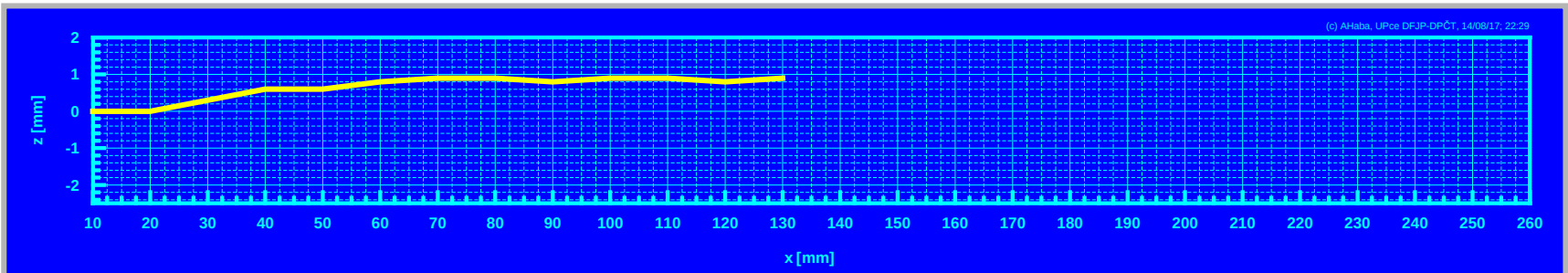
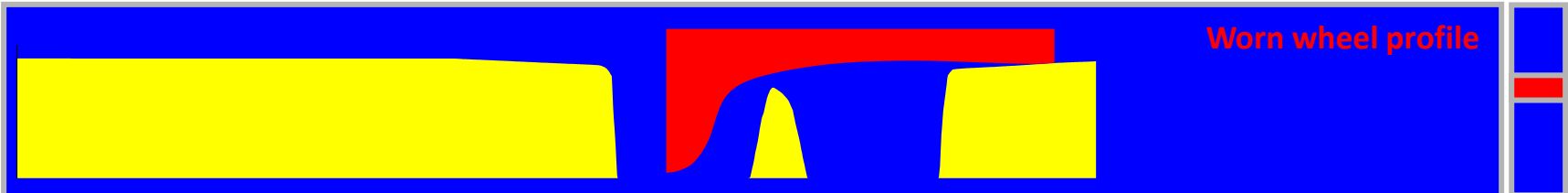
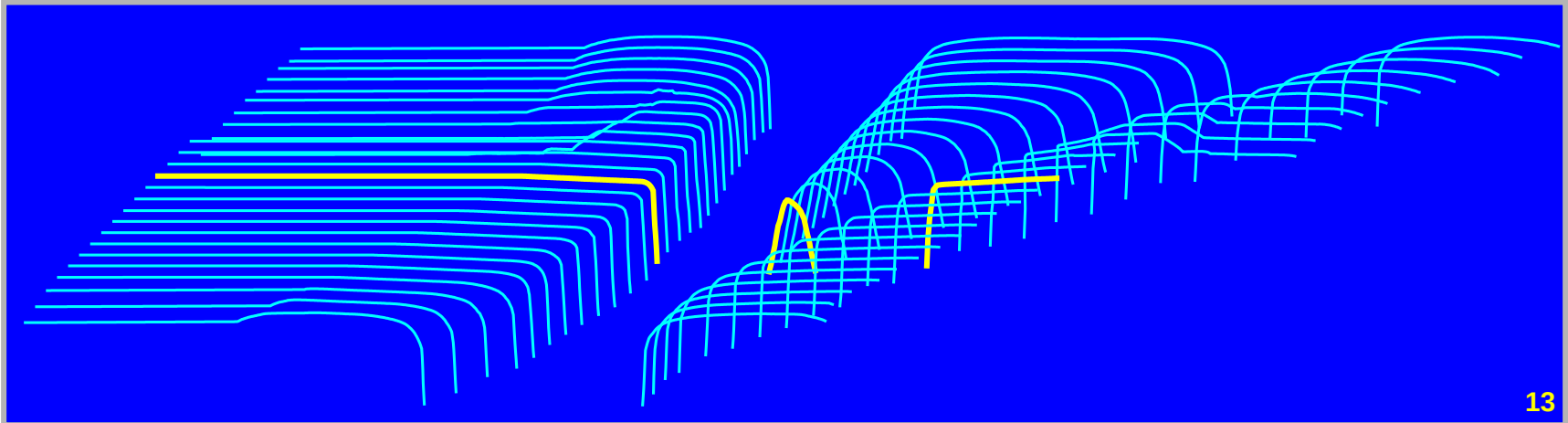
PASSING OF WHEELSET OVER FROG AREA



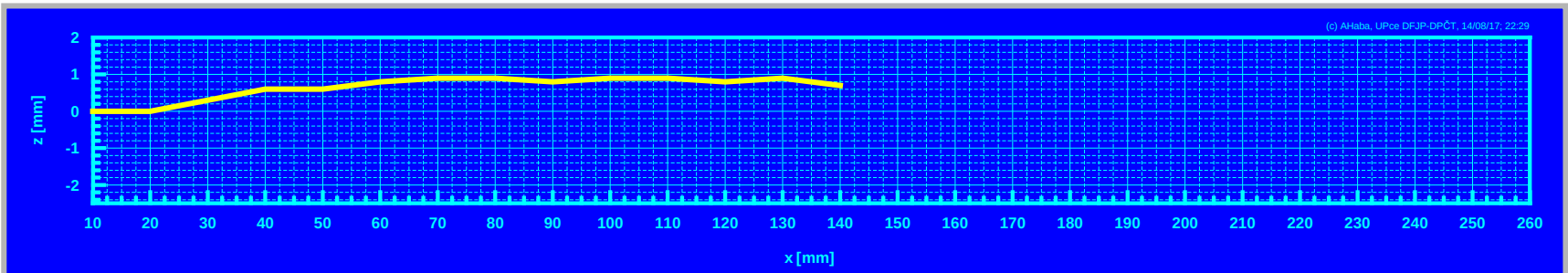
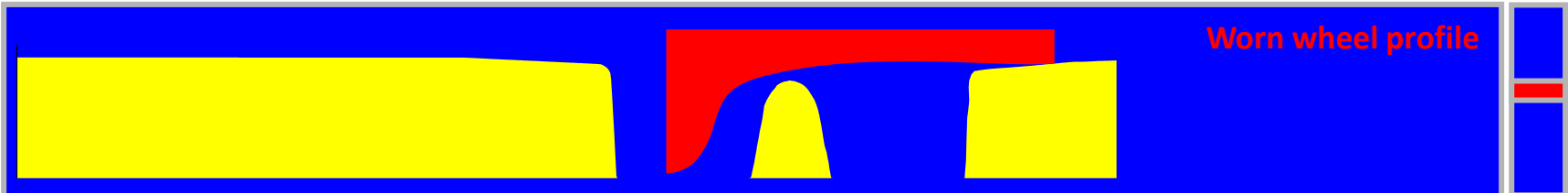
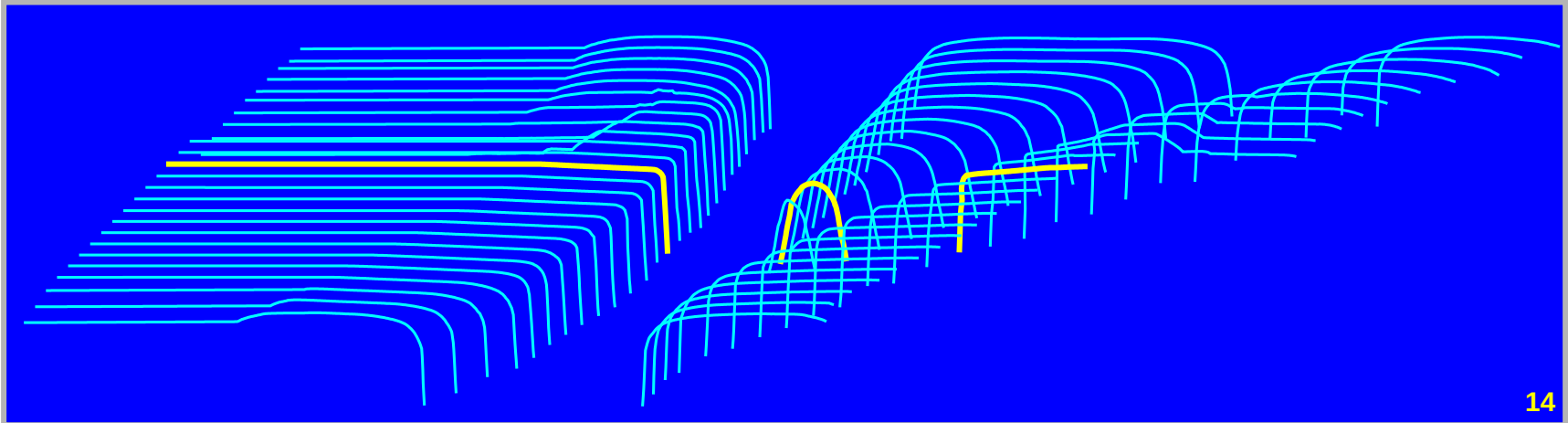
PASSING OF WHEELSET OVER FROG AREA



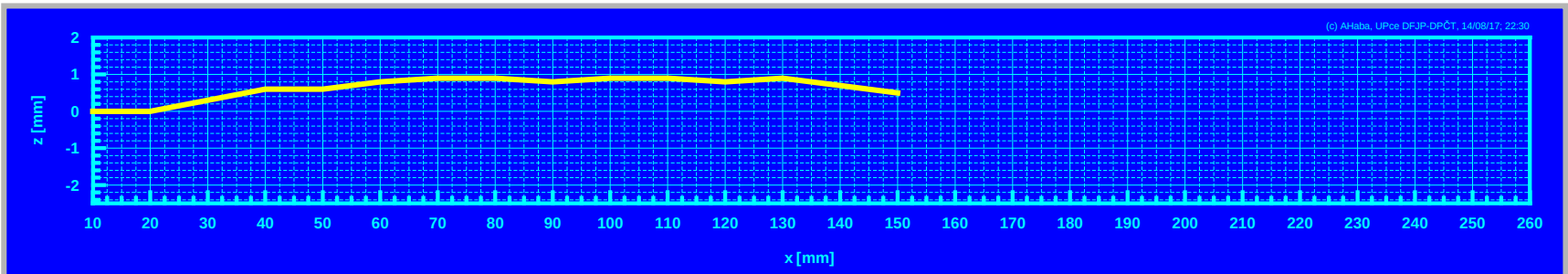
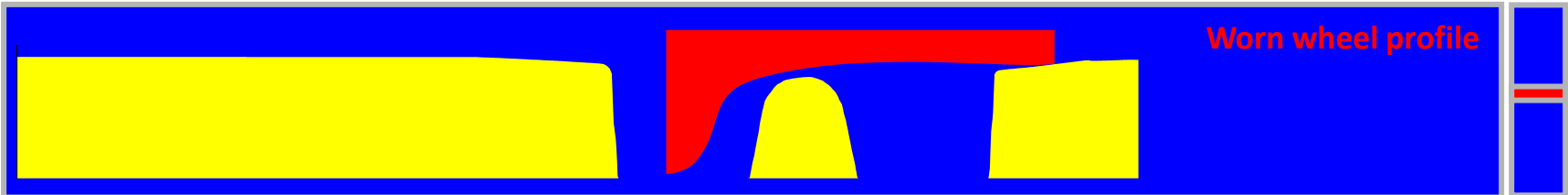
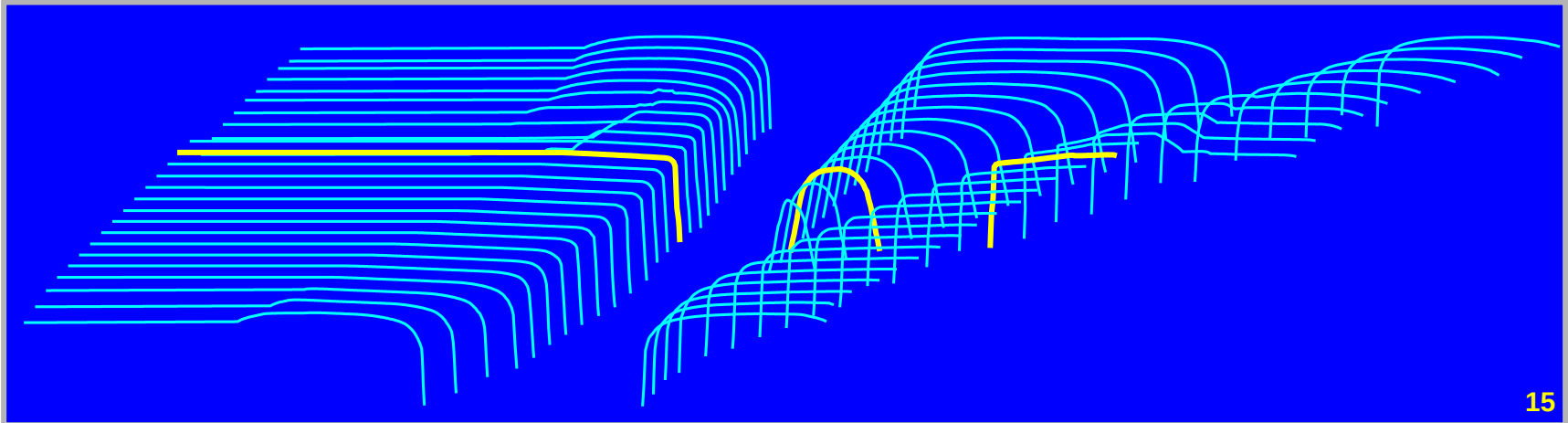
PASSING OF WHEELSET OVER FROG AREA



