

Građevinski fakultet  
Univerzitet u Beogradu

Katedra za hidrotehniku i vodno ekološko  
inženjerstvo



Seminarski rad

# Mehanika fluida - CFD

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Robert Ljubičić

Profesori:

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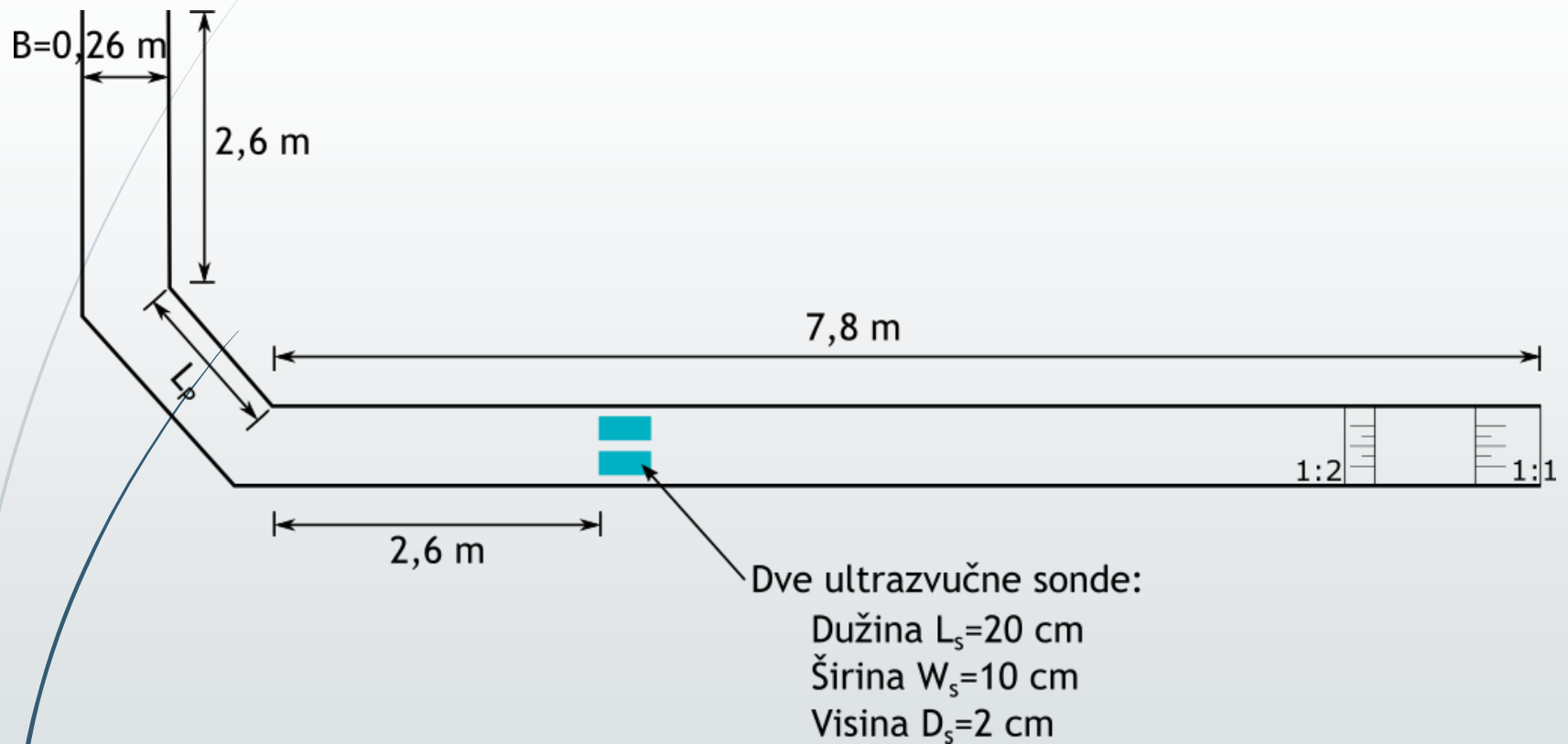
doc. dr Nenad Jaćimović

Beograd, maj 2016

# Sadržaj

1. Uvod
2. Postavke zadatka
3. Formiranje mreže i odabir uslova proračuna
4. Analitičko rešenje
5. Varijanta I:  $L_p=10 \times B$  - Filip Stanić
6. Varijanta II:  $L_p=2 \times B$  - Robert Ljubičić
7. Poređenje rezultata
8. Zaključci

# Postavke zadatka

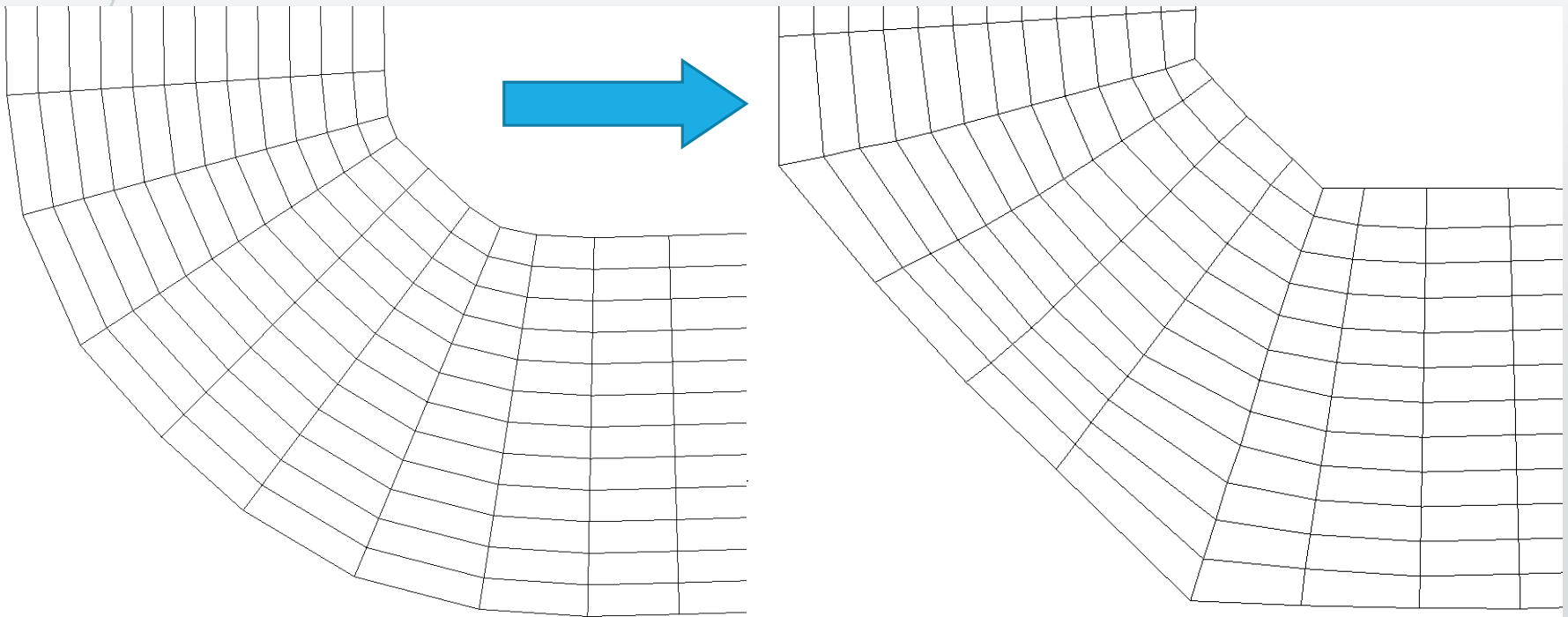


Zadatak 5:  $L_p = 2,0 \times B = 0,52$  m

Zadatak 6:  $L_p = 0,4 \times B = 0,10$  m

# Formiranje mreže (Grid creation)

- Grid formiran duž putanje
- Za formiranje grid-a u zoni krivine neophodna ručna intervencija (**nestabilnost proračuna**)

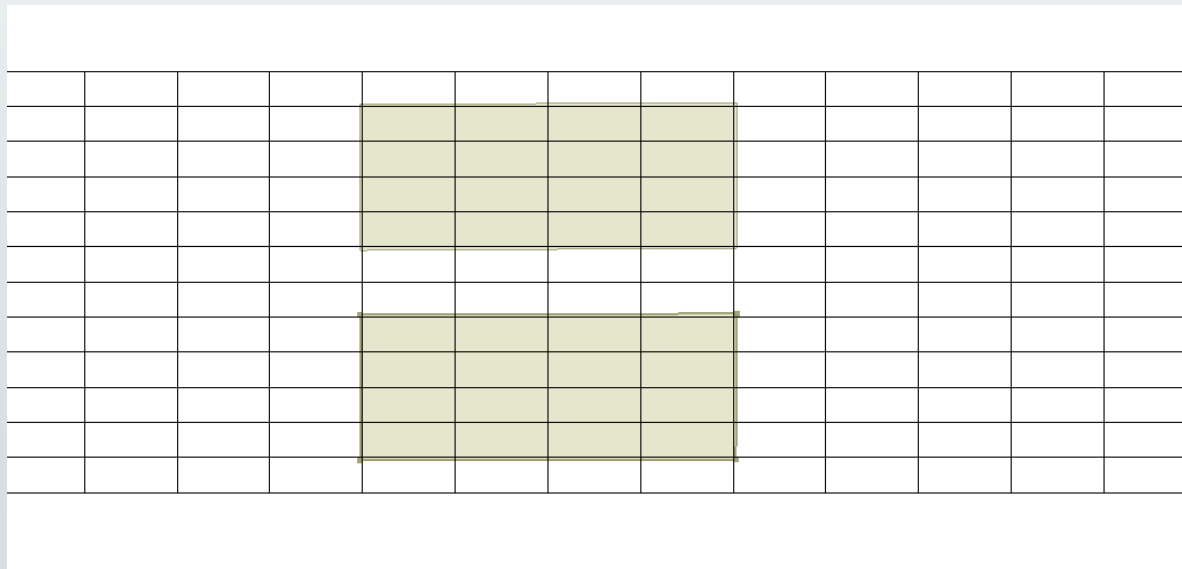


# Formiranje mreže (Grid creation)

- Neophodno formirati pad dna kanala:

grid **export** as .csv → **edit** → **import** .csv grid

- Visina prepreka (sondi) se usvaja u broju ćelija u pravcu **z** ose  $\approx 2$  ćelije



# Napomene

- Voditi računa o dužini širokog praga ( $3h_p-5h_p$ )
- Poželjno obezbediti mirno tečenje u deonici uzvodno od praga
- Vreme proračuna bi trebalo da bude dovoljno dugo da se obezbedi relativno ustaljeno tečenje u zoni sonde i u krivini
- Geometrija i mreža u zoni krivine mogu biti uzrok nestabilnog proračuna!

# Uslovi proračuna

Calculation Condition

Groups

- Basic Parameters
- Time Conditions
- Flow Conditions
- Roughness Conditions
- Bed Conditions
- Vegetation Conditions
- Boundary conditions
- Hot start conditions
- Additional output files
- Initial topography co...
- DriftWood
- Advanced settings