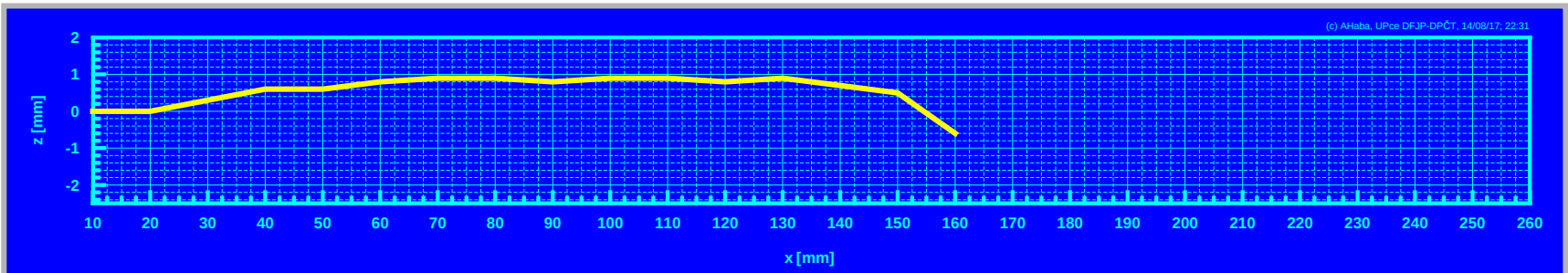
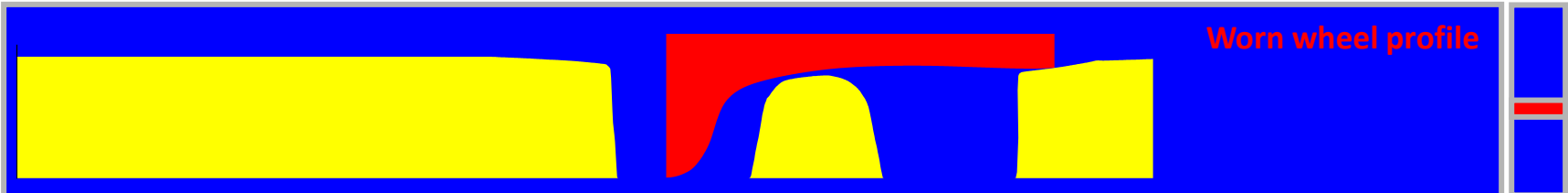
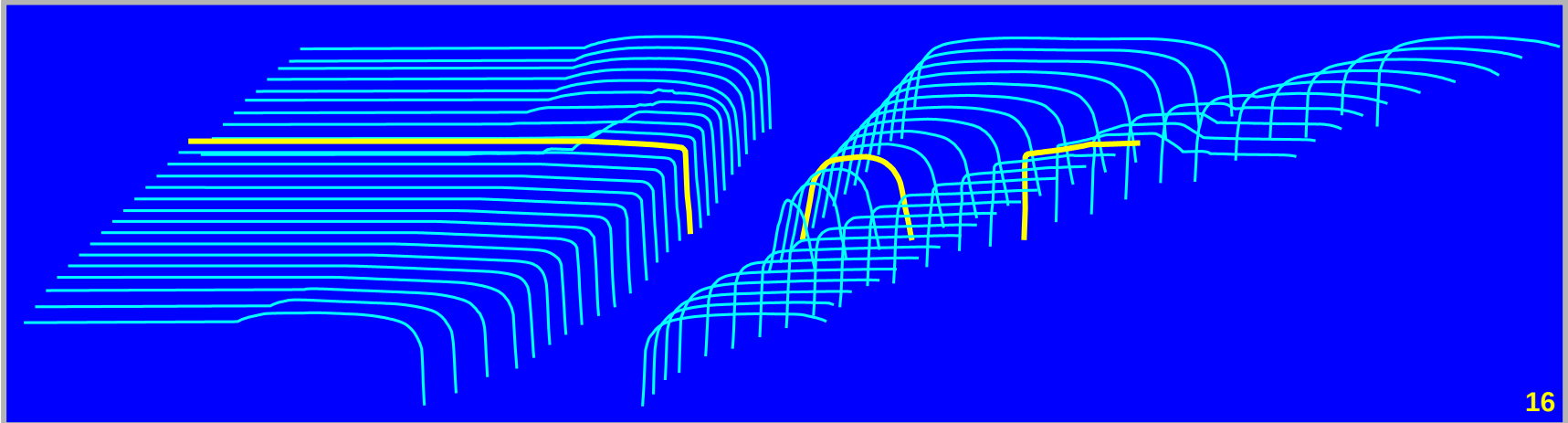
PASSING OF WHEELSET OVER FROG AREA



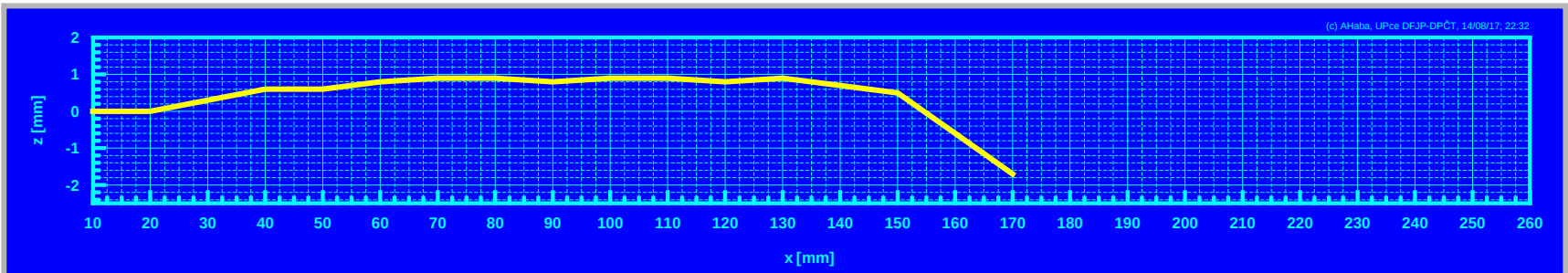
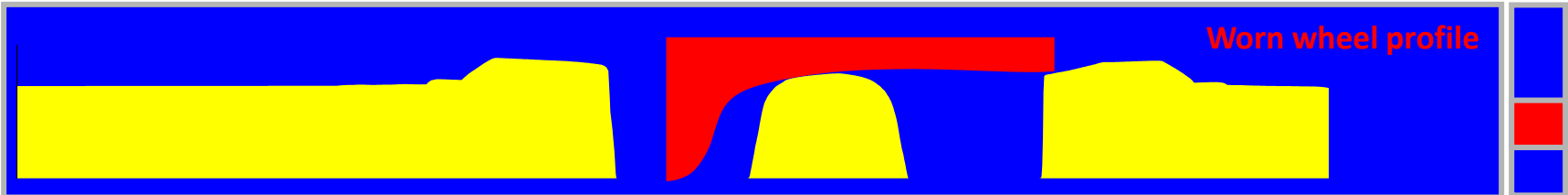
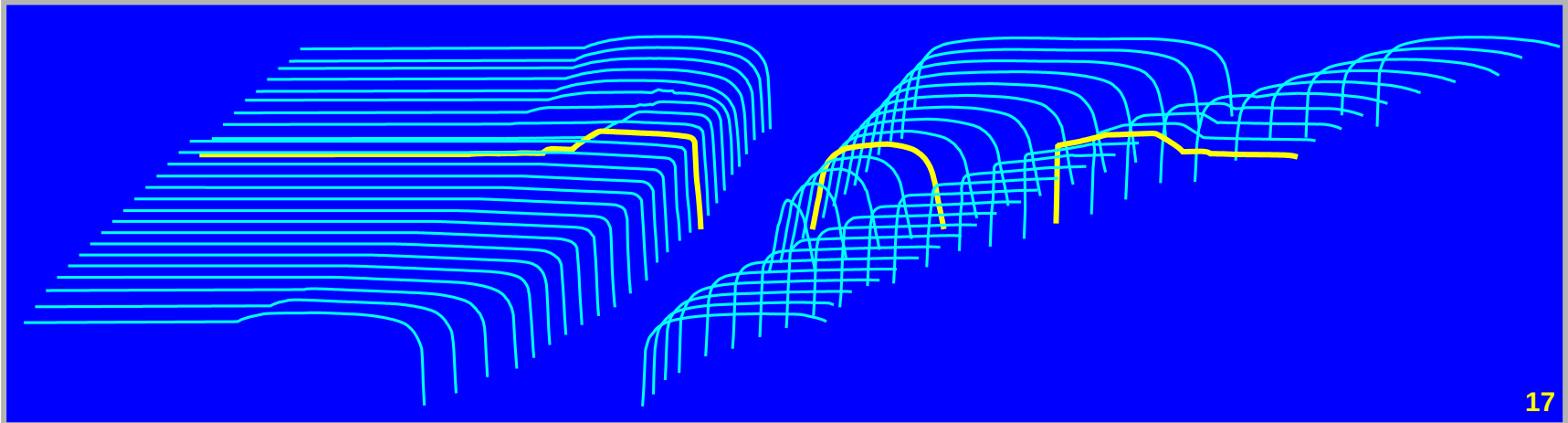
PASSING OF WHEELSET OVER FROG AREA



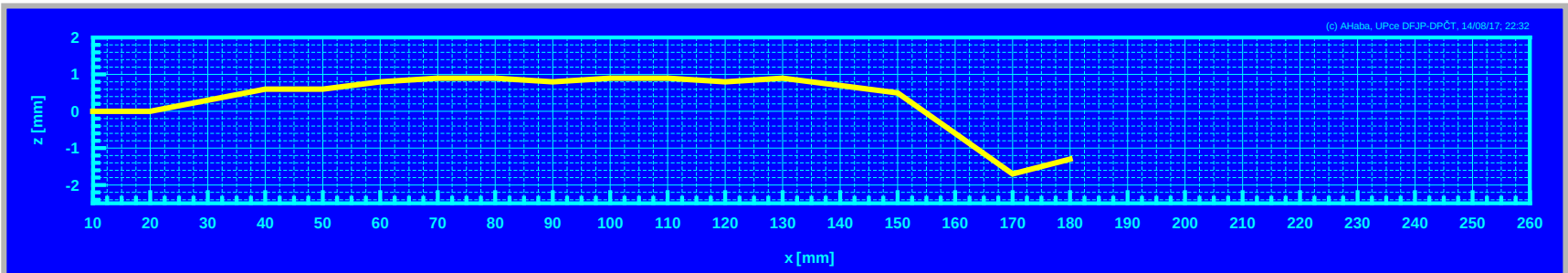
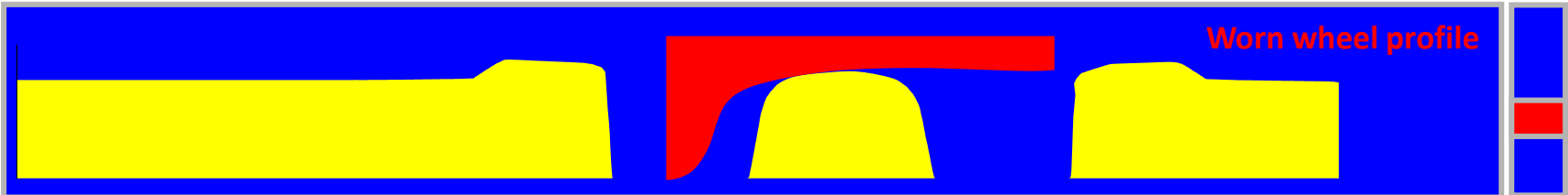
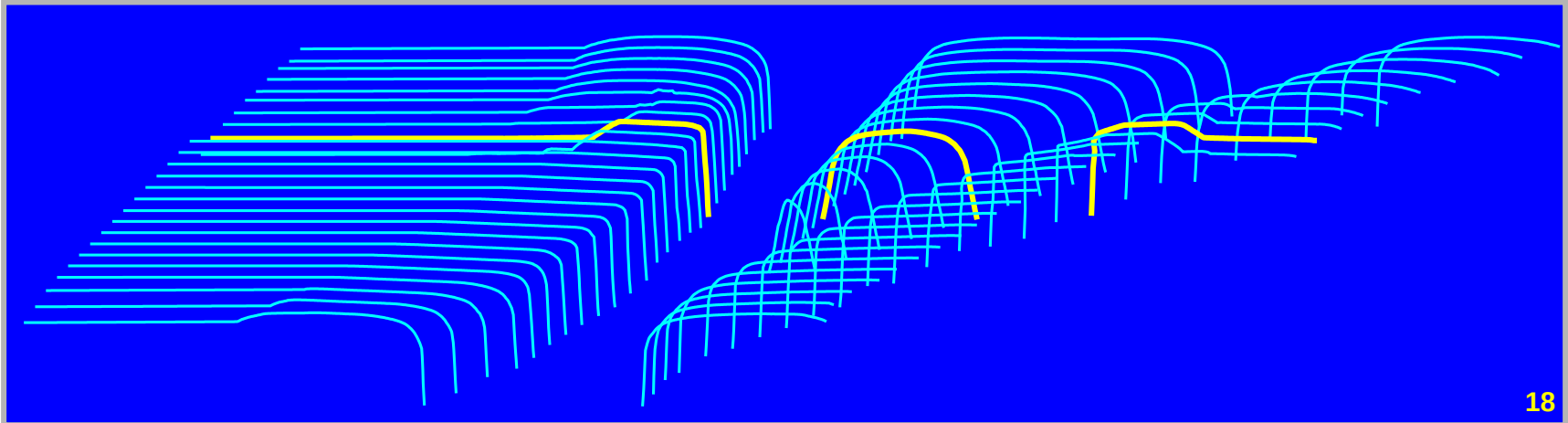
PASSING OF WHEELSET OVER FROG AREA



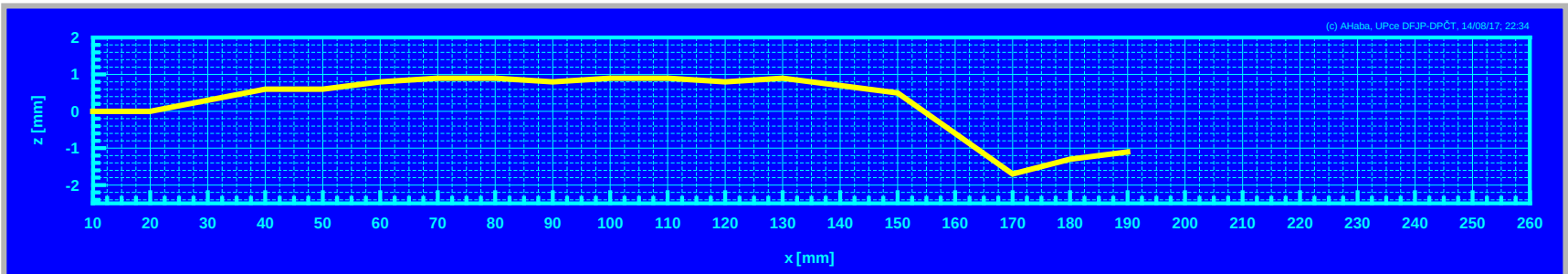
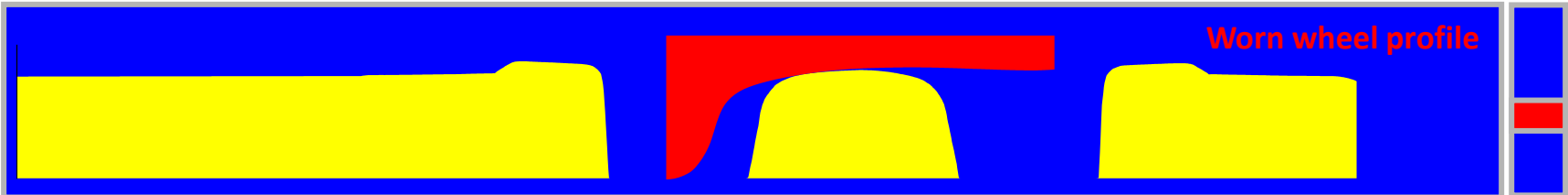
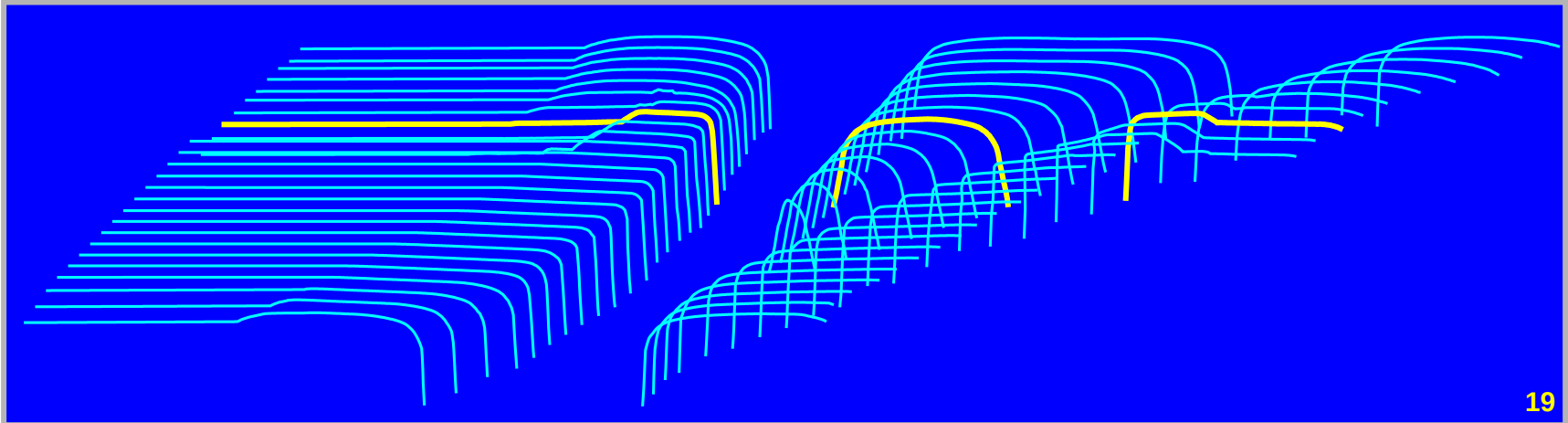
PASSING OF WHEELSET OVER FROG AREA



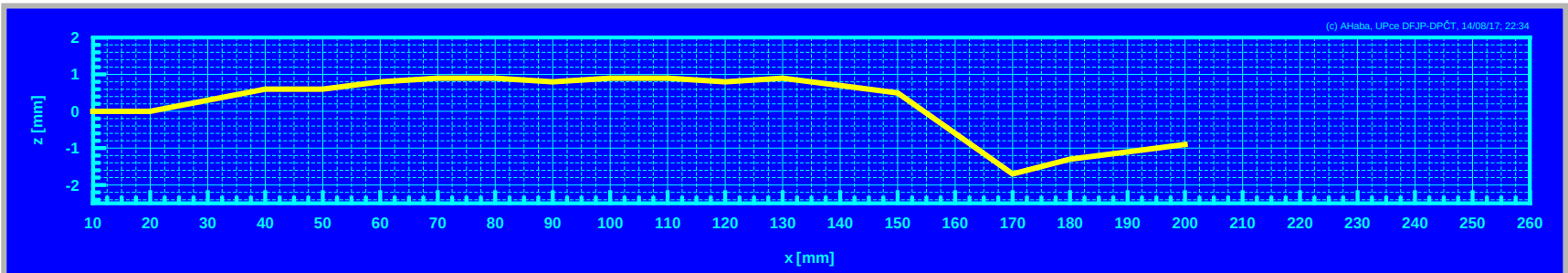
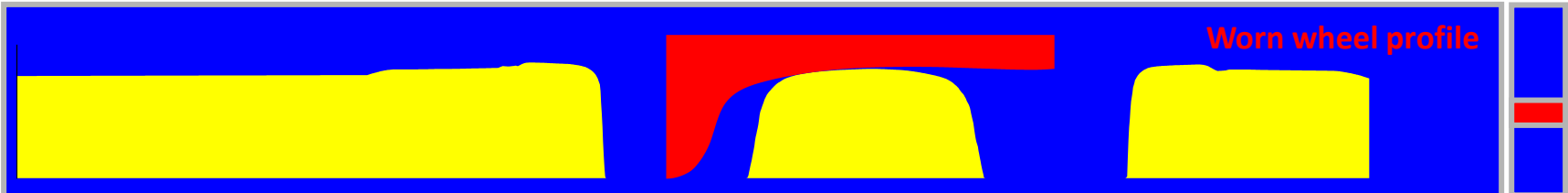
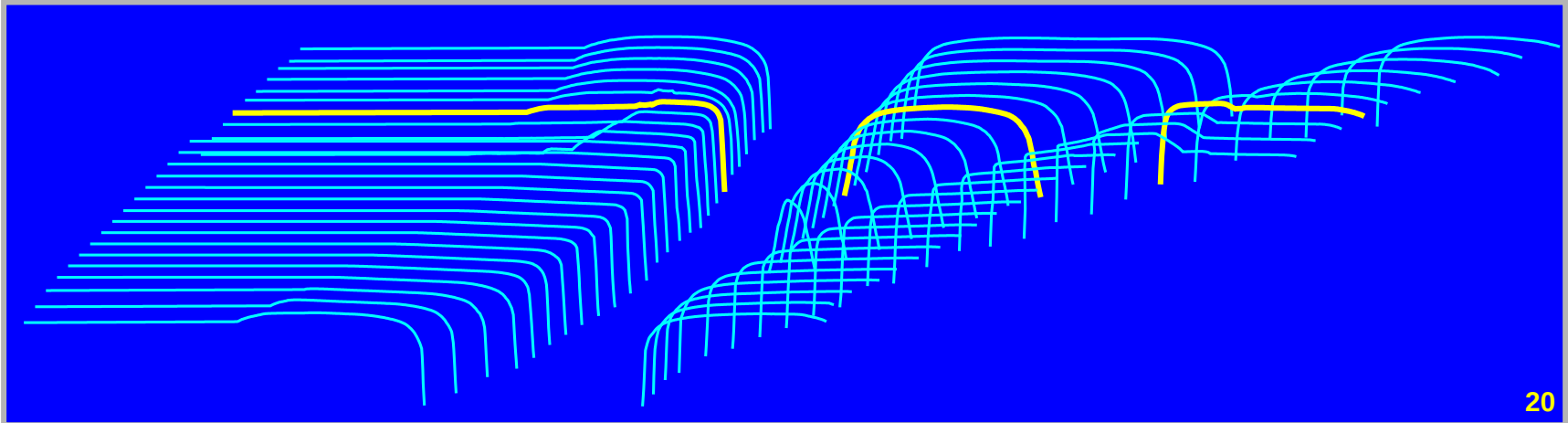
PASSING OF WHEELSET OVER FROG AREA



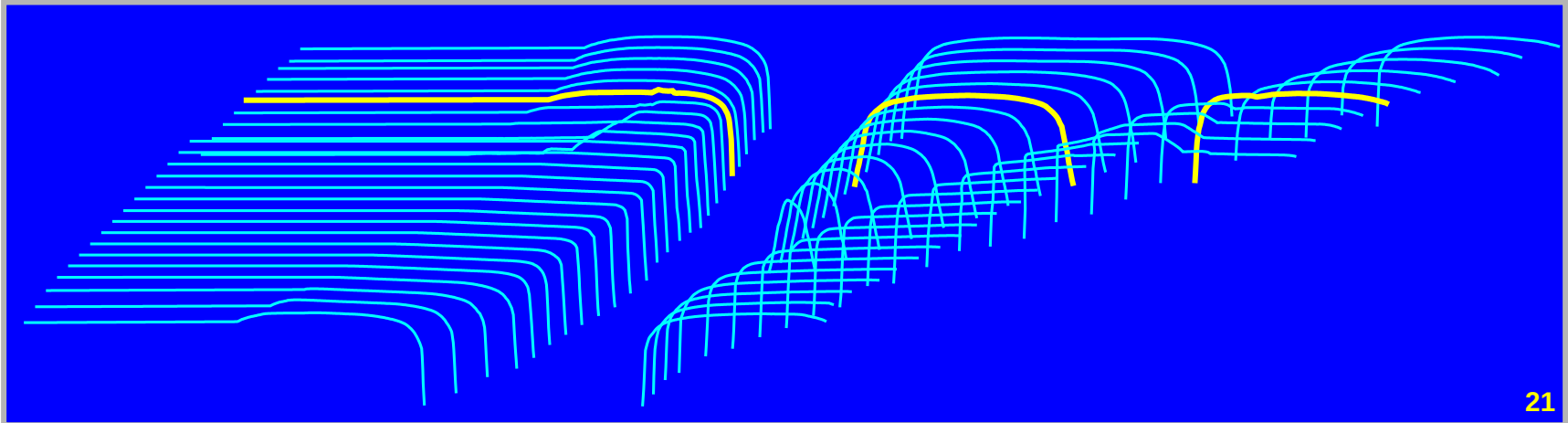
PASSING OF WHEELSET OVER FROG AREA



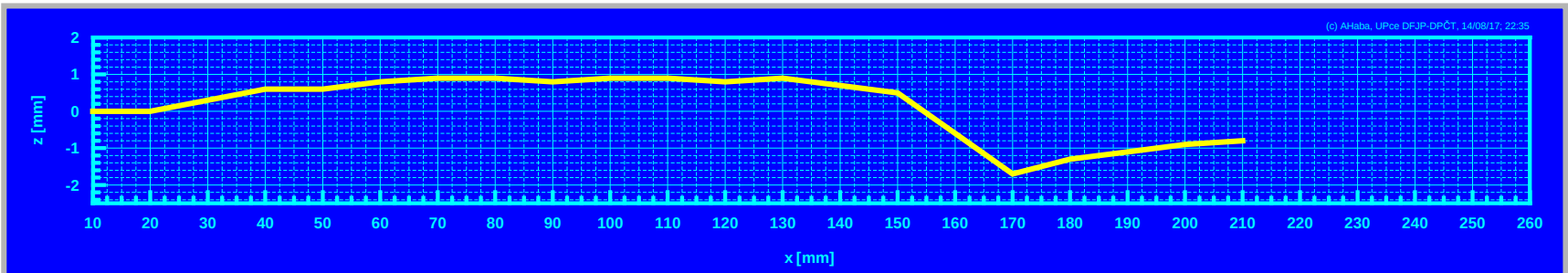
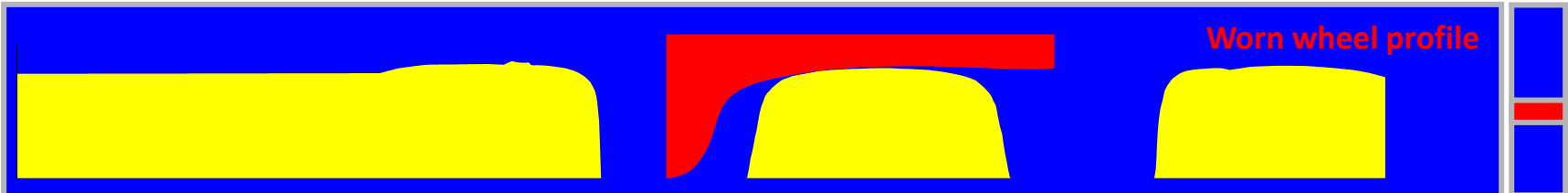
PASSING OF WHEELSET OVER FROG AREA