Number of Vertical Layers: 15

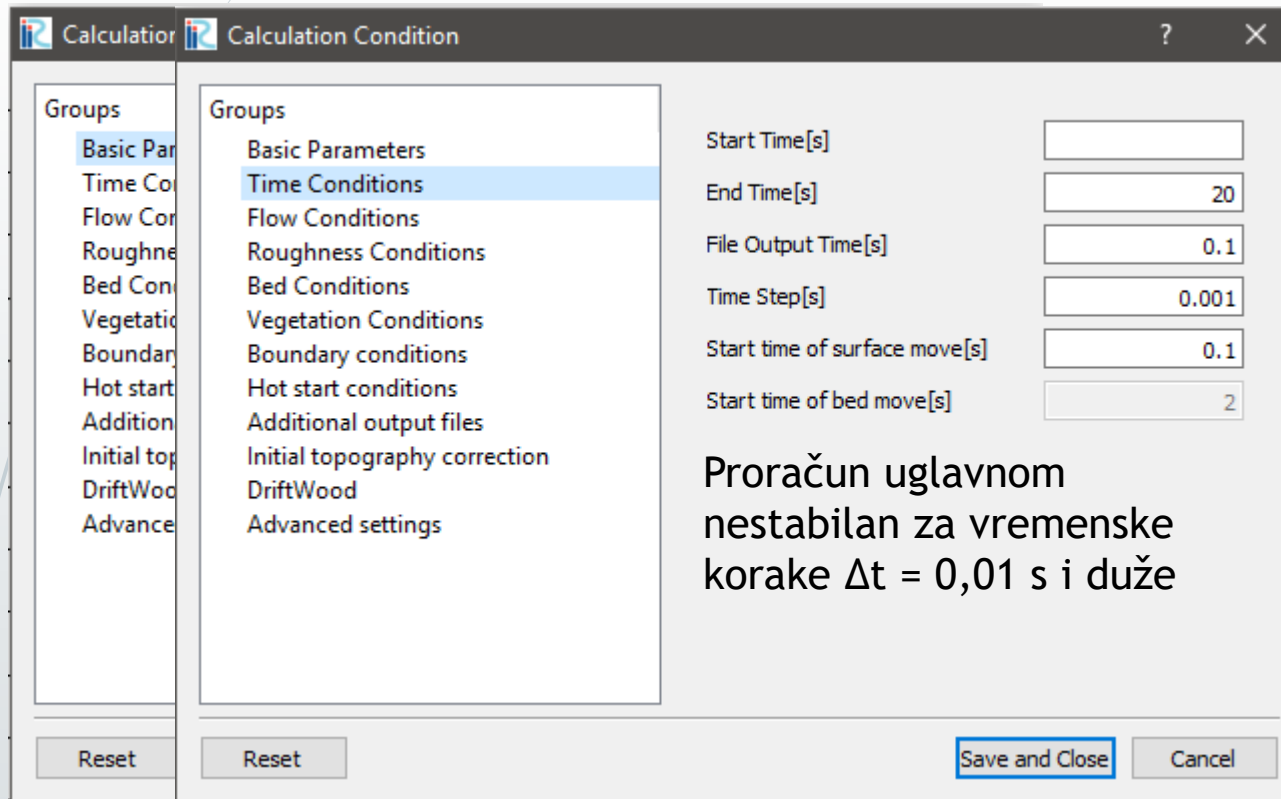
Fixed or Movable Bed: Fixed bed

Turbulence Model: Non-linear k-e model

Spatial Scheme for Advection Terms: TVD MUSCL

Reset Save and Close Cancel

# Uslovi proračuna





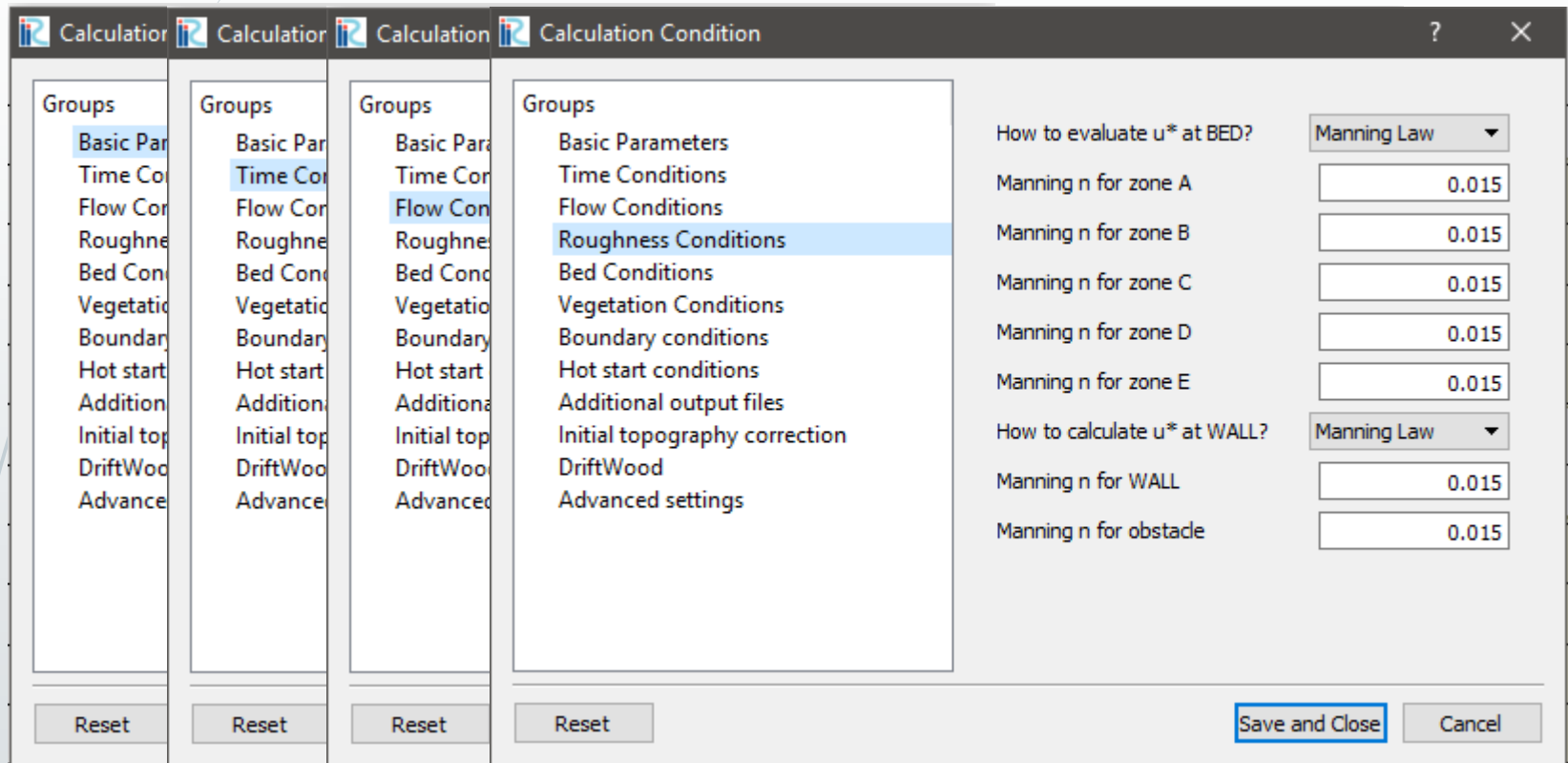
# Uslovi proračuna

The screenshot shows the 'Calculation Condition' dialog box with the following settings:

Parameter	Value
Discharge[m3/s]	0.04
How to give outlet water level?	Given directly
Downstream Water Level[m]	1.055
Minimum Depth[m]	0
How to give initial surface slope?	Given by initial average bed slope
Initial surface slope	0.0001
Q gradual increase	Q given directly
Initial Q rate	0.1
Time for Q slope[s]	10

Buttons: Reset (under each pane), Save and Close, Cancel.

# Uslovi proračuna



# Uslovi proračuna

Calculation Condition

Groups

- Basic Parameters
- Time Conditions
- Flow Conditions
- Roughness Conditions
- Bed Conditions
- Vegetation Conditions
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- Hot start conditions
- Additional output files
- Initial topography co...
- DriftWood
- Advanced settings

Discharge[m3/s] 0.04

How to give outlet water level? Given directly

Downstream Water Level[m] 1.055

Minimum Depth[m] 0

How to give initial surface slope? Given by initial average bed slope

Initial surface slope 0.0001

Q gradual increase Q given directly

Initial Q rate 0.1

Time for Q slope[s] 10

Reset Save and Close Cancel

Nizvodni granični uslov (zadana KOTA nivoa) se može dobiti ili iz analitičkih izraza, probanjem, ili kombinacijom navedenog

$$I_d = 0,01$$

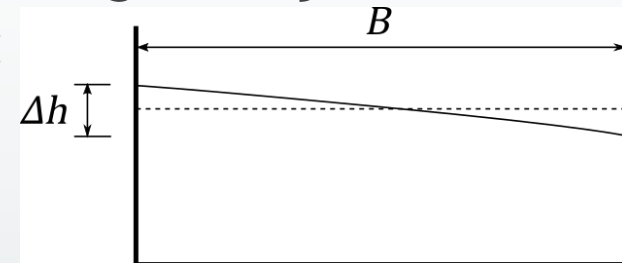
$$h_N = 0,1395 \text{ m}$$

$$h_{KR} = 0,1341 \text{ m}$$

# Analitičko rešenje

- ▶ Za krivinu u osnovi toka, poprečni nagib linije nivoa se može oceniti na osnovu izraza:

$$\Delta h = \frac{v^2 B}{gR}$$



gde su:  $v$  - prosečna brzina u poprečnom preseku

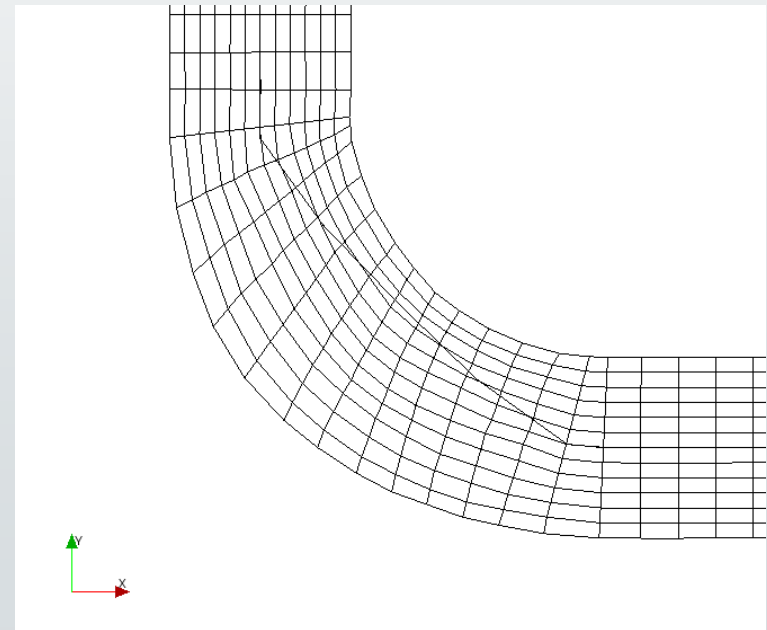
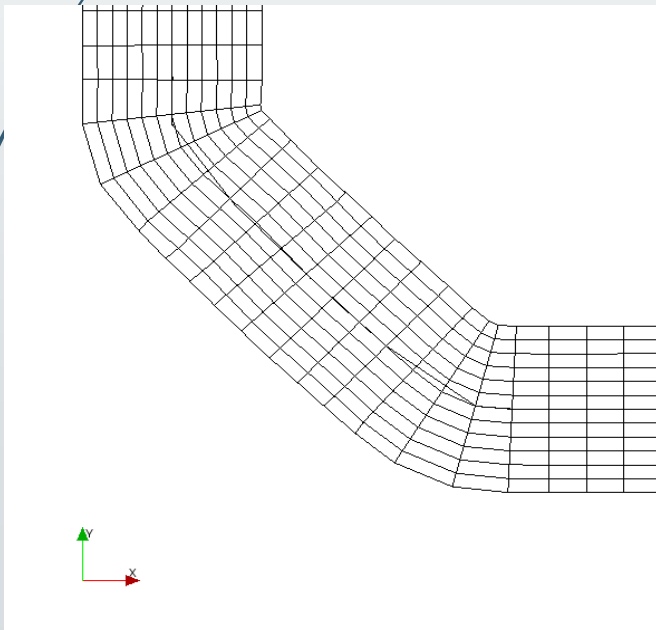
$B$  - širina vodenog ogledala

$R$  - poluprečnik krivine u osnovi

a  $\Delta h$  predstavlja razliku nivoa konkavne i konveksne obale.

# Varijanta I - $L_p = 2 \times B$

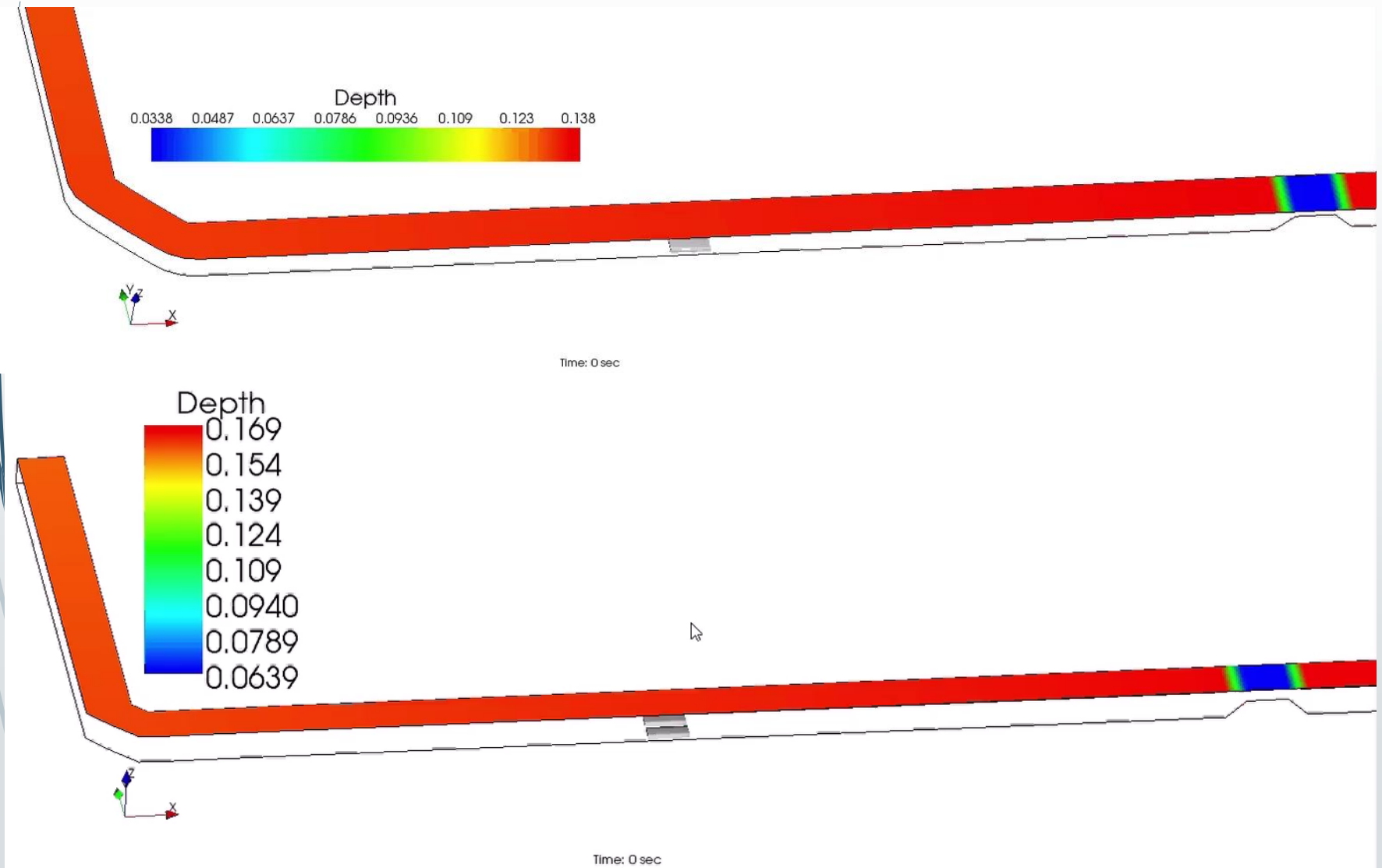
- ▶ Varijanta sa dužom krivinom - očekuje se slabije izražena turbulencija
- ▶ Podvarijante:
  - ▶ Oštra (zasečena krivina)
  - ▶ Kružna krivina