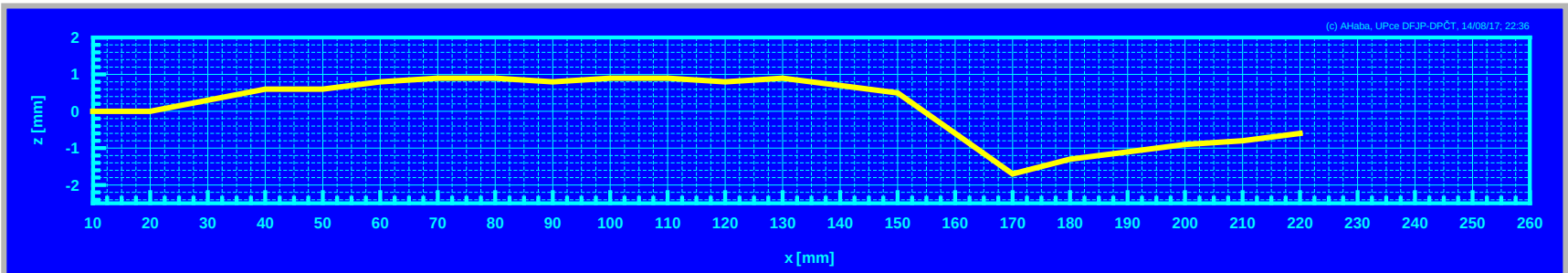
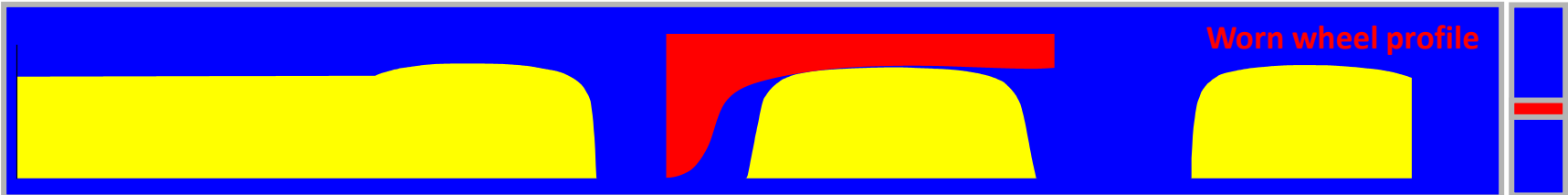
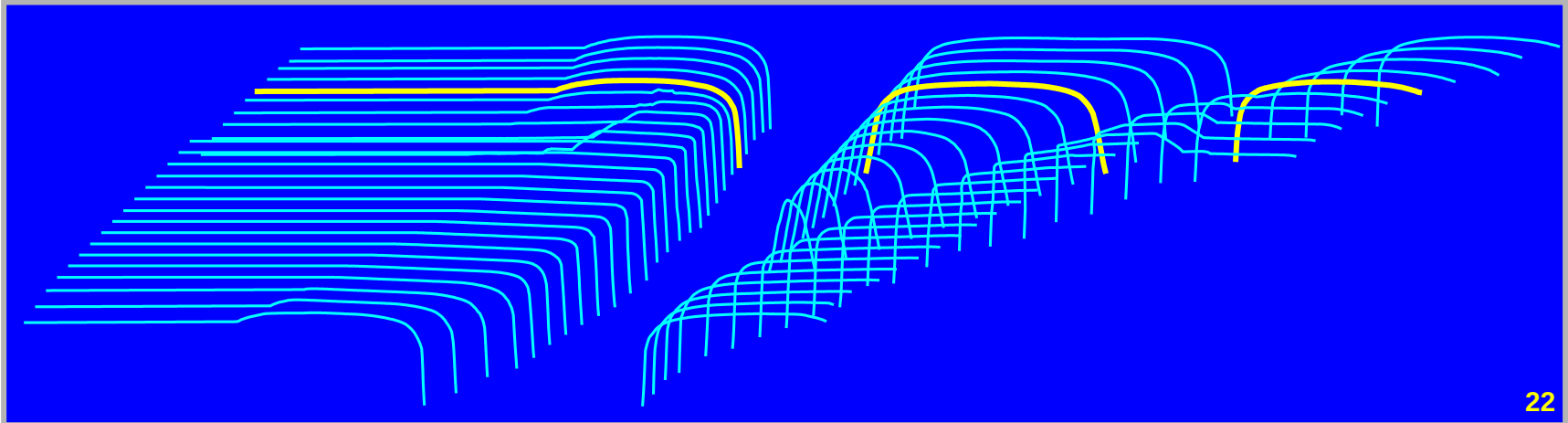
PASSING OF WHEELSET OVER FROG AREA



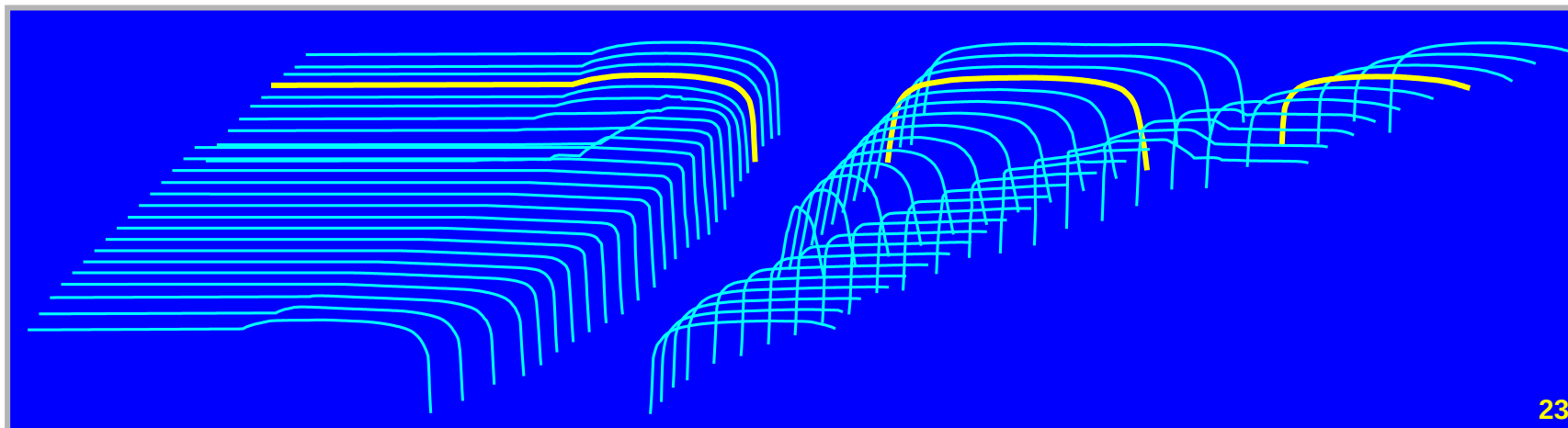
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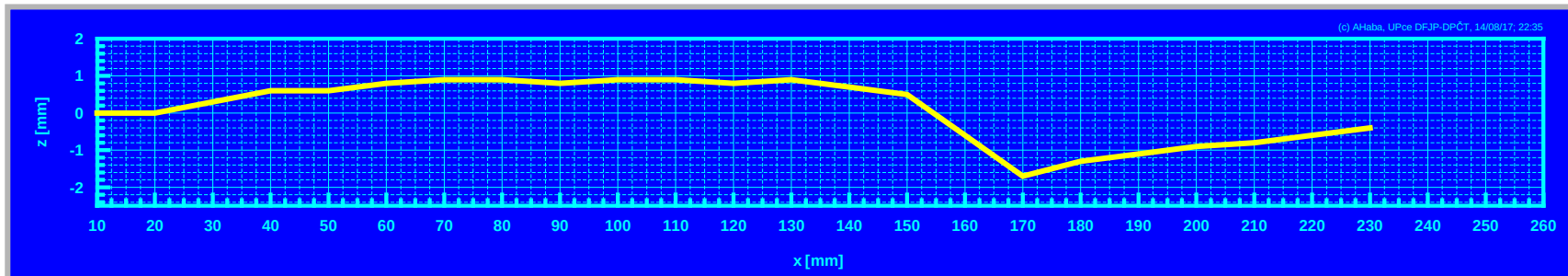
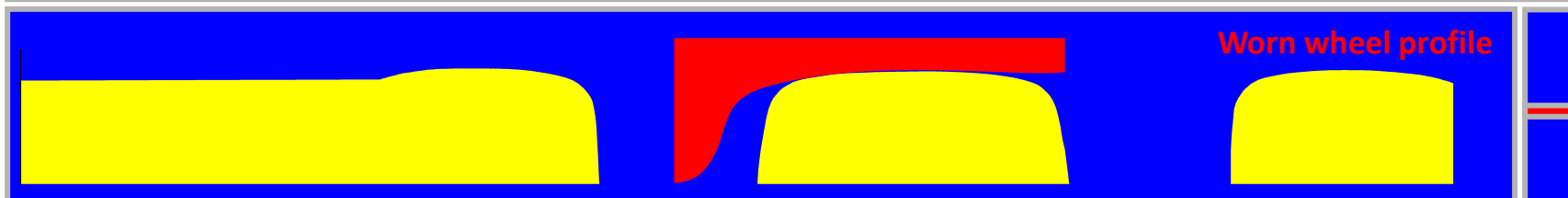
PASSING OF WHEELSET OVER FROG AREA



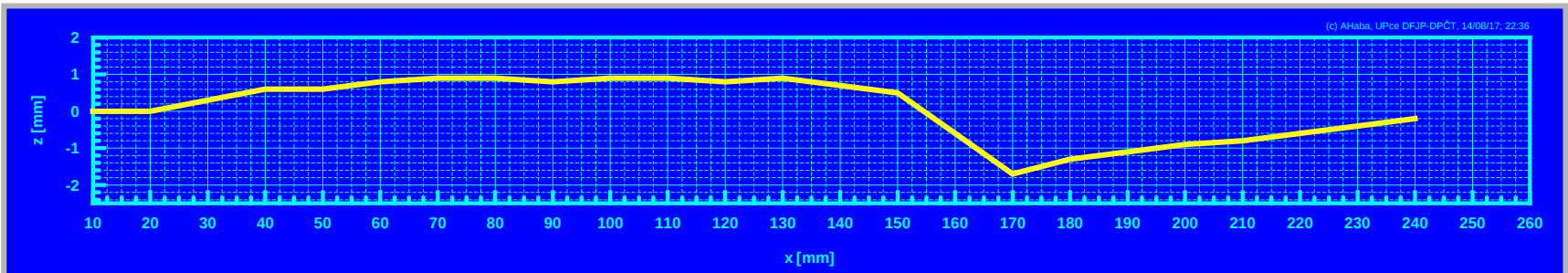
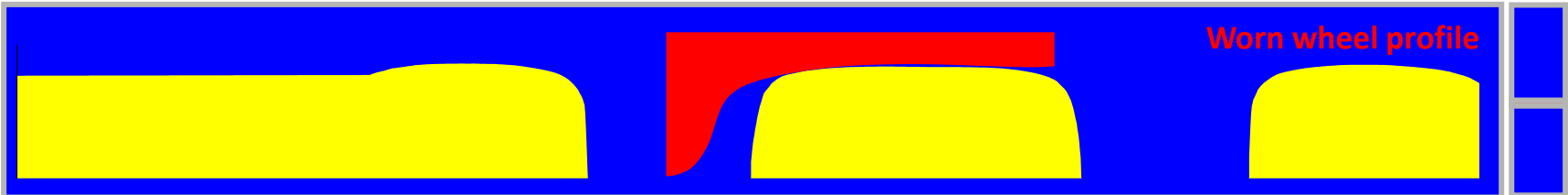
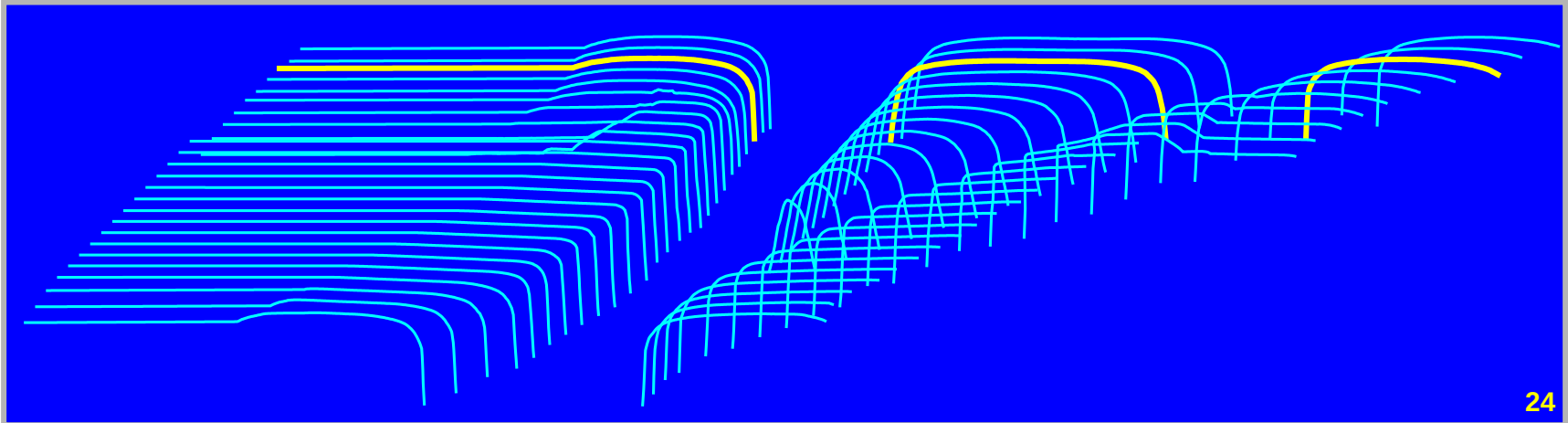
PASSING OF WHEELSET OVER FROG AREA



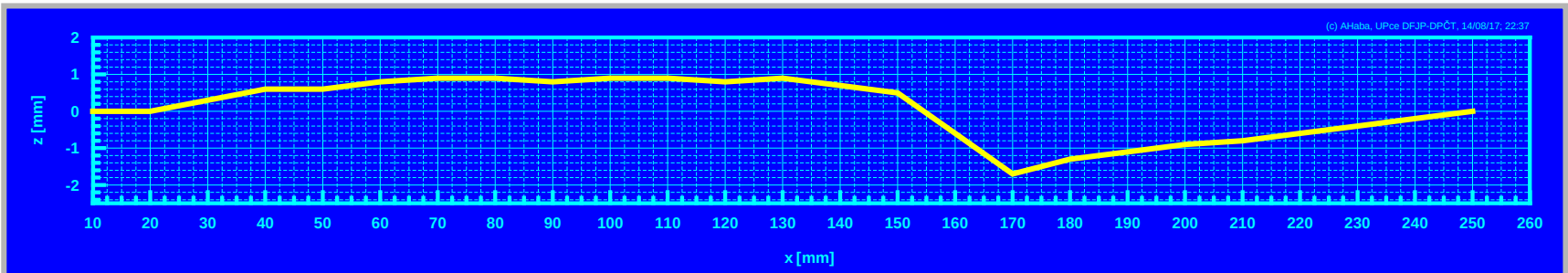
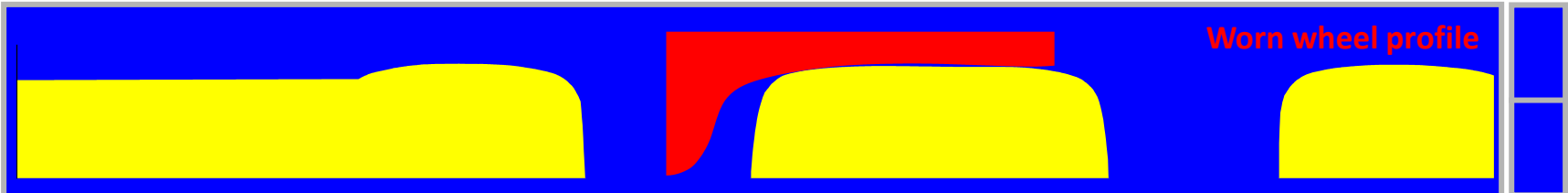
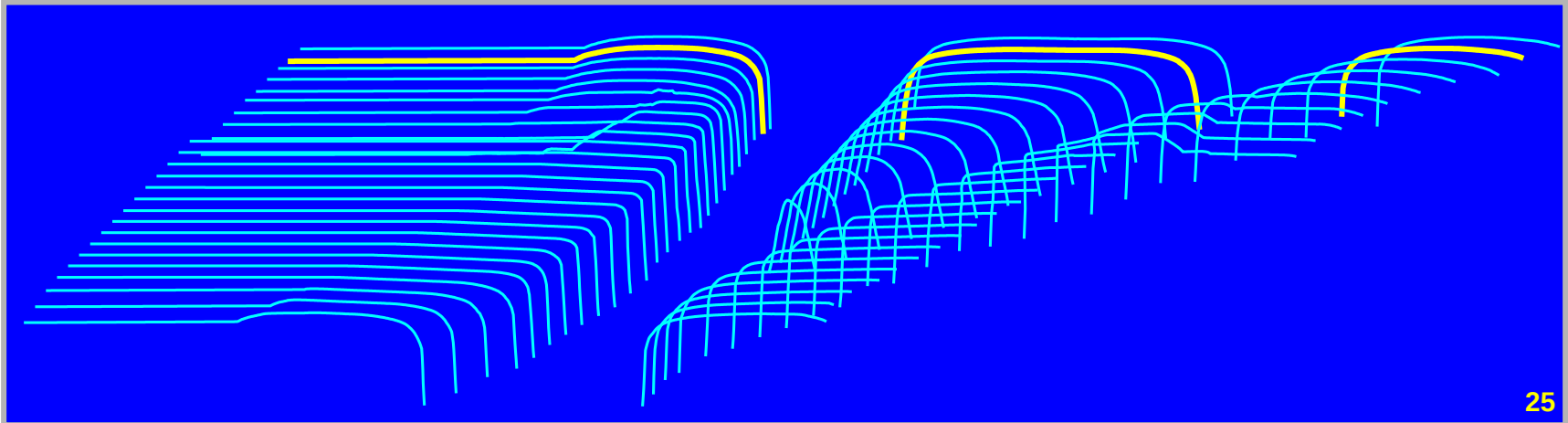
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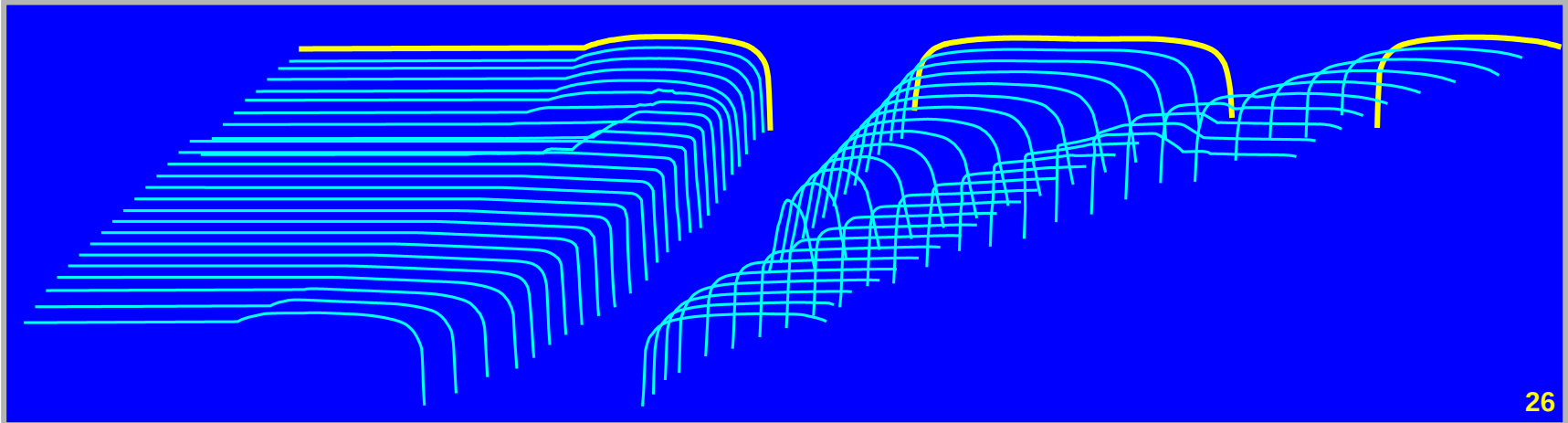
PASSING OF WHEELSET OVER FROG AREA



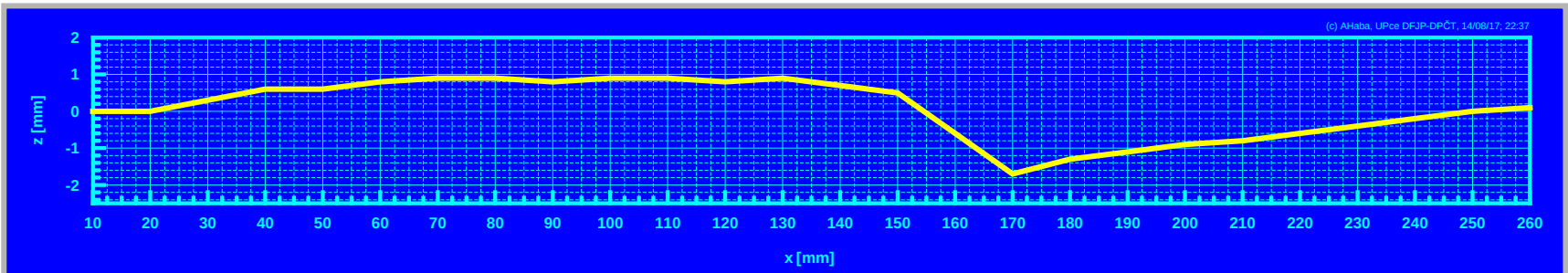
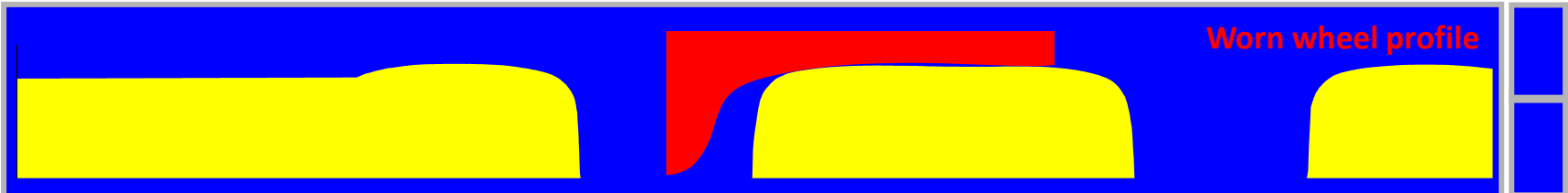
PASSING OF WHEELSET OVER FROG AREA



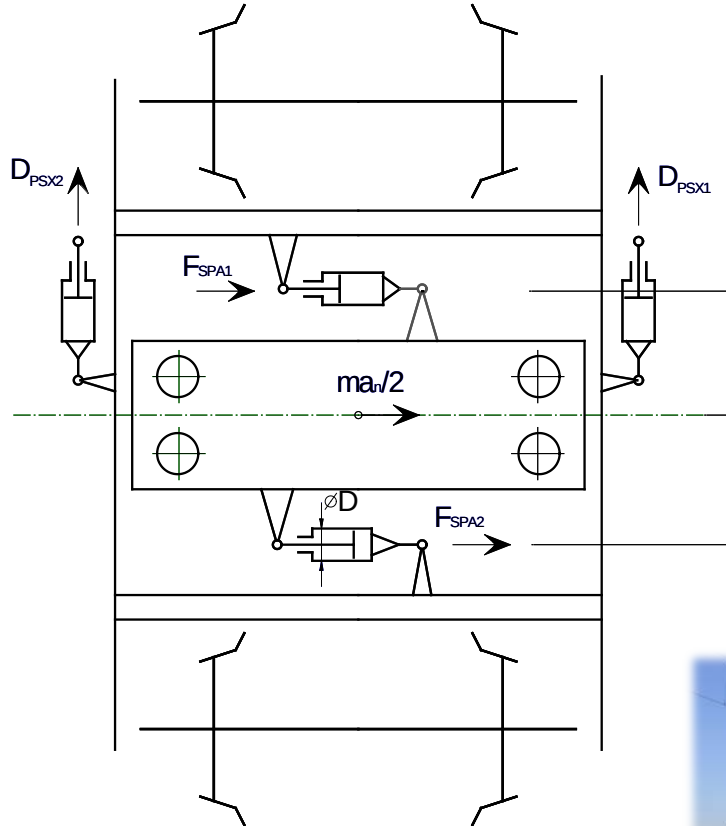
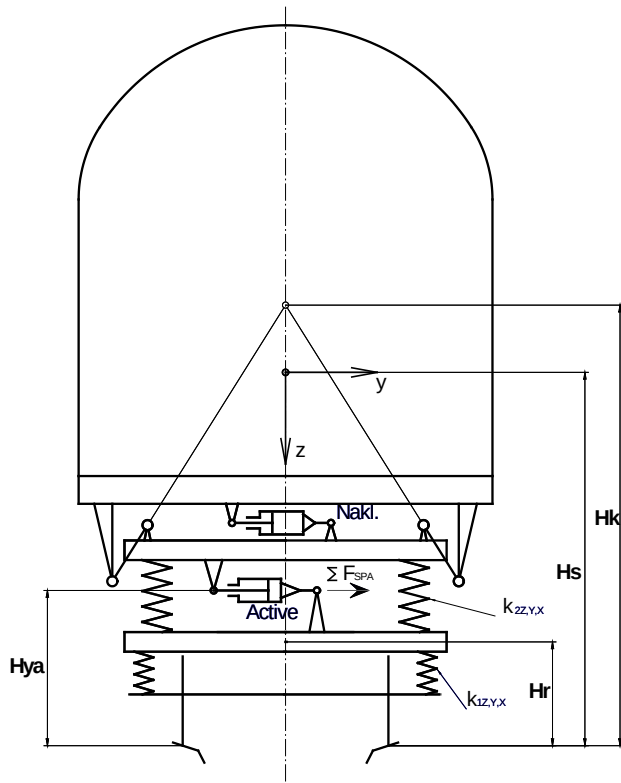
PASSING OF WHEELSET OVER FROG AREA