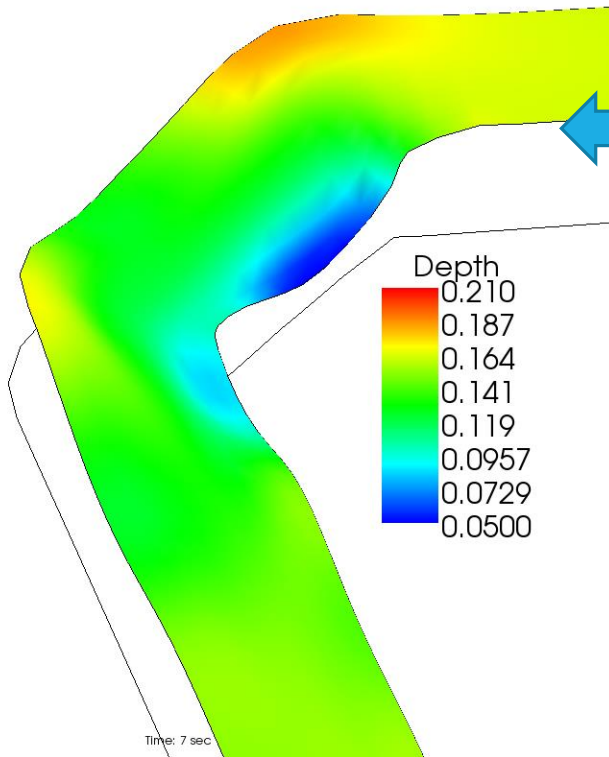
## ➤ Varijanta II - $L_p = 0,4 \times B$

- Varijanta sa 5 puta kracom prelaznom deonicom - očekuje se znatno veća turbulencija
- Podvarijante:
  1. Prava prelaznica sa širokim pragom nizvodno
  2. Prava prelaznica bez nizvodnog praga
  3. Kružna prelaznica sa nizvodnim pragom
  4. Kružna prelaznica bez nizvodnog praga  
(za 1-4: **nelinearni k- $\epsilon$**  model, **TVD MUSCL** šema)
  5. Kružna prelaznica bez nizvodnog praga, **linearni k- $\epsilon$**  model, advektivni članovi diskretizovani **upwind** šemom 1 reda

# Poređenje rezultata - Dubine



# Varijanta I - Dubine



Analitički t=7,0 s:

$$\Delta h = 8,6 \text{ cm}$$

NaysCUBE t=7,0 s:

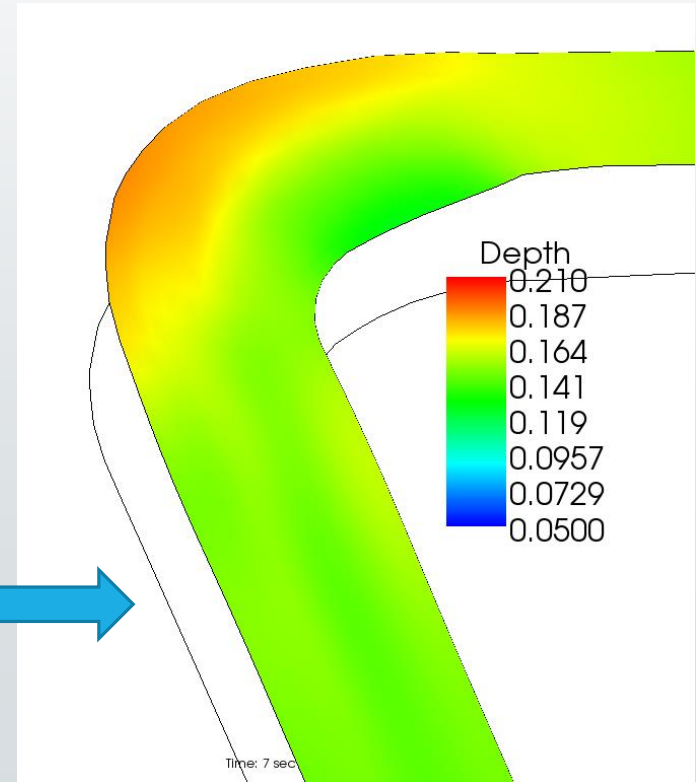
$$\Delta h = 11,5 \text{ cm}$$

Analitički t=7,0 s:

$$\Delta h = 7,2 \text{ cm}$$

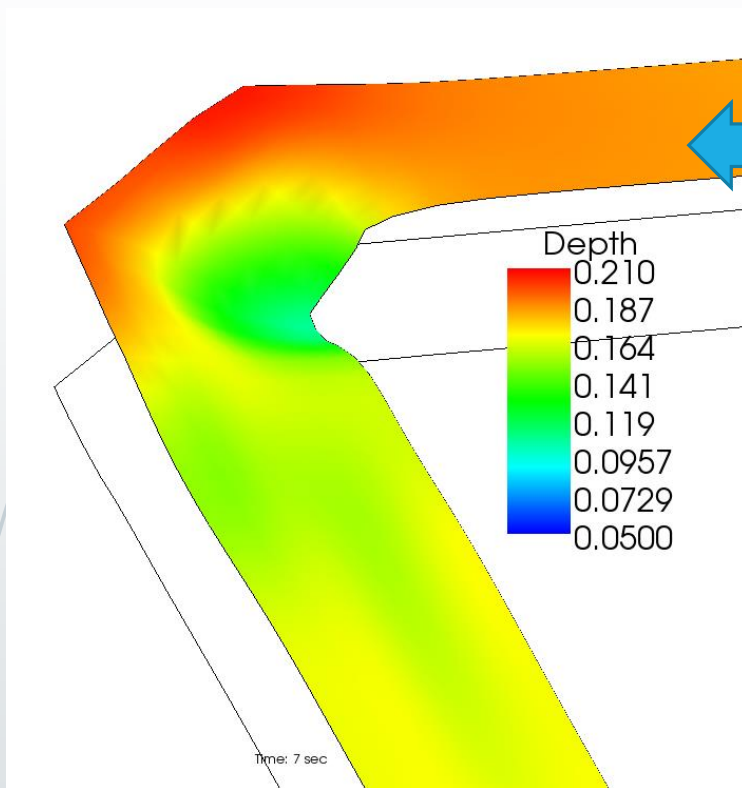
NaysCUBE t=7,0 s:

$$\Delta h = 6,8 \text{ cm}$$





# Varijanta II - dubine

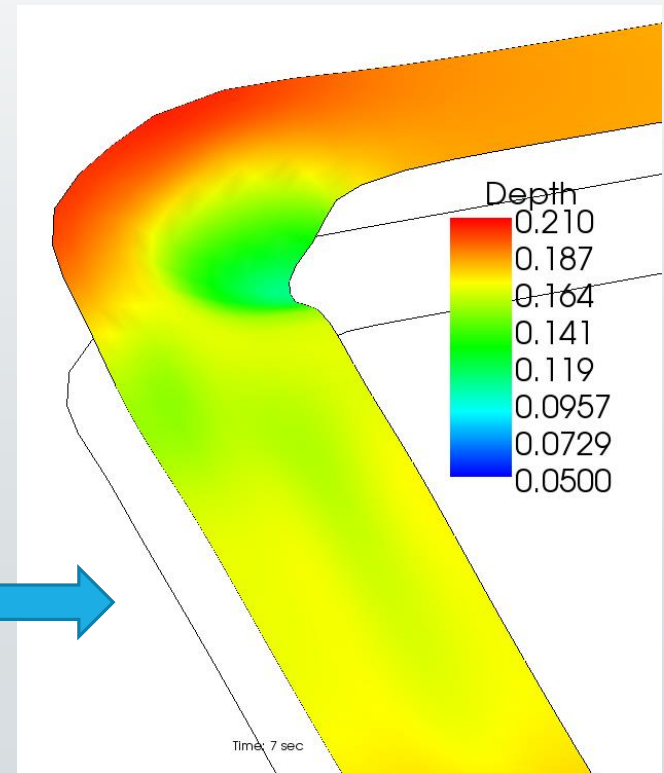


Analitički t=7,0 s:  
 $\Delta h = 10,2$  cm

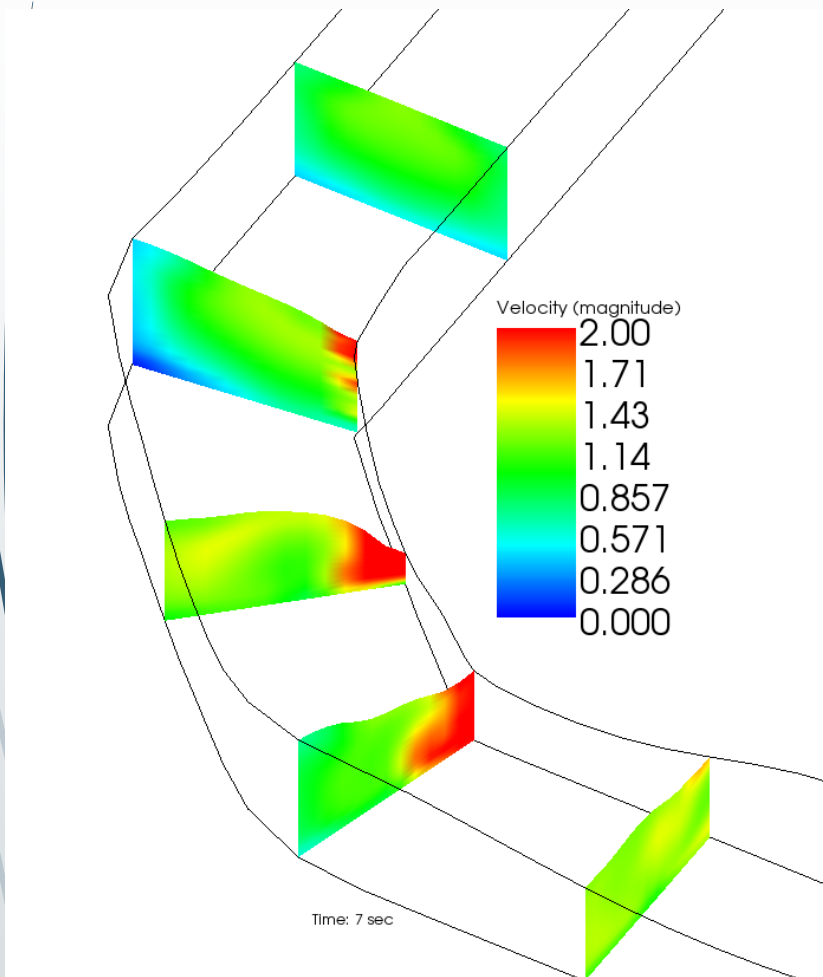
NaysCUBE t=7,0 s:  
 $\Delta h = 8,5$  cm

Analitički t=7,0 s:  
 $\Delta h = 9,3$  cm

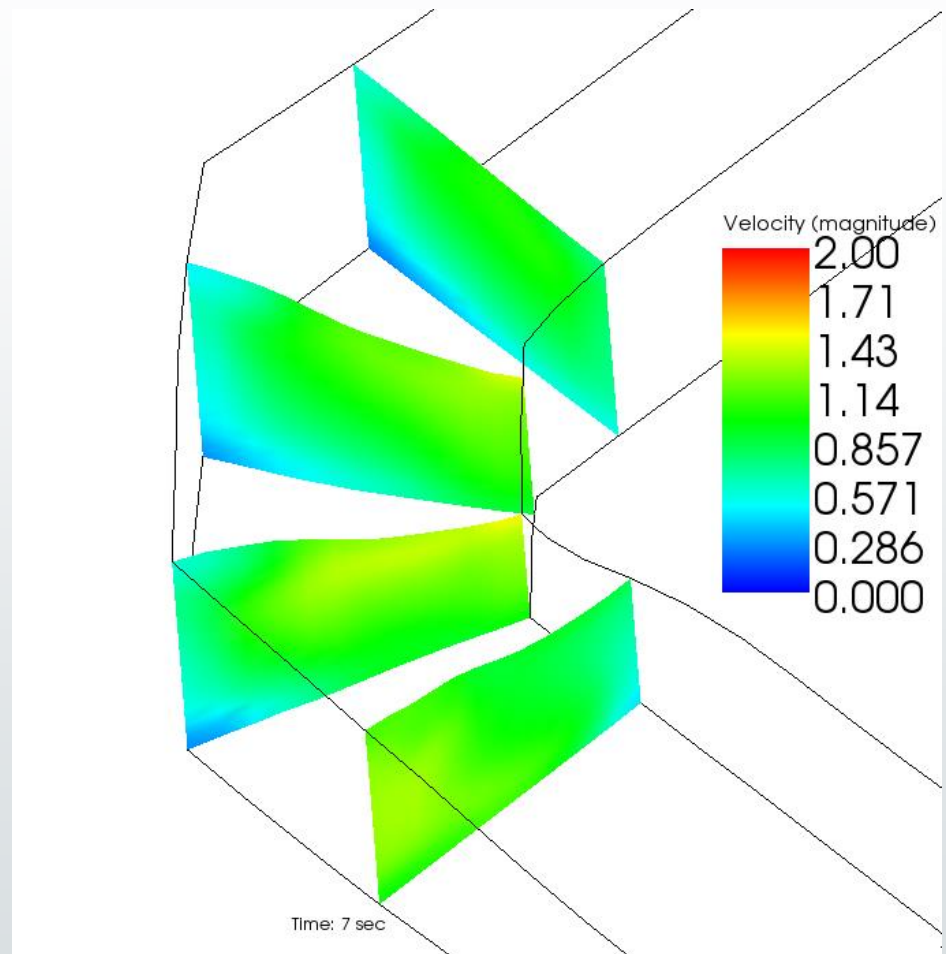
NaysCUBE t=7,0 s:  
 $\Delta h = 8,5$  cm