26



COMPUTATIONAL SIMULATION

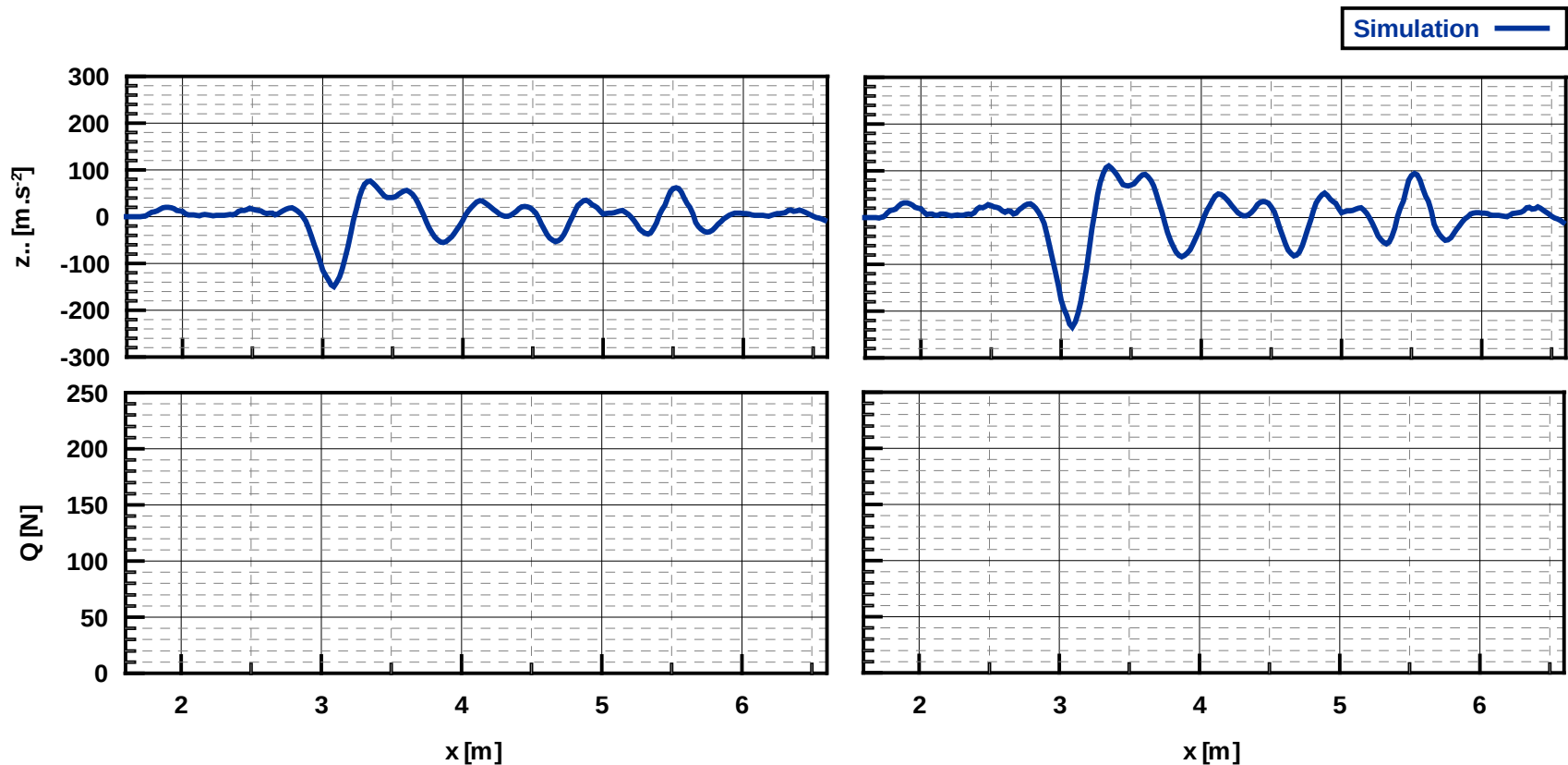


Model of unit class 680



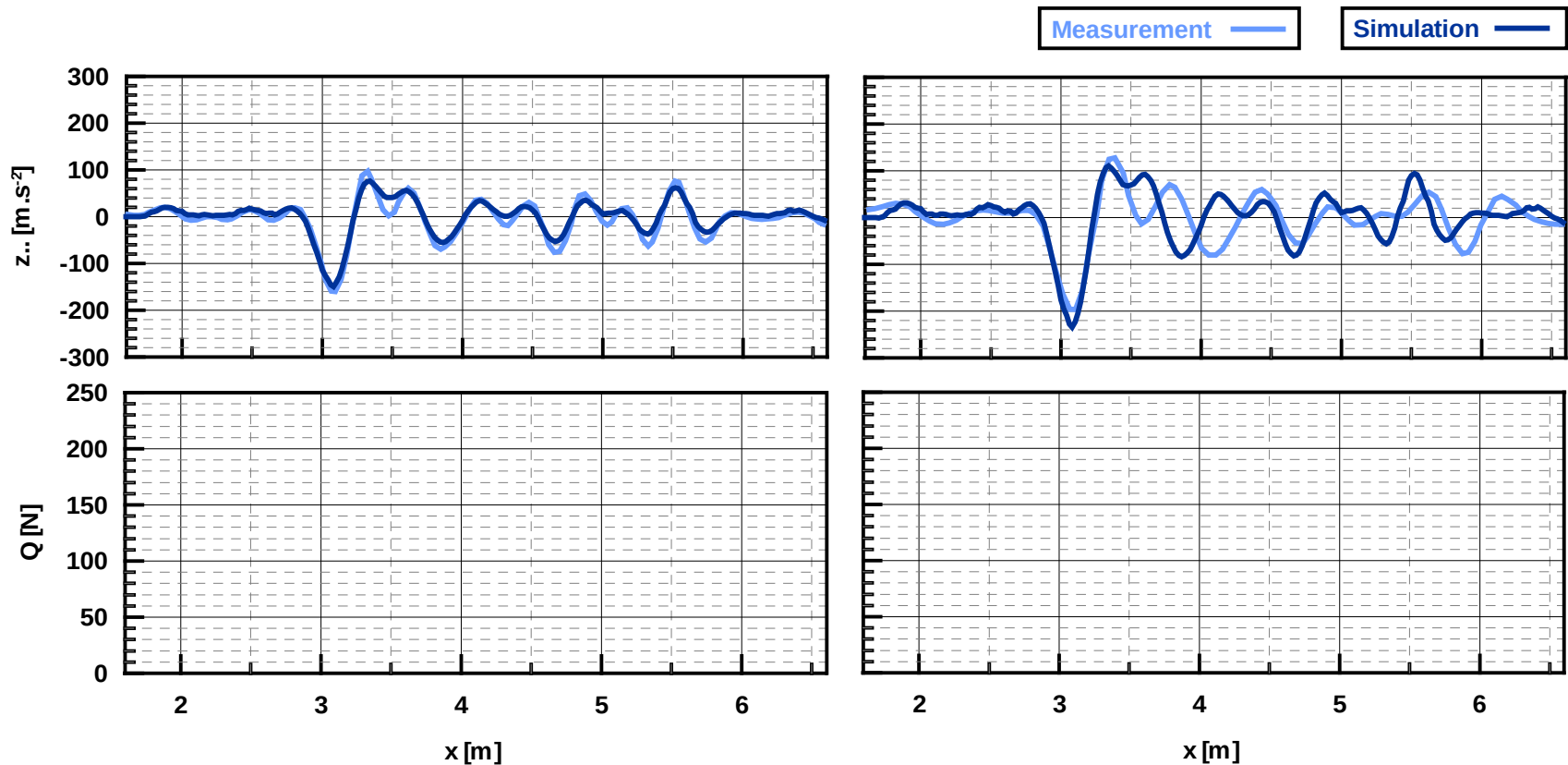
COMPUTATIONAL SIMULATION - MEASUREMENT

- **Vertical irregularities** (kinematical excitation) - vertical movement of the wheel passing over a turnout frog



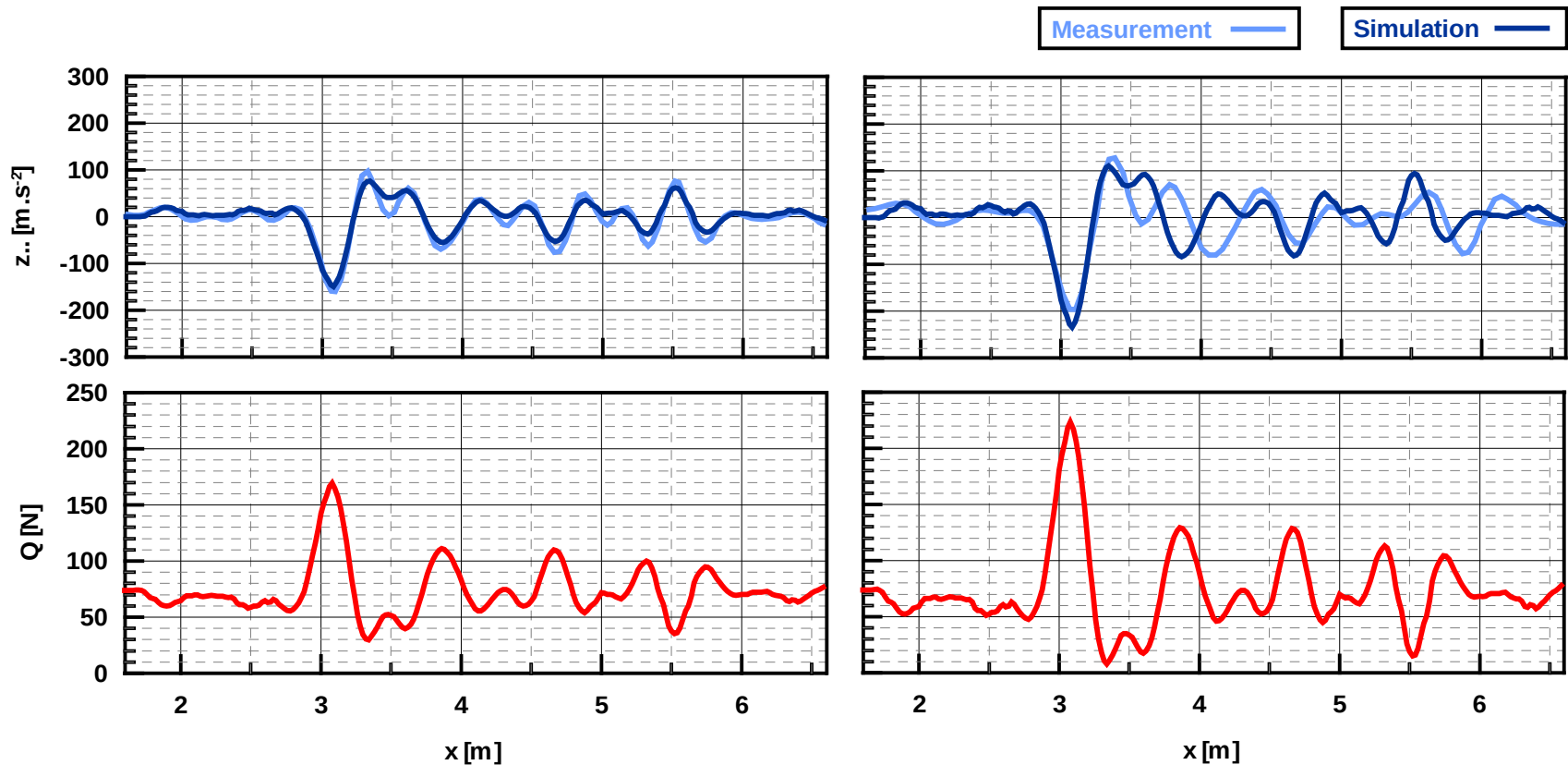
COMPUTATIONAL SIMULATION - MEASUREMENT

- **Vertical irregularities** (kinematical excitation) - vertical movement of the wheel passing over a turnout frog



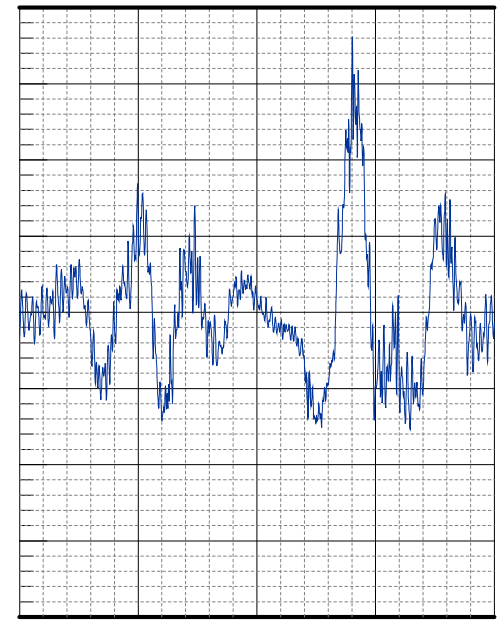
COMPUTATIONAL SIMULATION - MEASUREMENT

- **Vertical irregularities** (kinematical excitation) - vertical movement of the wheel passing over a turnout frog



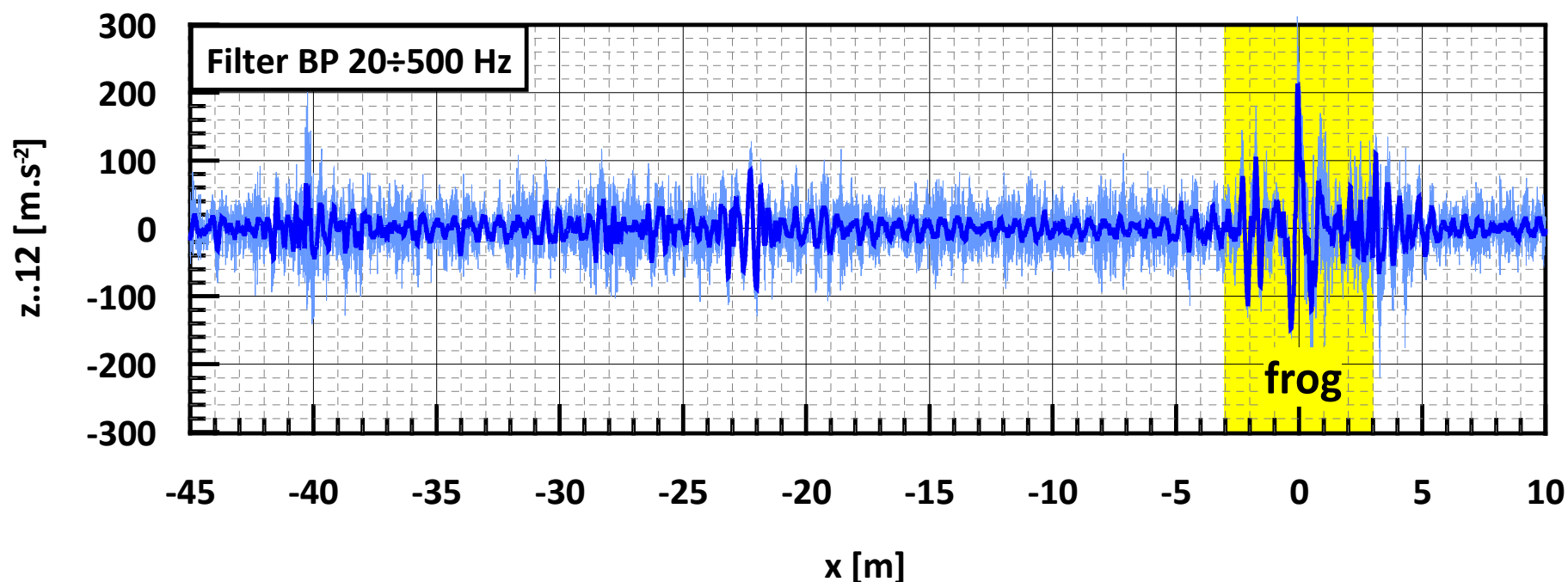
MEASURING OF DYNAMICAL RESPONSE

- acceleration measured on the **wheelset axle box**,
- high **sampling rate** – 20 kHz; **filtering** 20÷500 Hz,
- heavy **locomotive** – 22 t per axle.