# Poređenje rezultata - brzine

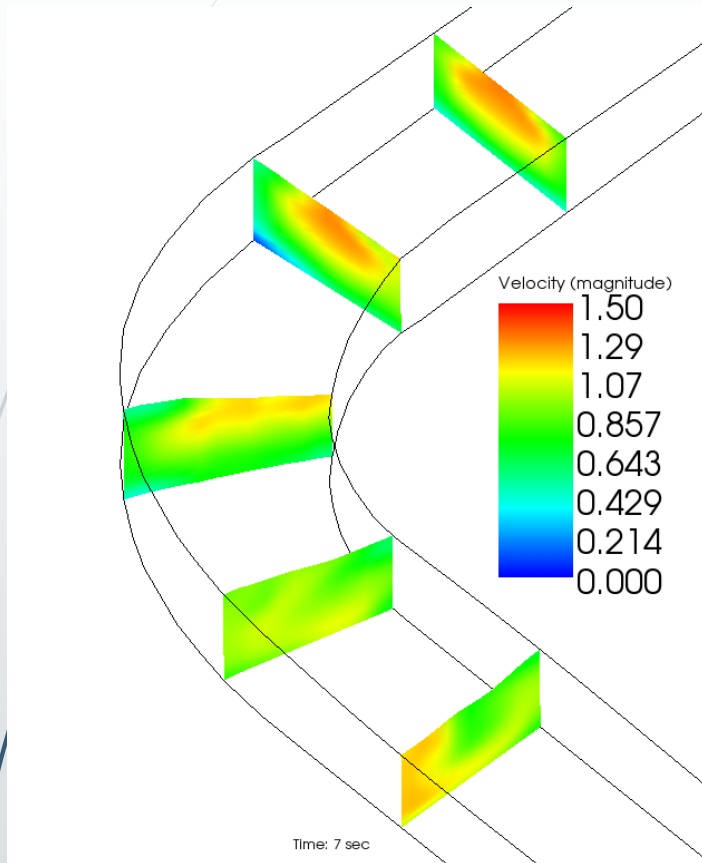


Varijanta I.1, t=7s

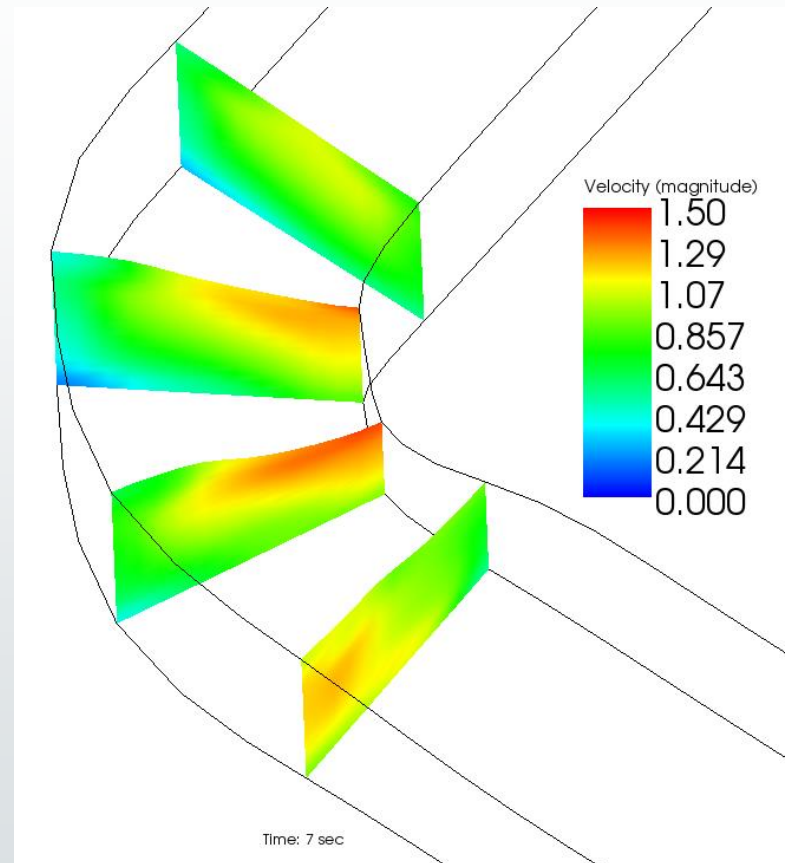


Varijanta II.1, t=7s

# Poređenje rezultata - brzine

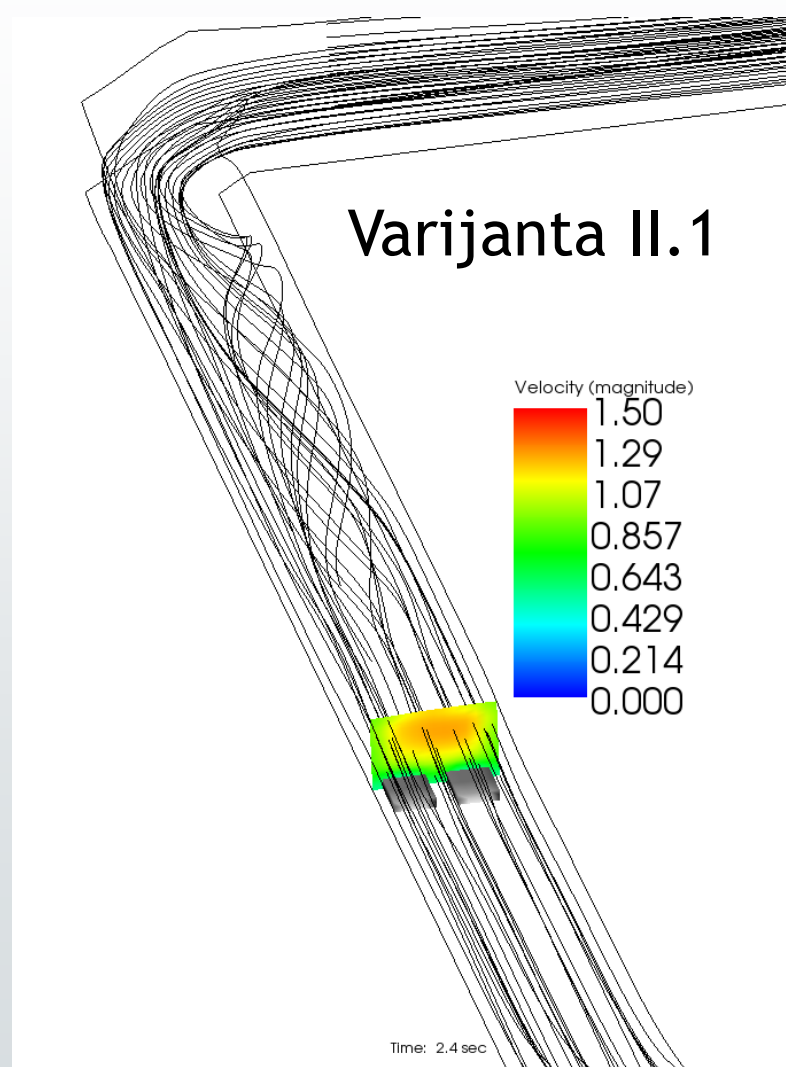
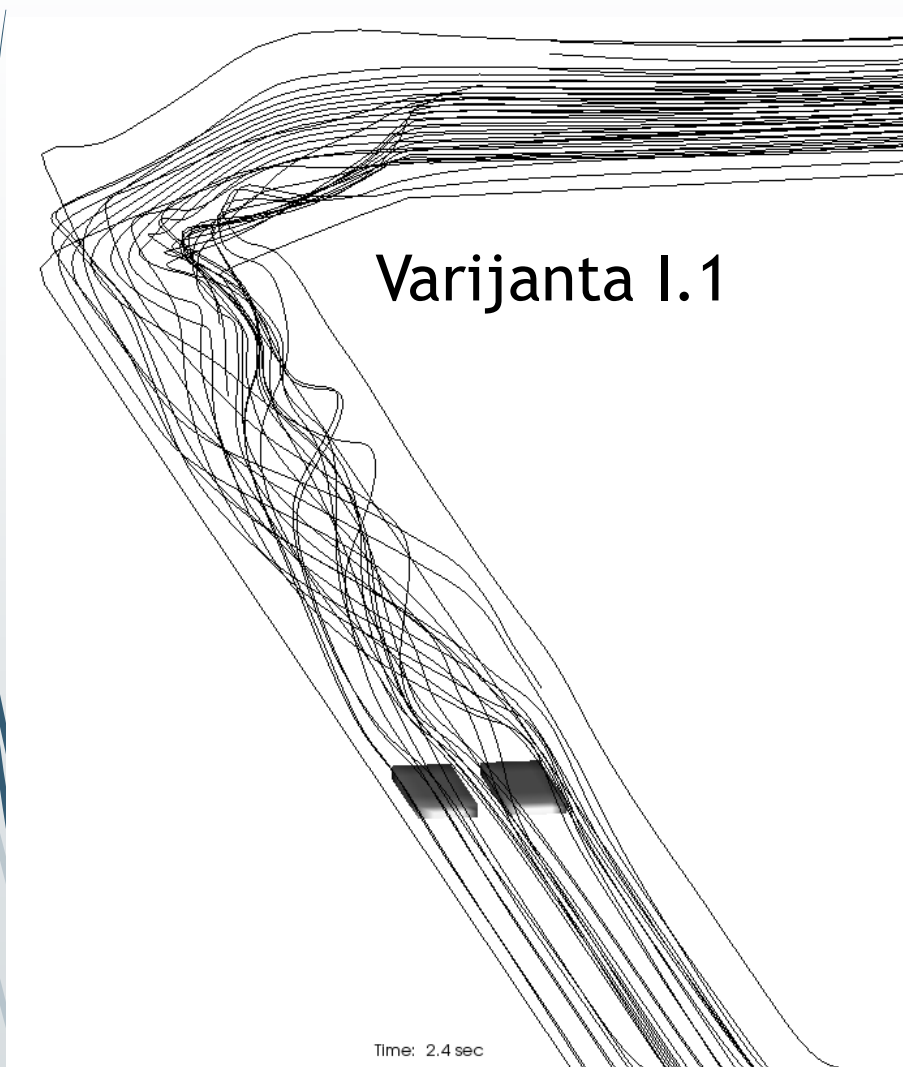


Varijanta 1.2, t=7s



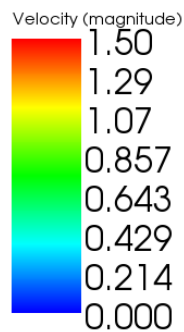
Varijanta 11.2, t=7s

# Poređenje rezultata - Strujno polje

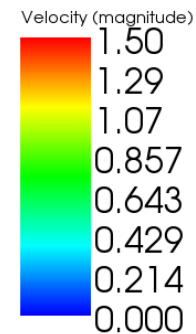


# Poređenje rezultata - Strujno polje

## Varijanta I.2



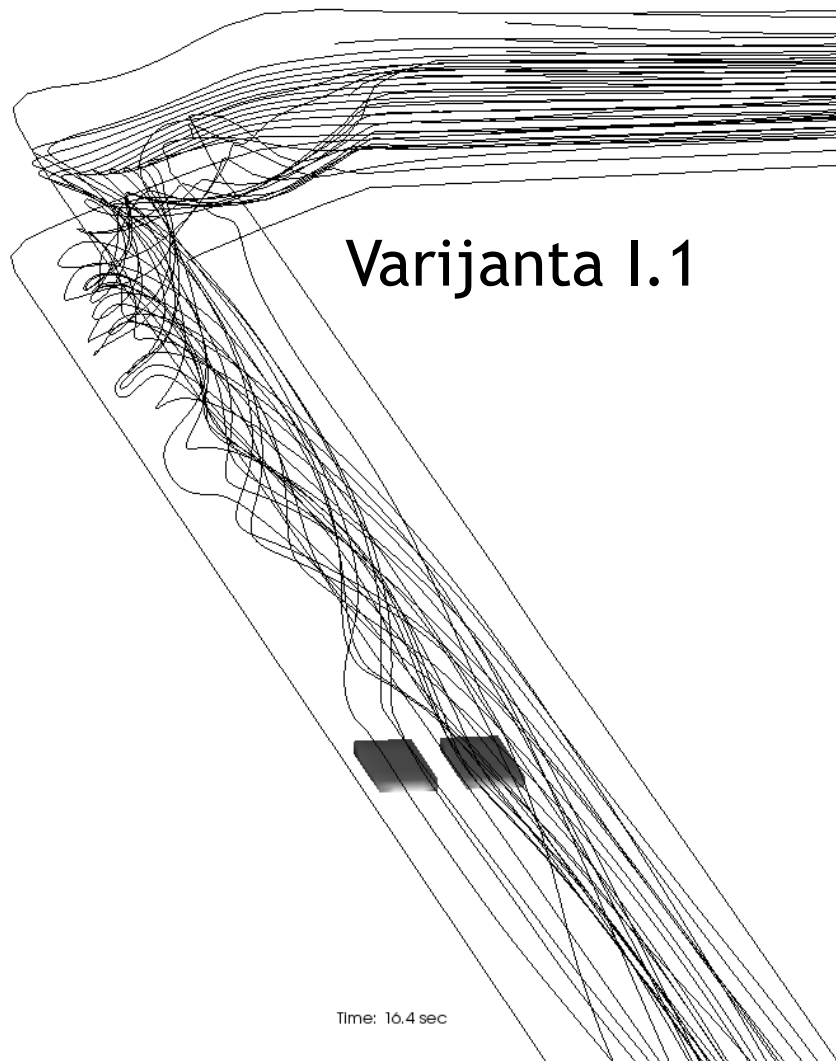
## Varijanta II.2



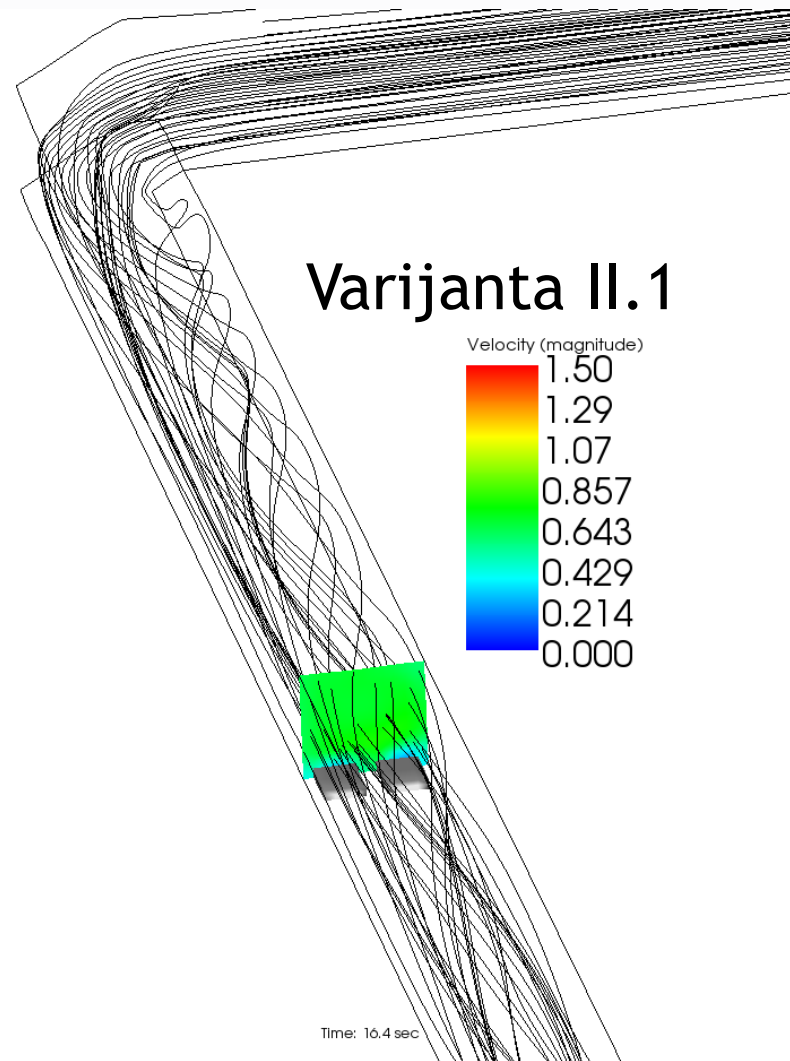
Time: 2.4 sec

Time: 2.4 sec

# Poređenje rezultata - Strujno polje



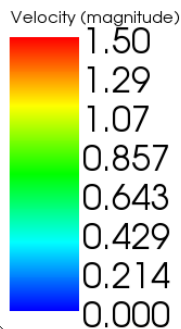
Varijanta I.1



Varijanta II.1

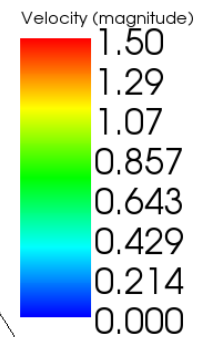
# Poređenje rezultata - Strujno polje

## Varijanta I.2



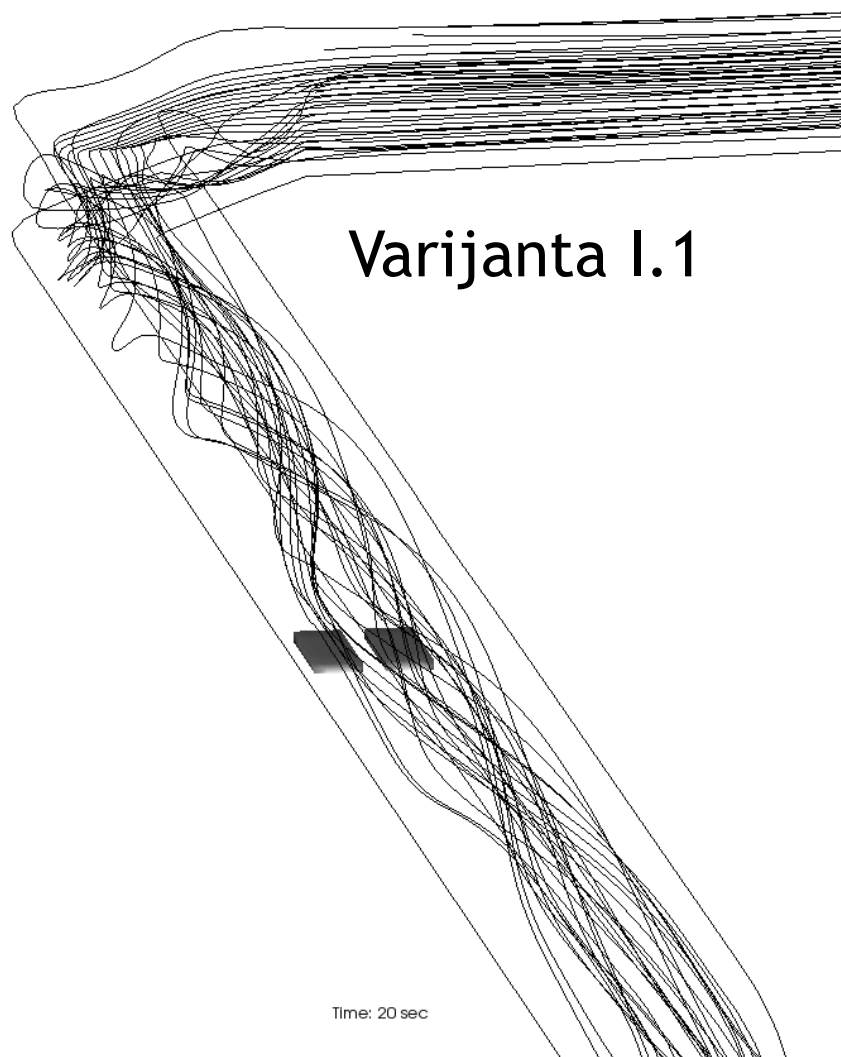
Time: 16.4 sec

## Varijanta II.2

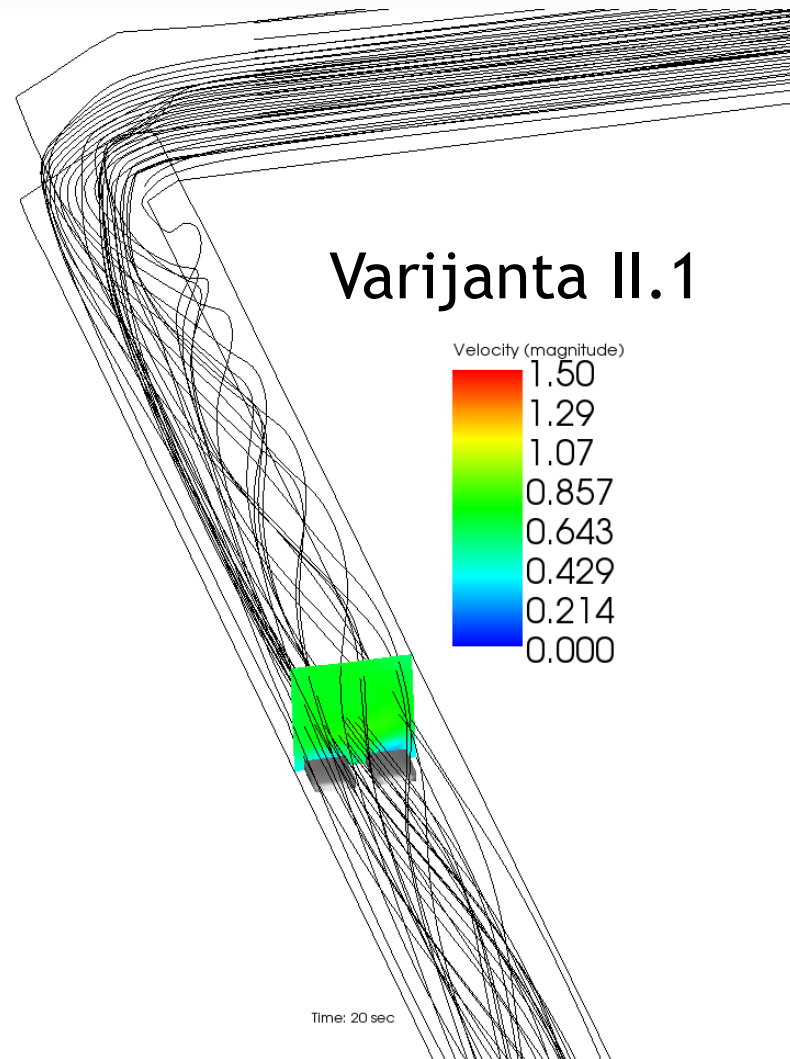


Time: 16.4 sec

# Poređenje rezultata - Strujno polje



Varijanta I.1

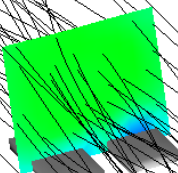
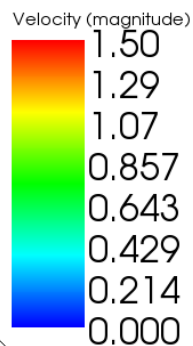


Varijanta II.1



# Poređenje rezultata - Strujno polje

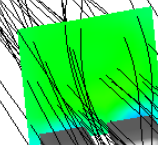
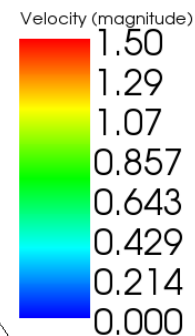
## Varijanta I.2