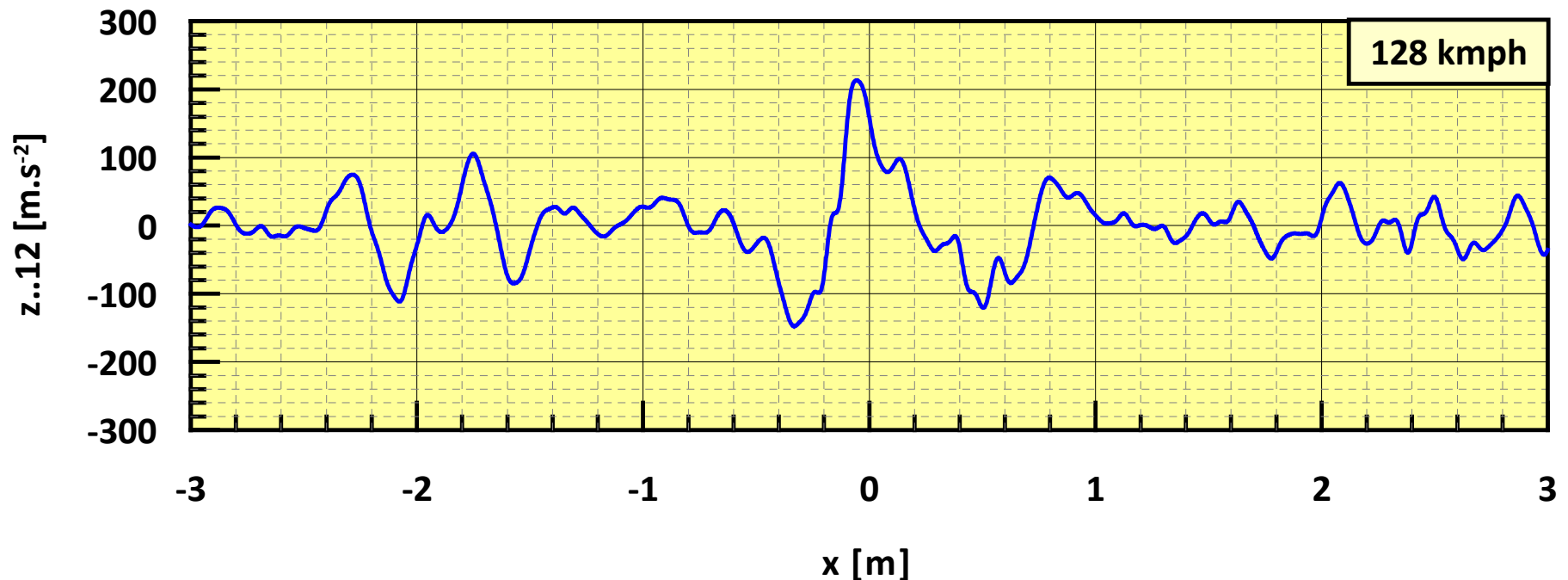
MEASURING OF DYNAMICAL RESPONSE

- **Acceleration signal** measured on the axle box of the appropriate wheel which passes over a turnout frog.
- **Increased dynamical response** – 20 m, resp. 2.5 m.



MEASURING OF DYNAMICAL RESPONSE

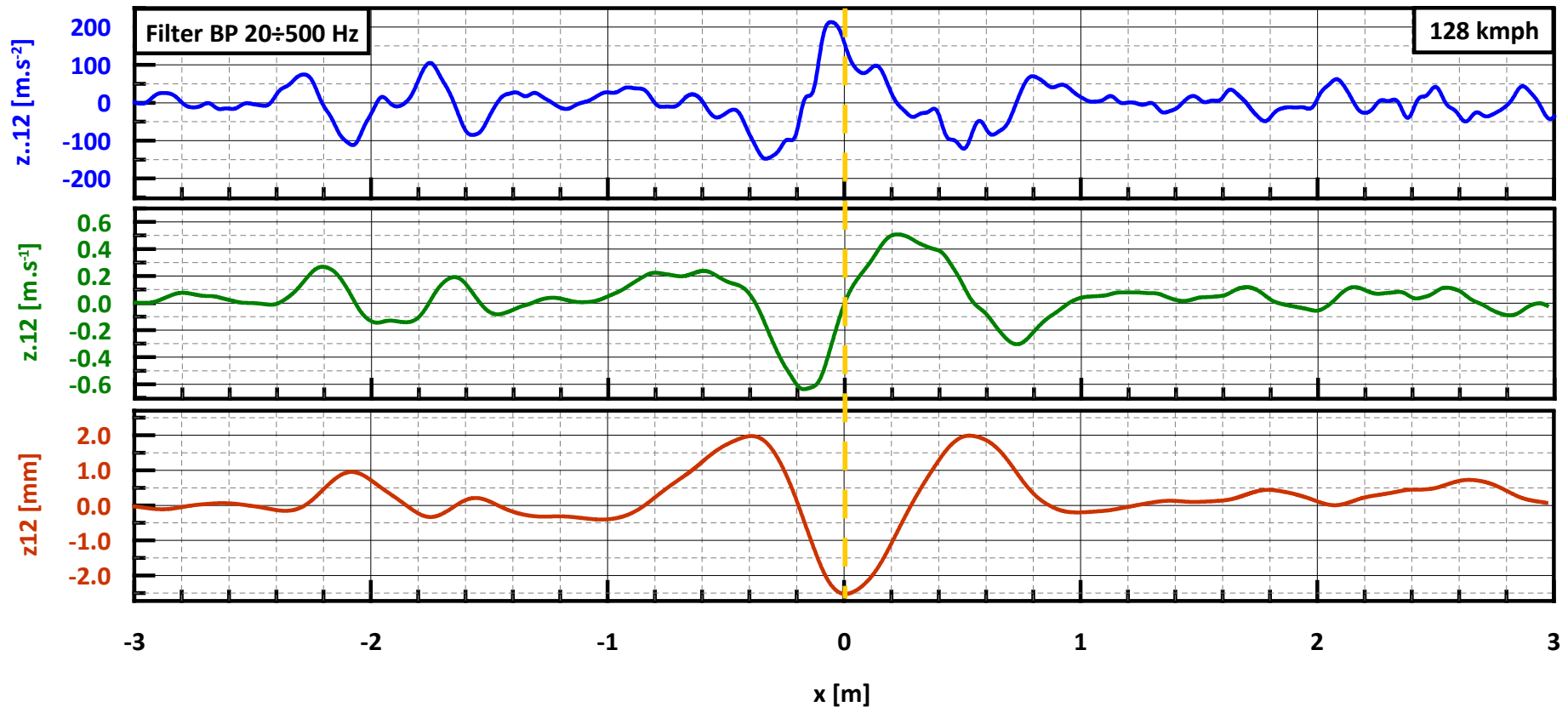
- **Acceleration signal** measured on the axle box of the appropriate wheel which passes over a turnout frog.
- **Increased dynamical response** – aprox. 2.5 m.





IDENTIFICATION OF FROG TIP

- Integration of measured acceleration on the axle box.



MEASUREMENT EVALUATION

- **Equivalent loading** - certified method

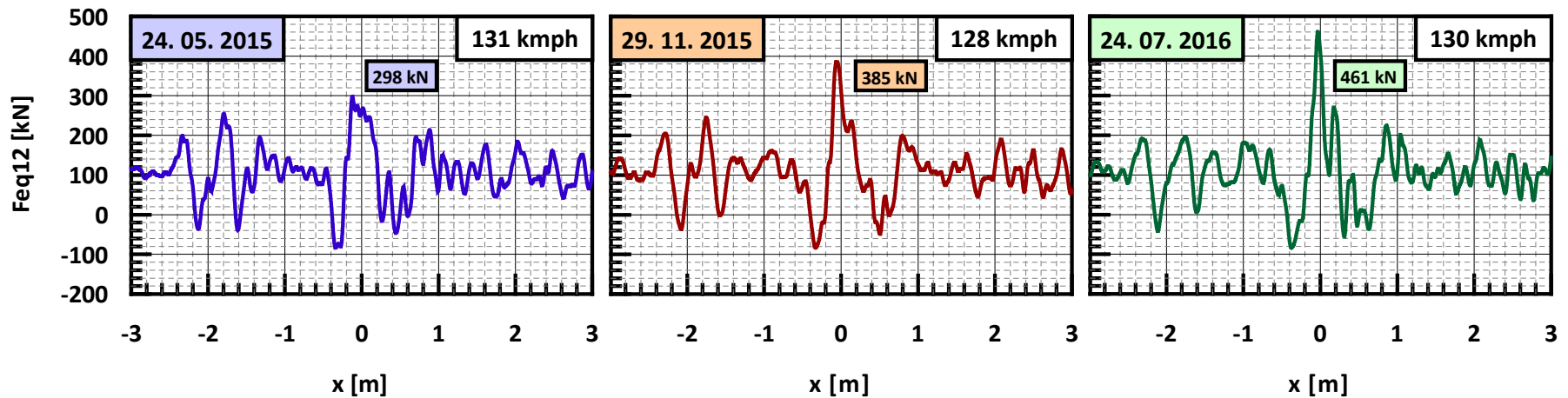
(based on inertia forces of relative unsuspended vehicle mass)

$$F_{eq} = m_{v_r} \cdot g - F_{eq_dyn}$$

$$F_{eq_dyn} = m_{w_r} \cdot \ddot{z}$$

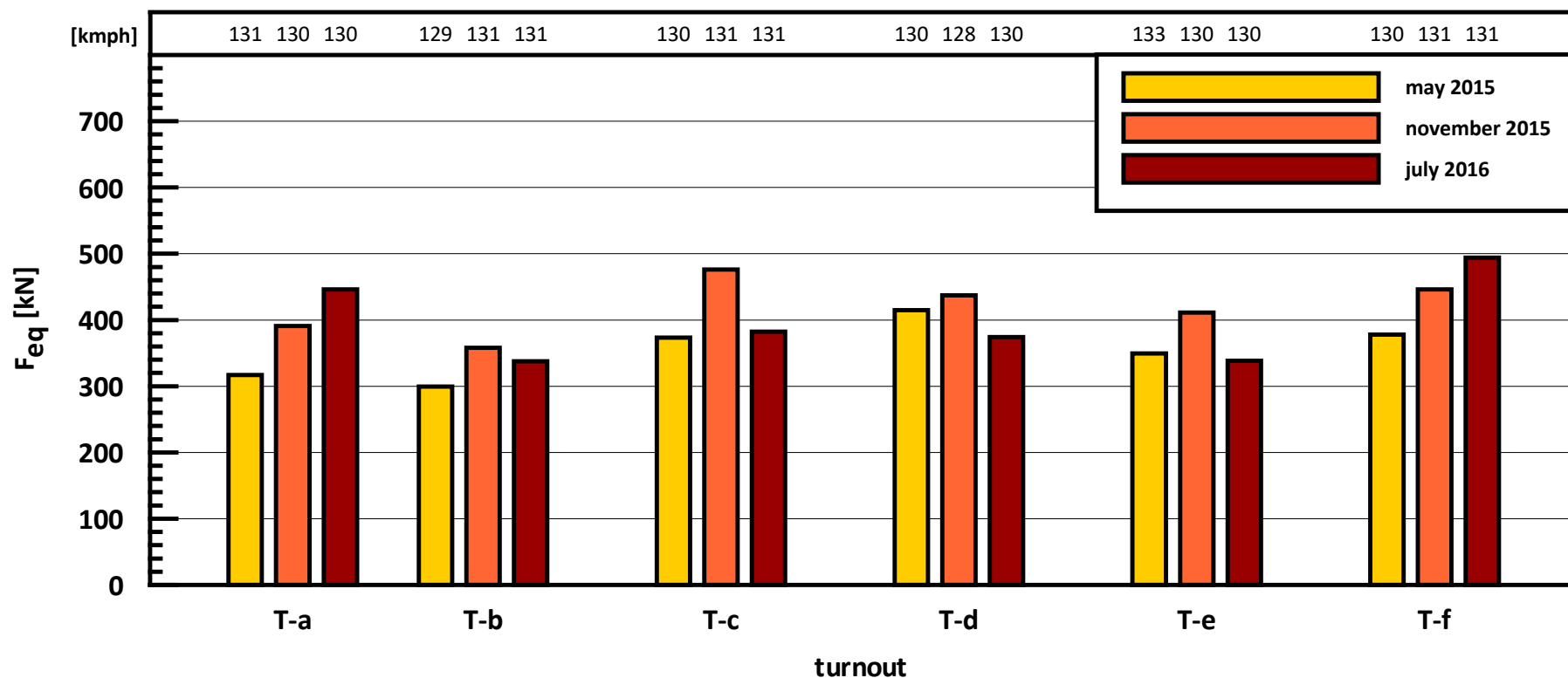
MEASUREMENT EVALUATION

- **Equivalent loading course** during passing over a turnout frog in one year period.