Time: 20 sec

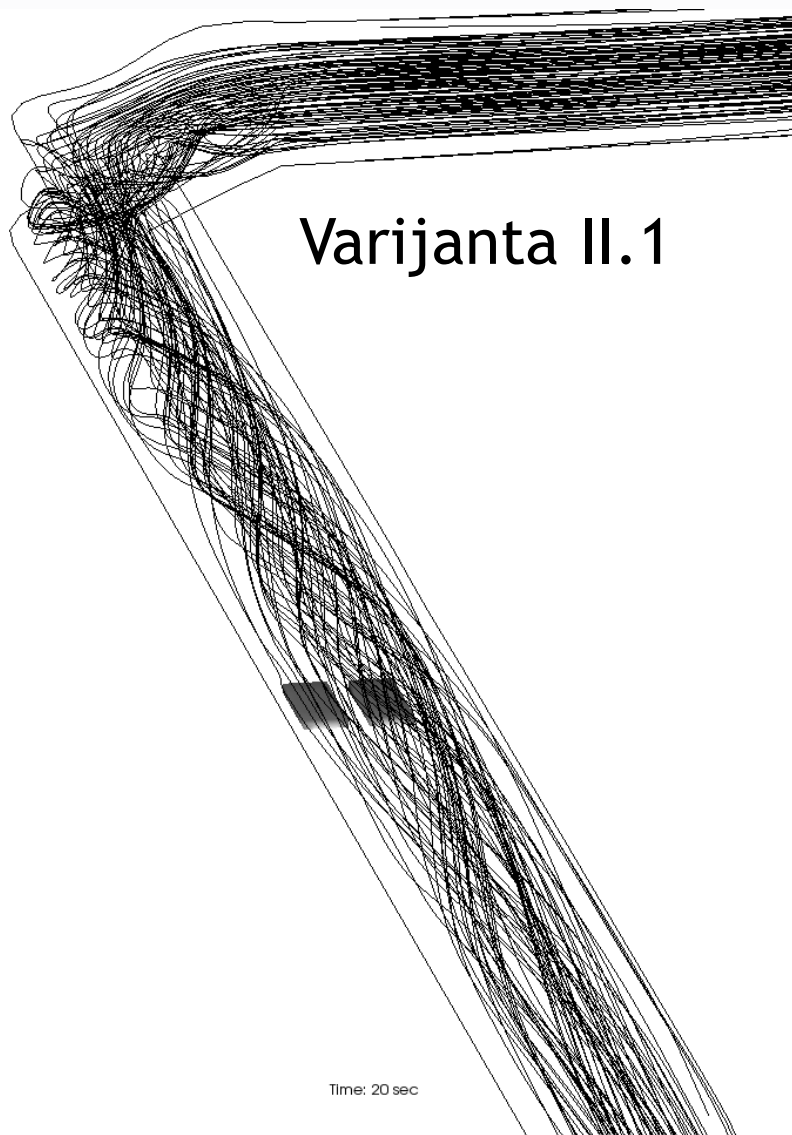


## Varijanta II.2

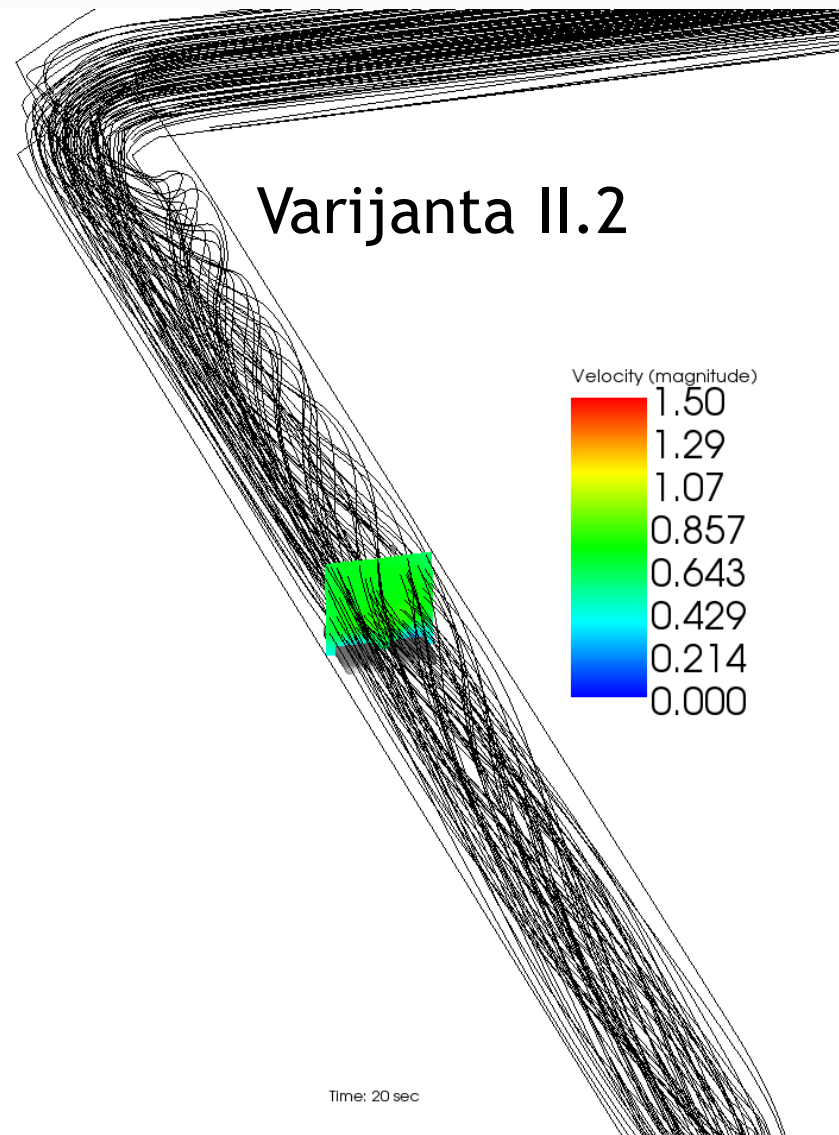


Time: 20 sec

# Poređenje rezultata - Strujno polje



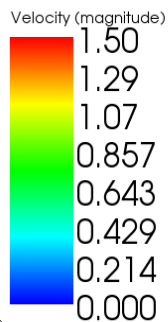
Varijanta II.1



Varijanta II.2

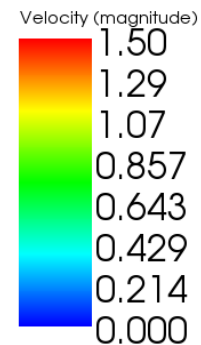
# Poređenje rezultata - Strujno polje

## Varijanta I.2



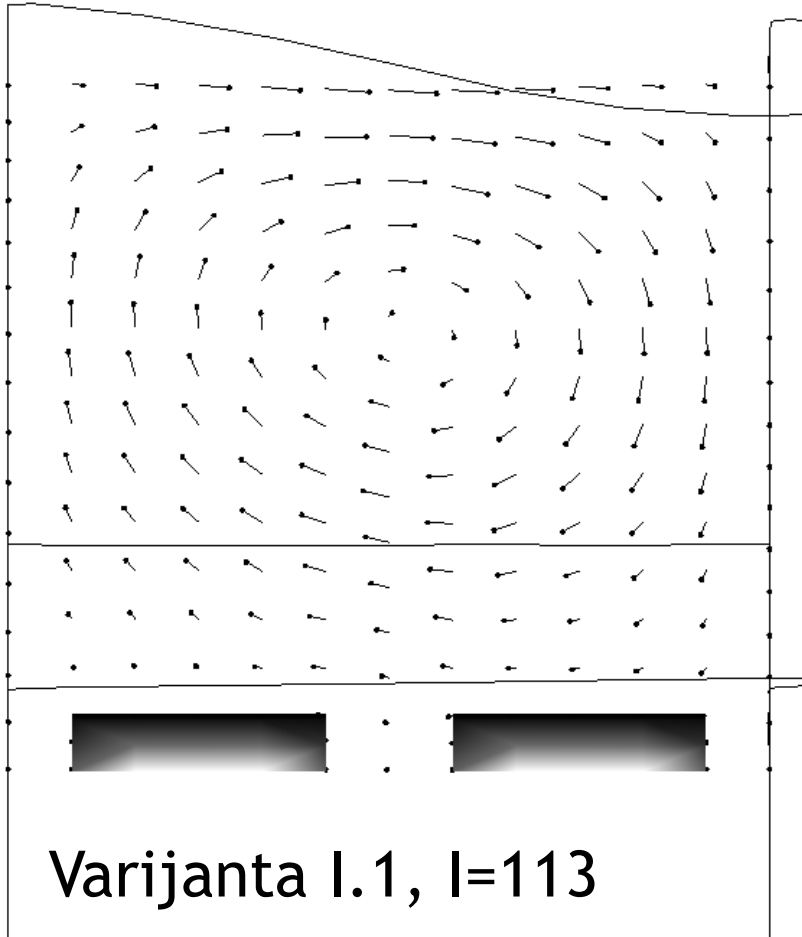
Time: 20 sec

## Varijanta II.2

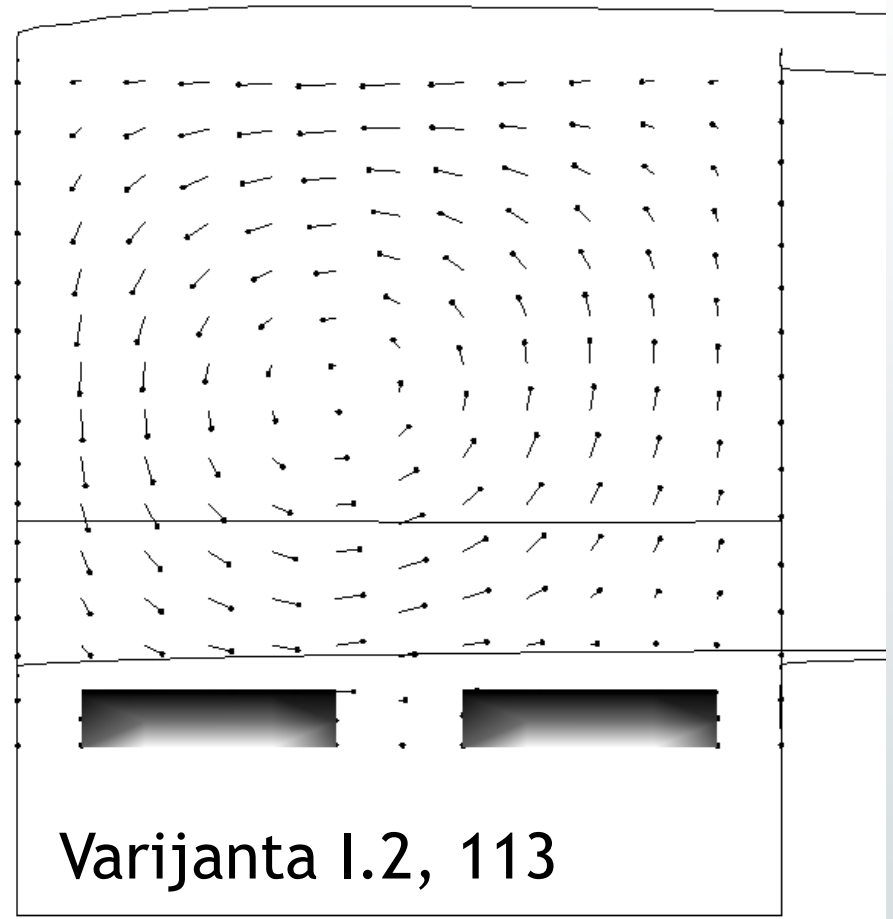


Time: 20 sec

# Varijanta I - Strujno polje

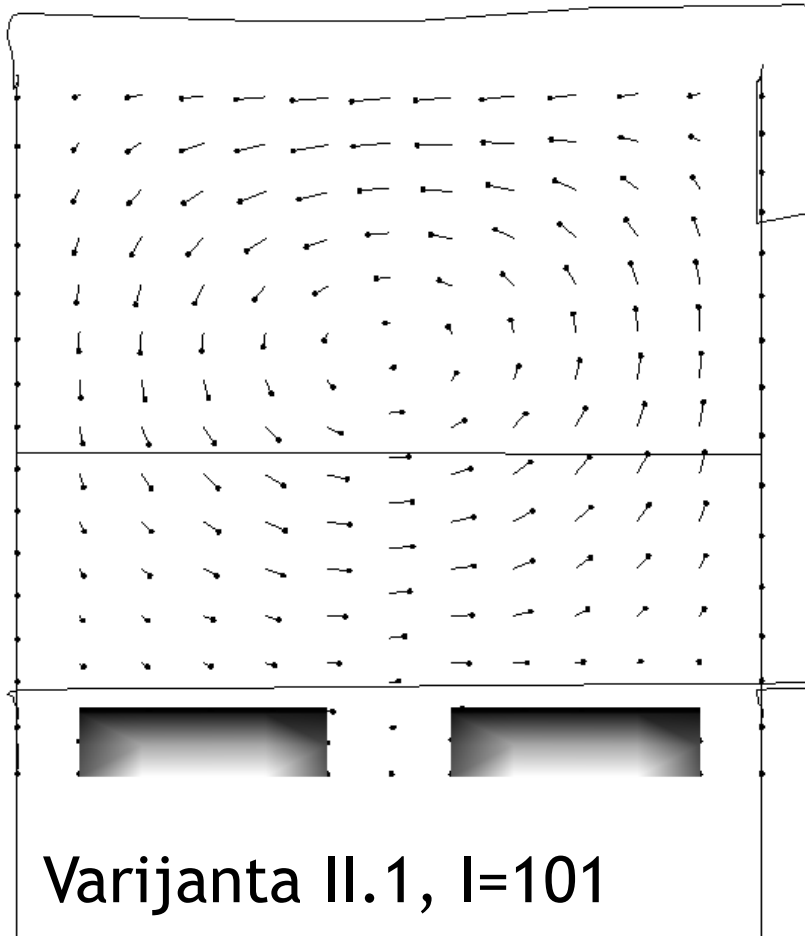


Time: 20 sec

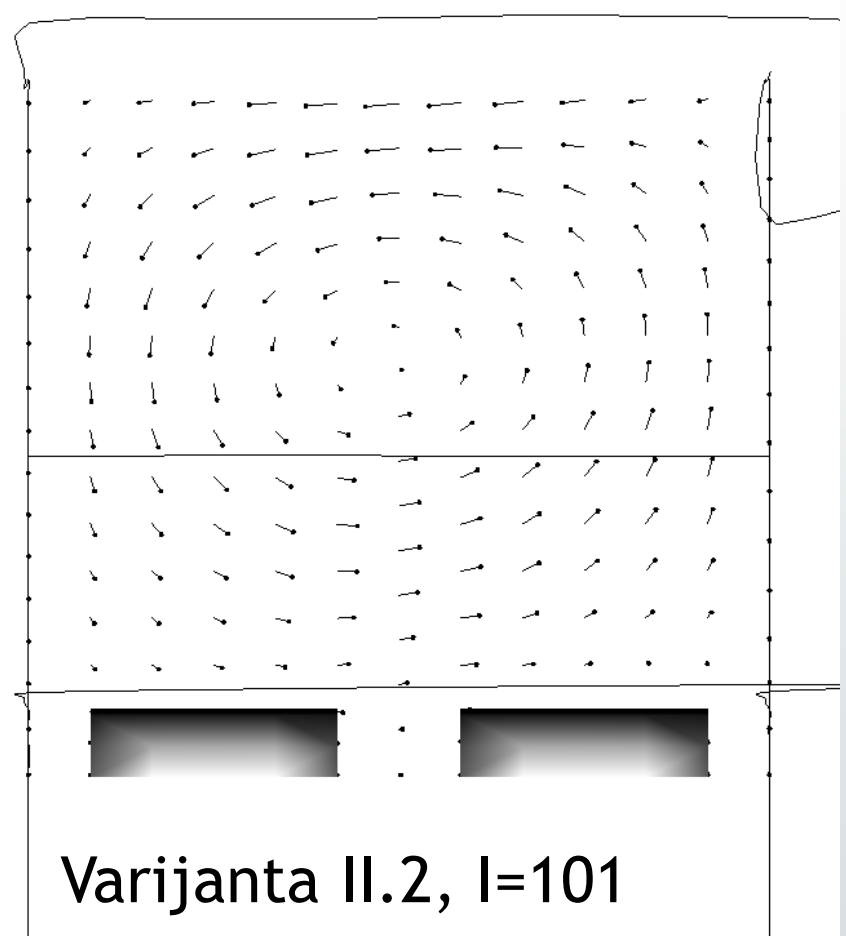


Time: 20 sec

# ➤ Varijanta II - Strujno polje

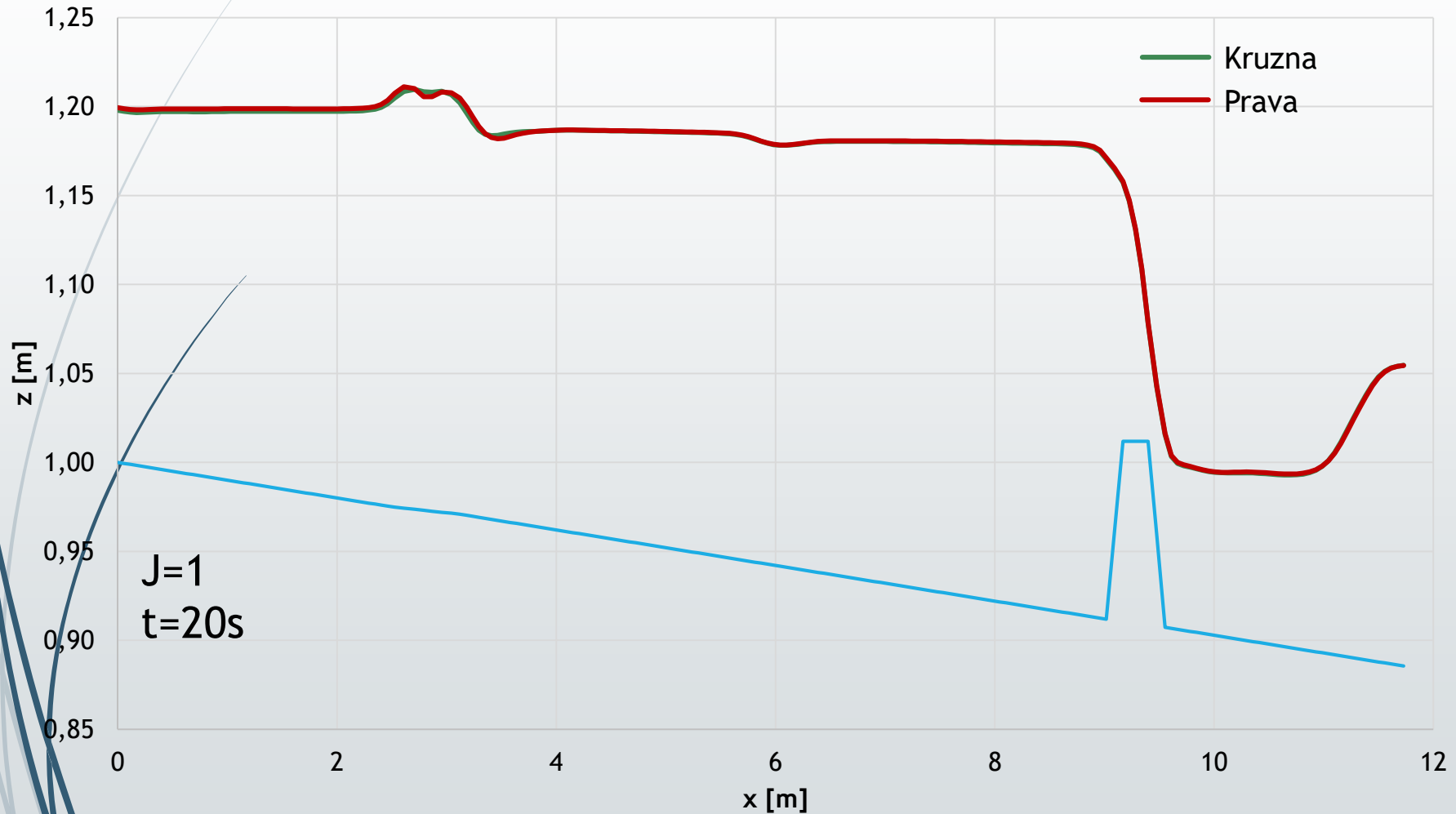


Time: 20 sec

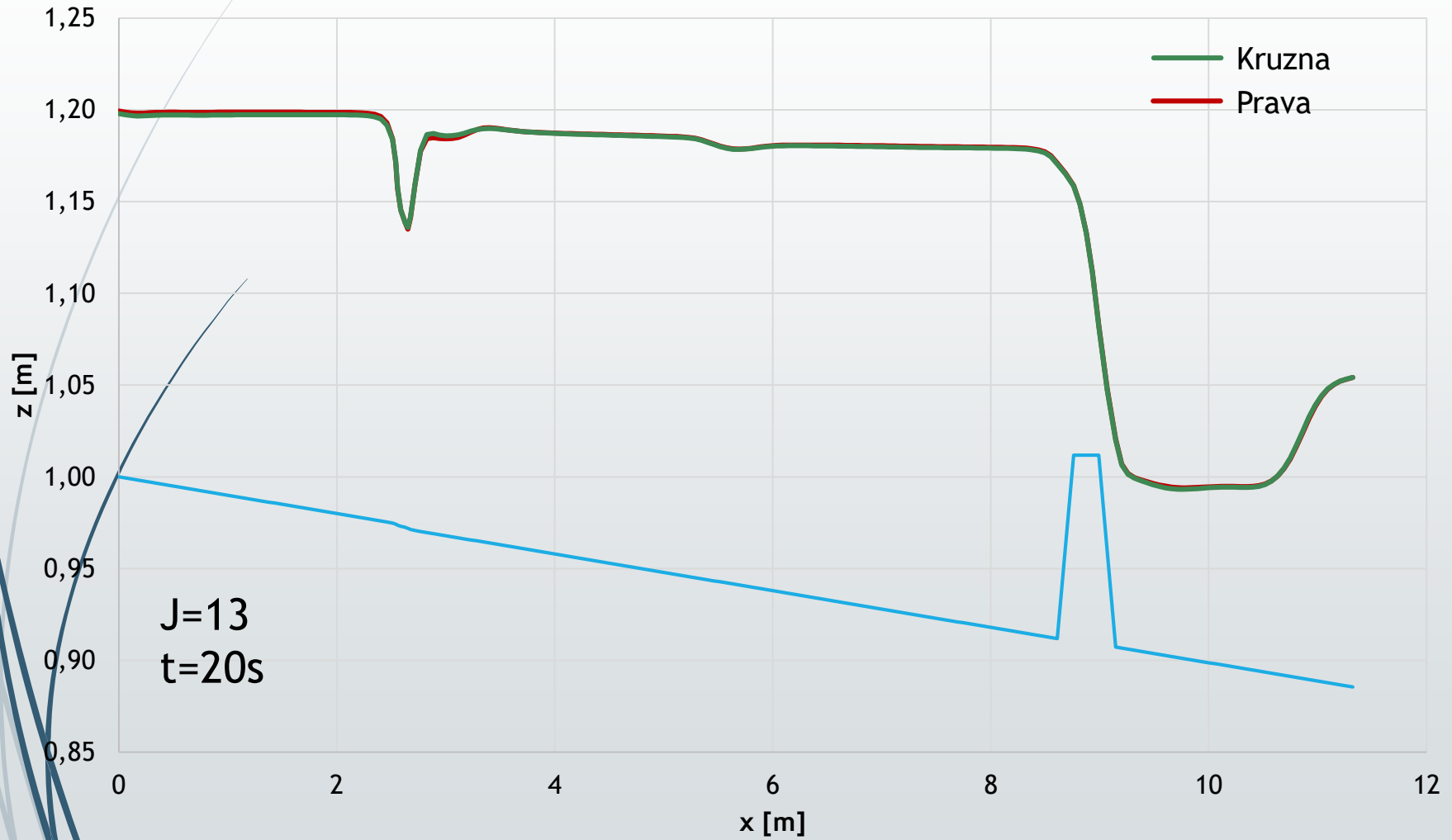


Time: 20 sec

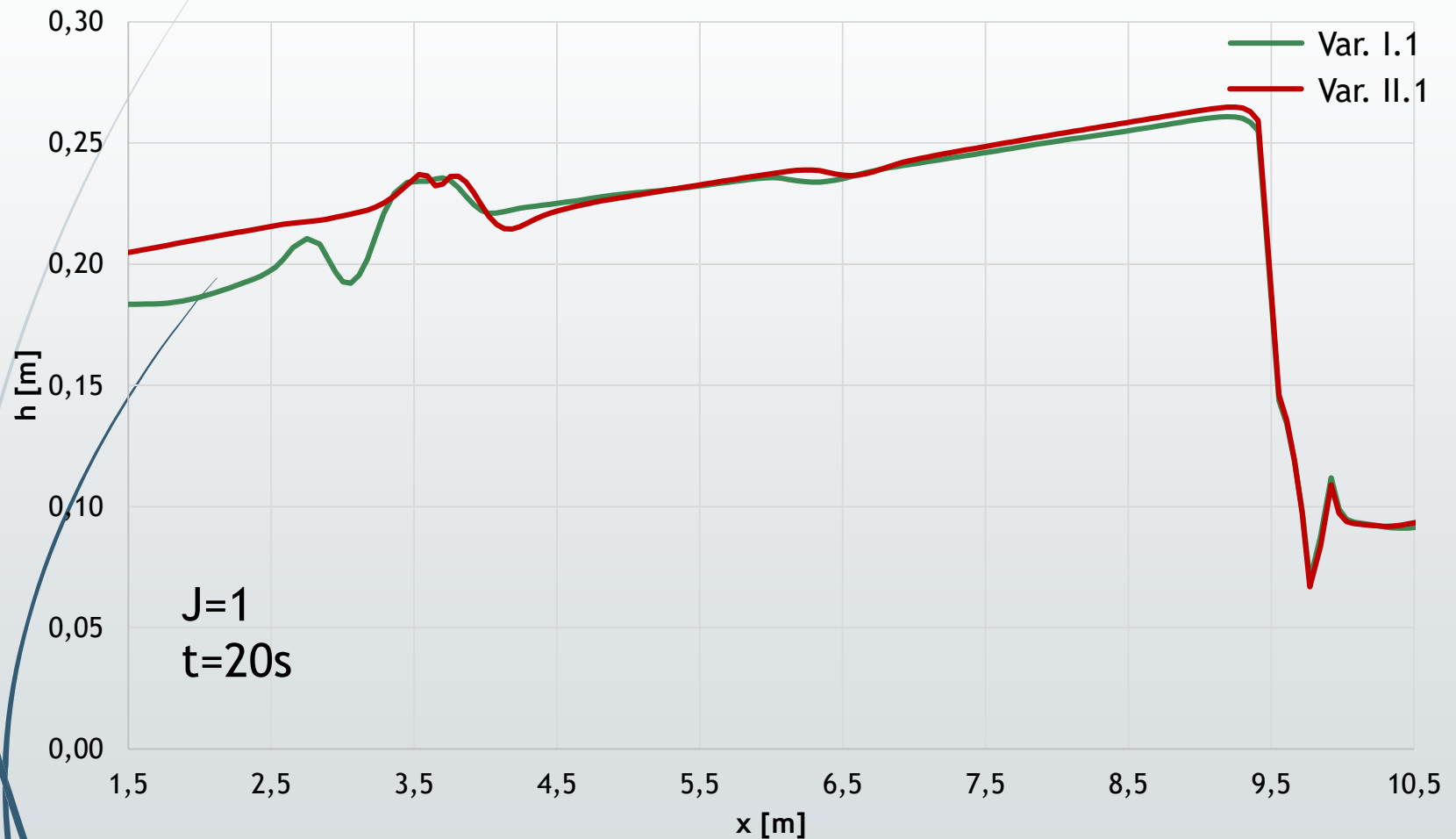
# Varijanta II - nivoi uz desni zid



# Varijanta II - nivoi uz desni zid

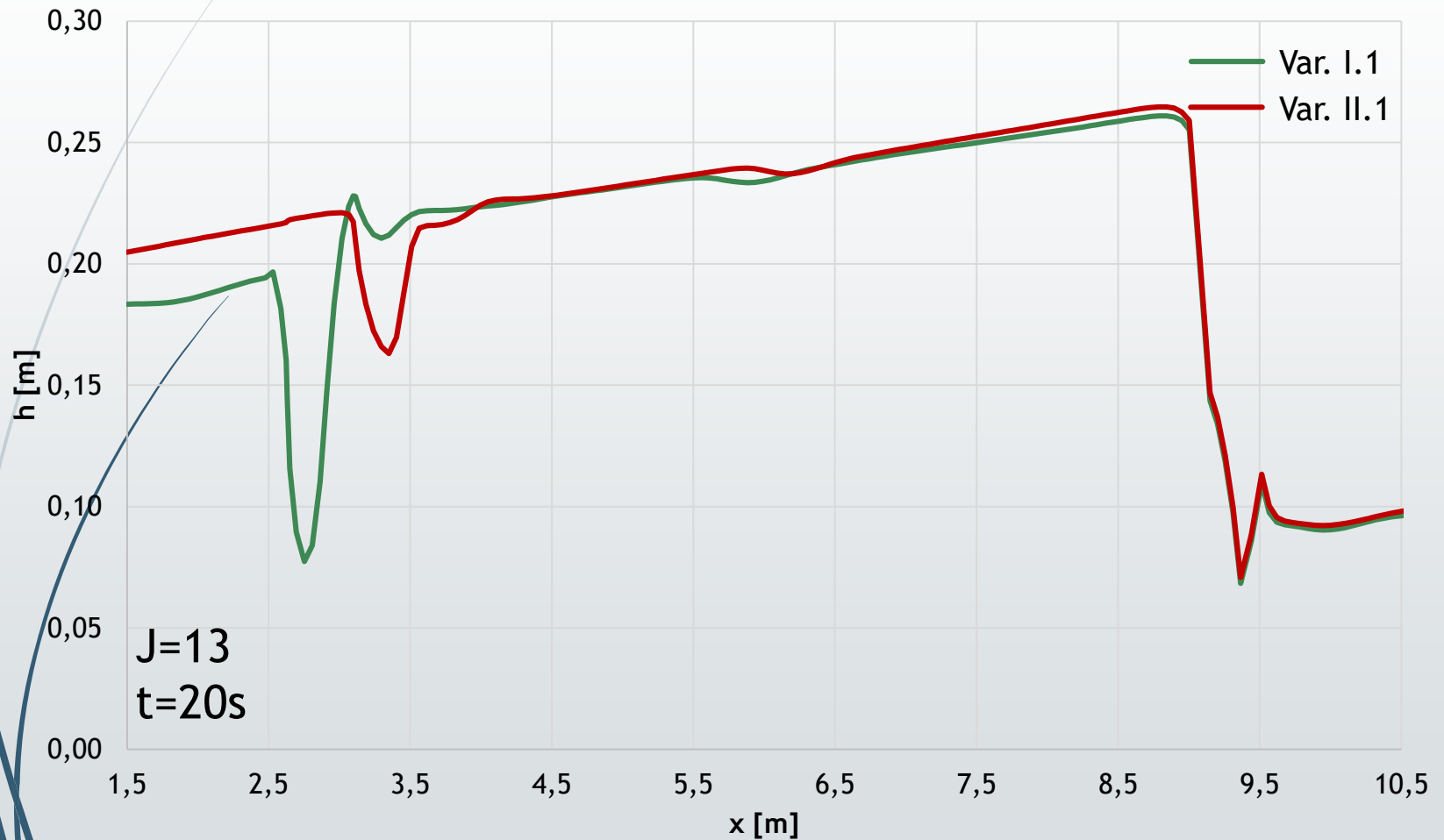