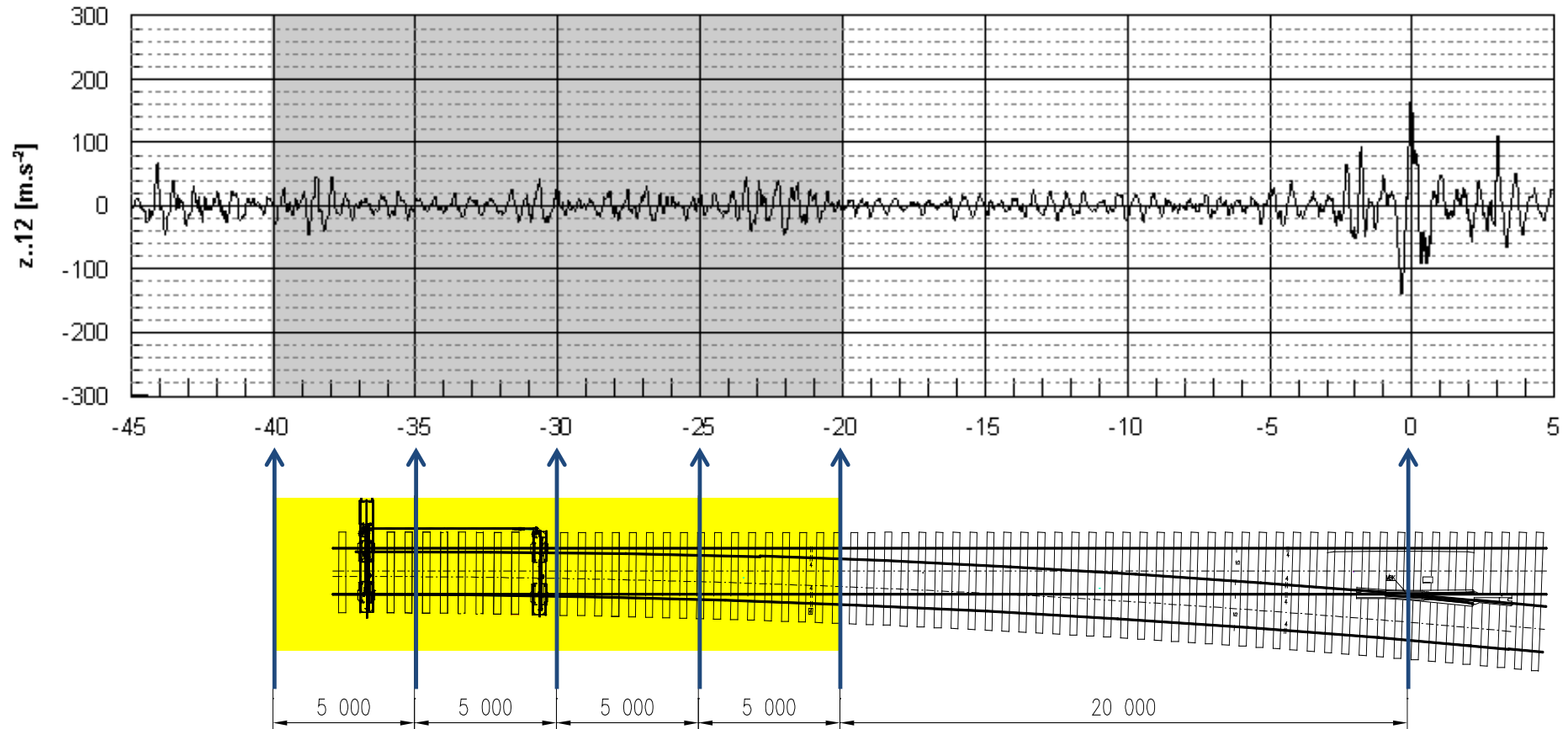


APPLICATION OF EVALUATION METHOD

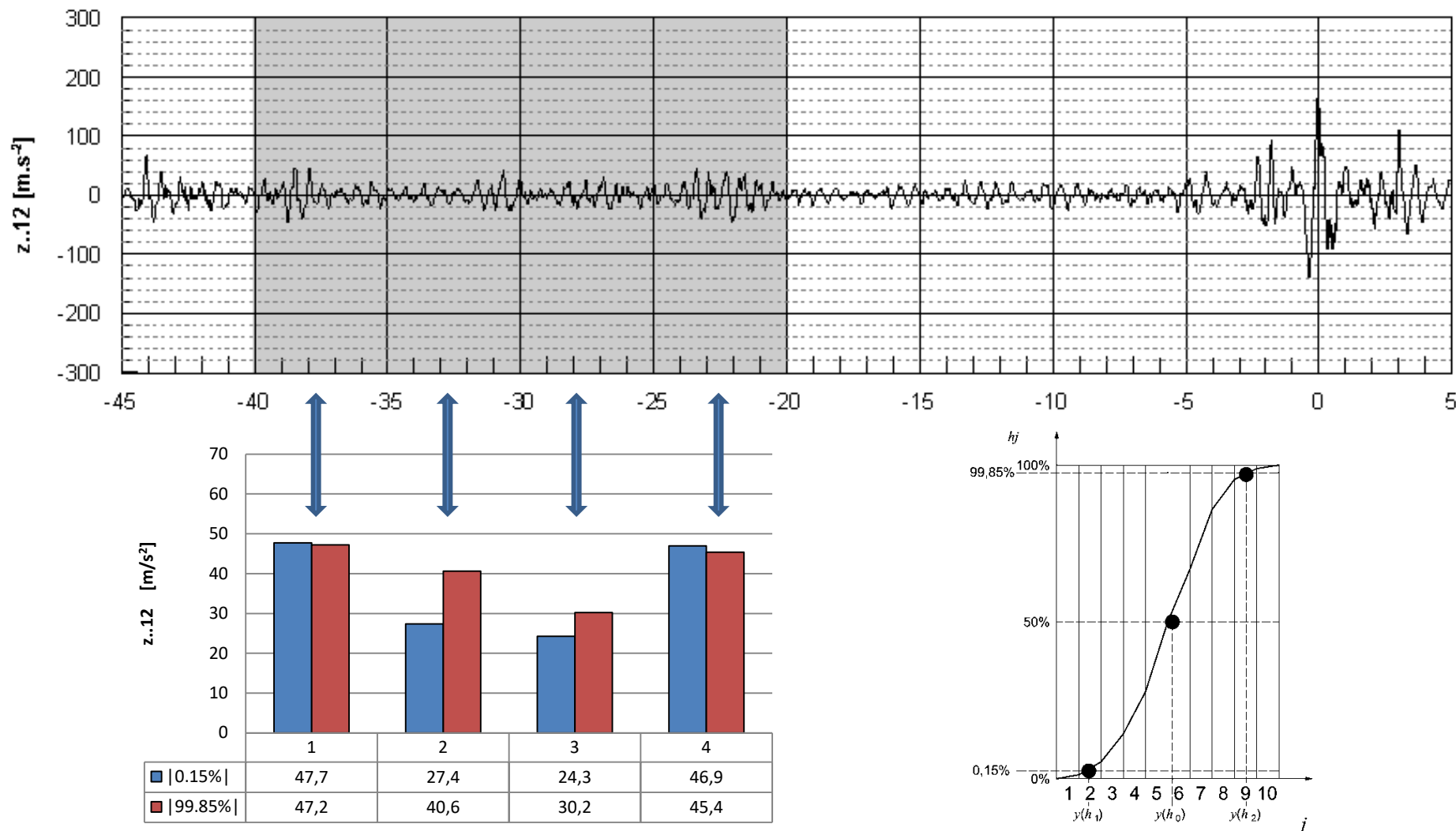
- **Maximum value of equivalent loading** of turnout frog area
(passing over choosed 6 turnouts in the corridor line Praha - Brno)



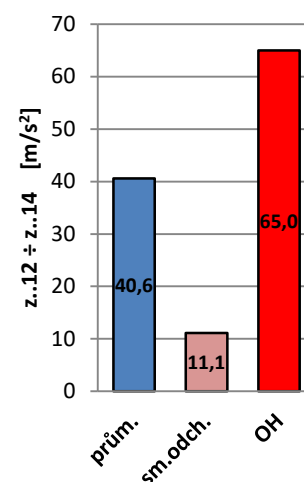
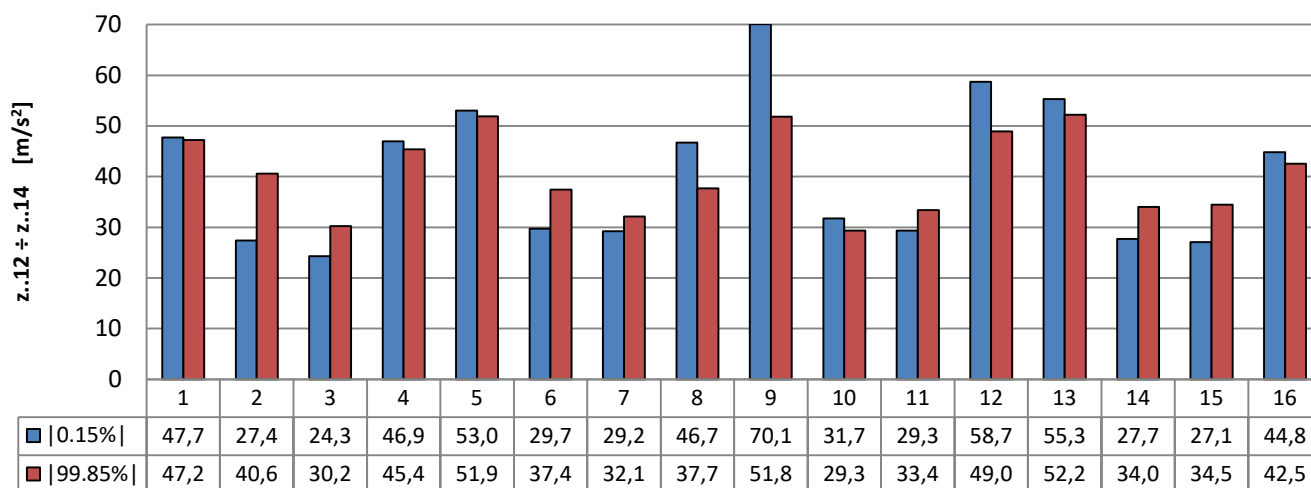
ASSESSMENT OF AREA WITH DIFFERENT STIFFNESS



ASSESSMENT OF AREA WITH DIFFERENT STIFFNESS



ASSESSMENT OF AREA WITH DIFFERENT STIFFNESS



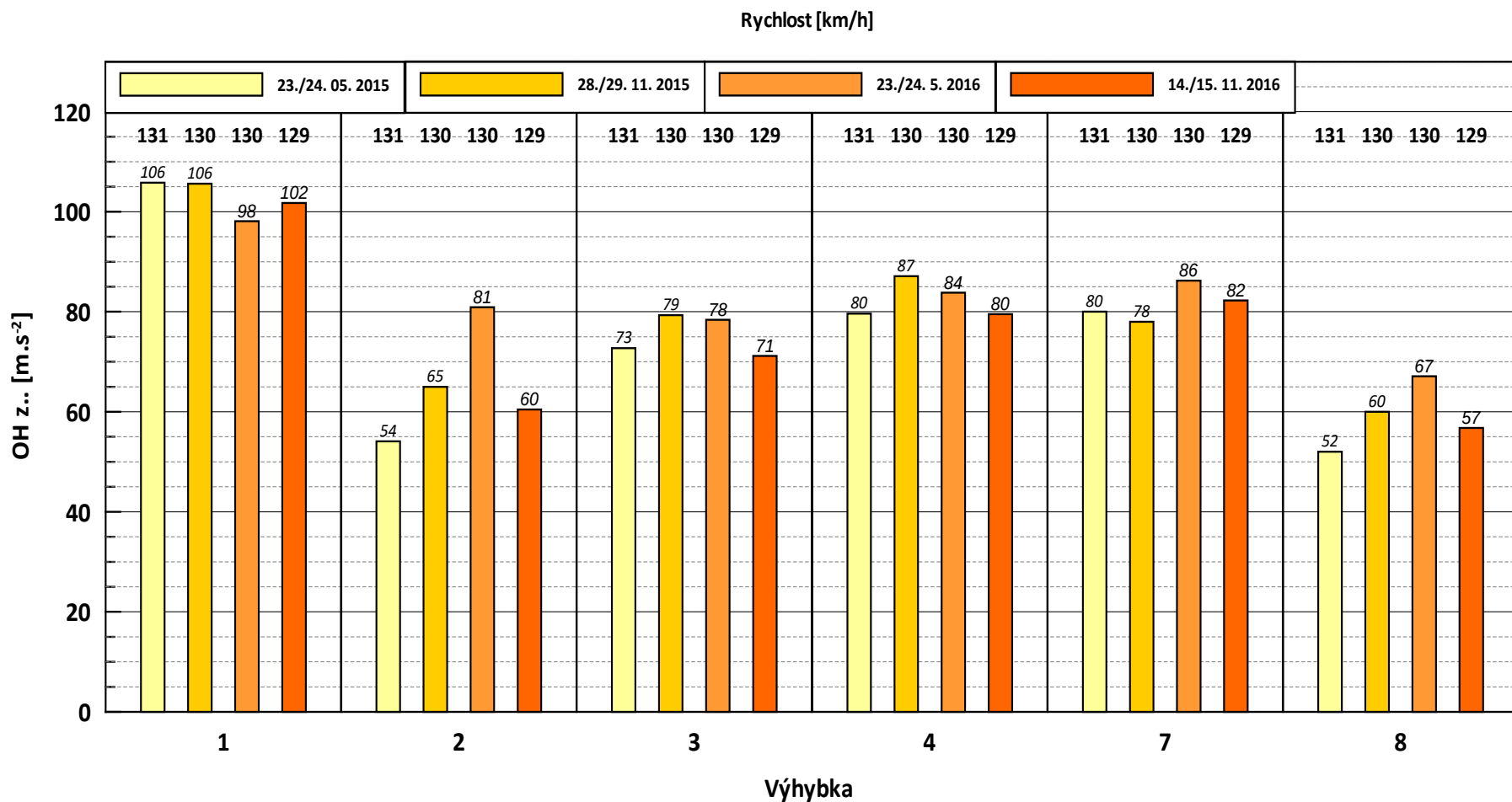
Intensity of vertical acceleration during passing of a vehicle over the area with different stiffness is determined by:

Estimated value $EV_{z..}$

$$EV_{z..} = MVP_{z..(0.15\%, 99.85\%)} + 2,2 \cdot s_{z..(0.15\%, 99.85\%)}$$



ASSESSMENT OF AREA WITH DIFFERENT STIFFNESS



CONCLUSION – FURTHER RESEARCH

- Analysis of **wheel-rail contact points** for different worn profiles detected in service.
- Monitoring of **frog area wear development** of measured turnouts related to different turnout design.
- Including of **dynamical response of the frog area** during passing of the vehicle.



THANK YOU FOR YOUR ATTENTION

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