# Dubine uz desni zid - prava prel.

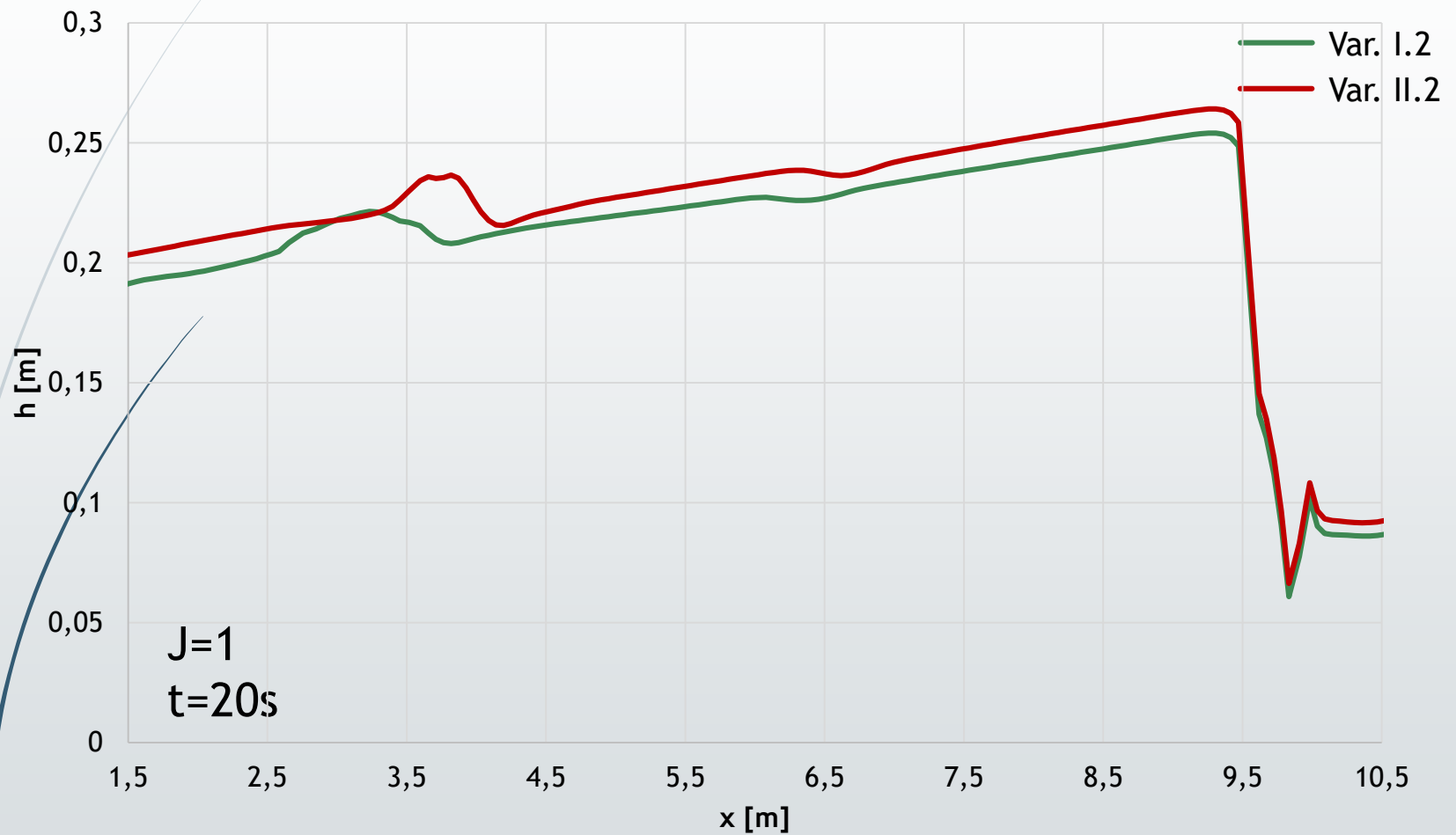




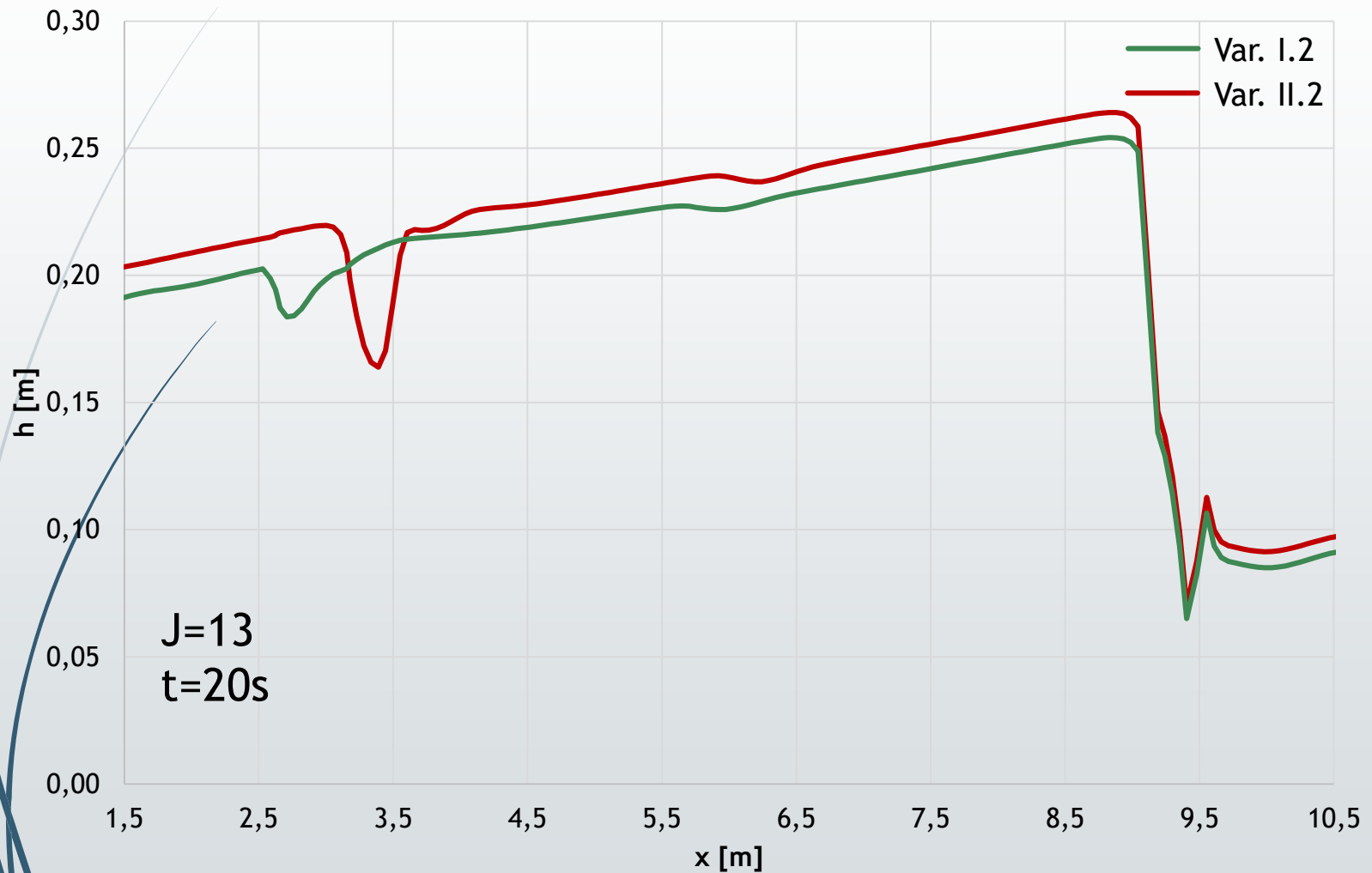
# Dubine uz levi zid - prava prel.



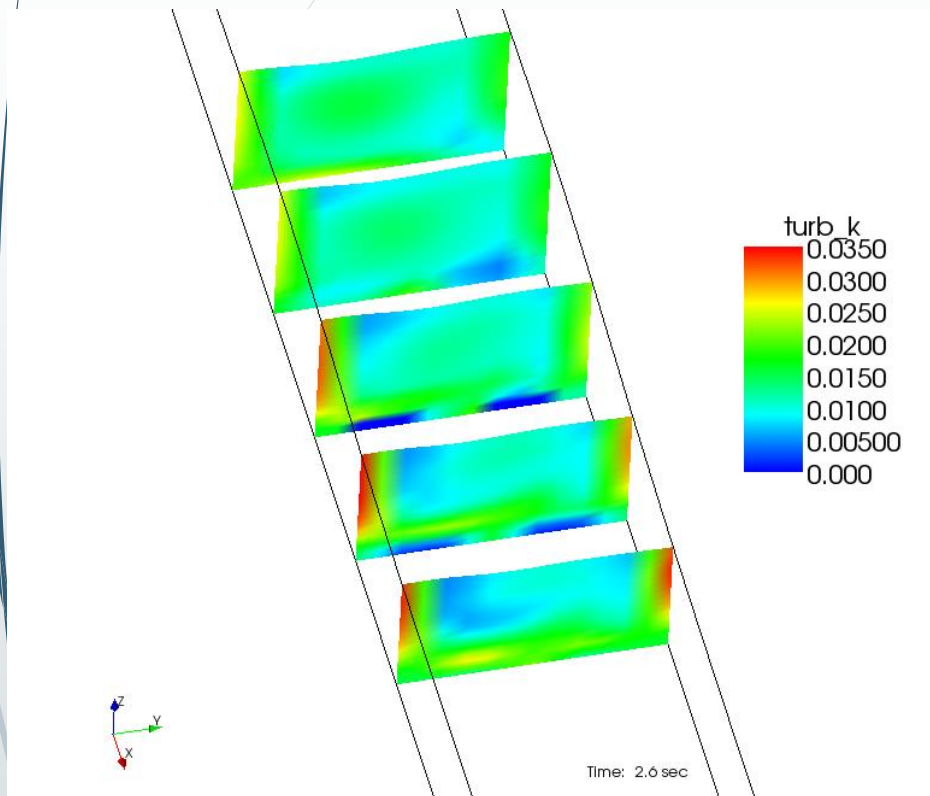
# Dubine uz desni zid - kružna prel.



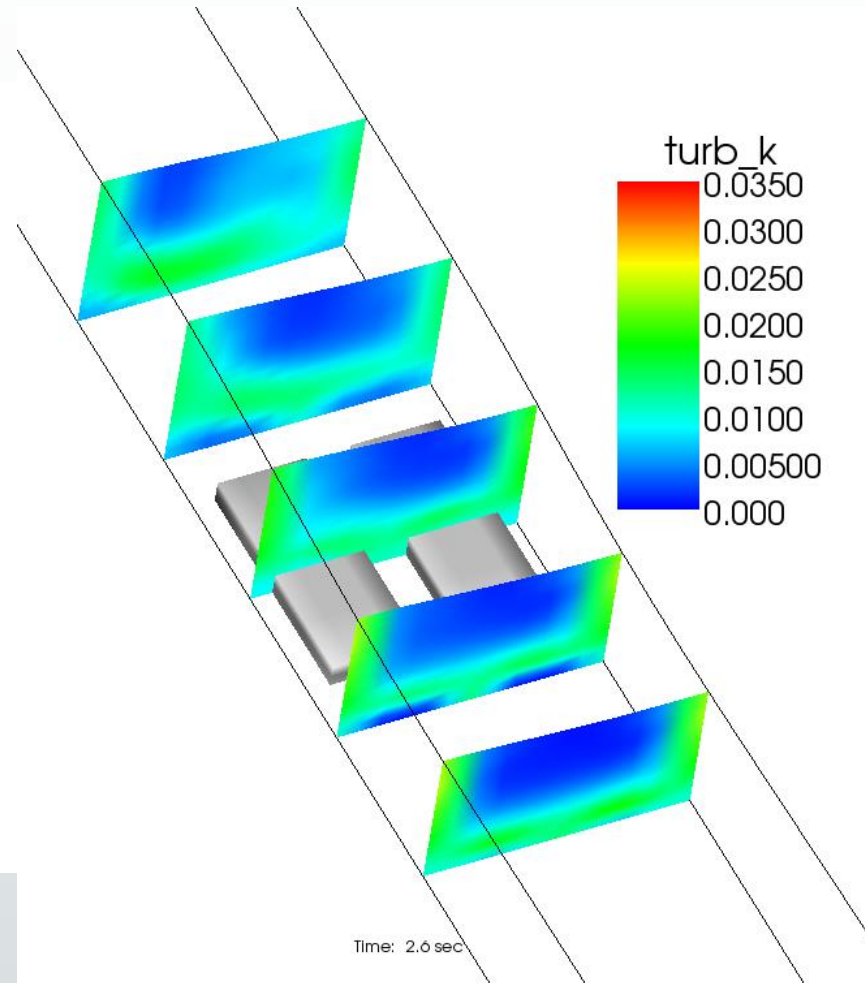
# Dubine uz levi zid - kružna prel.



# Poređenje rezultata - k

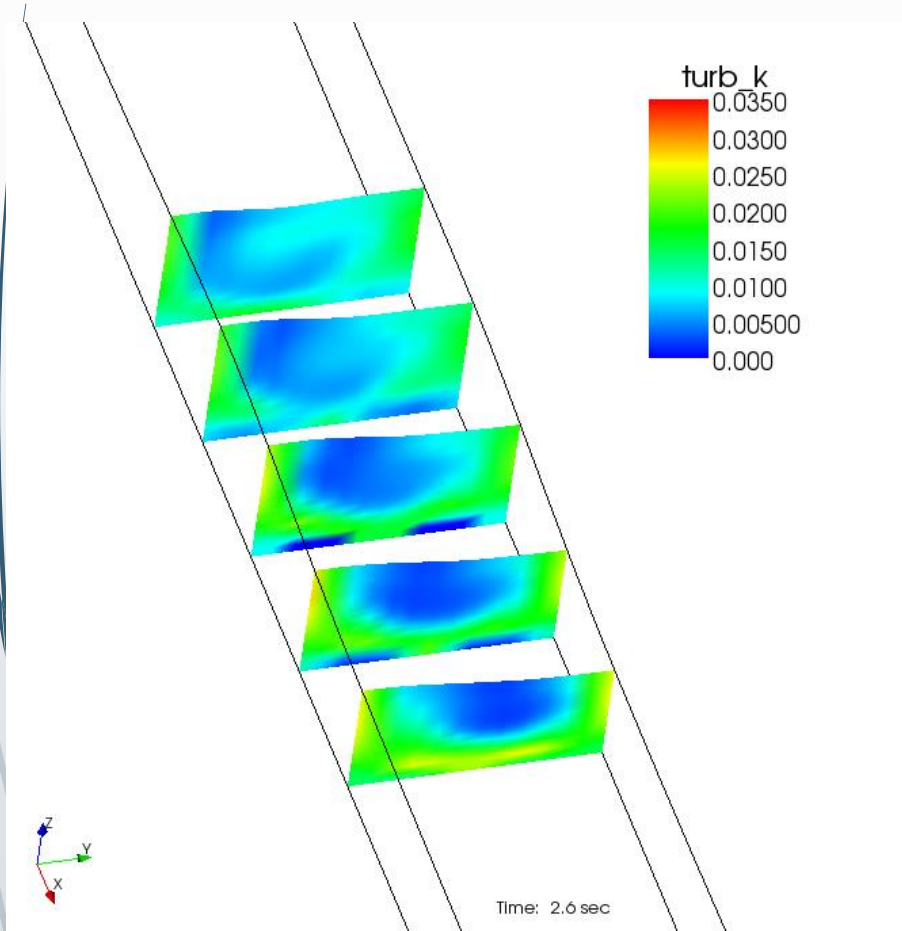


Varijanta I.1, t=2,6s

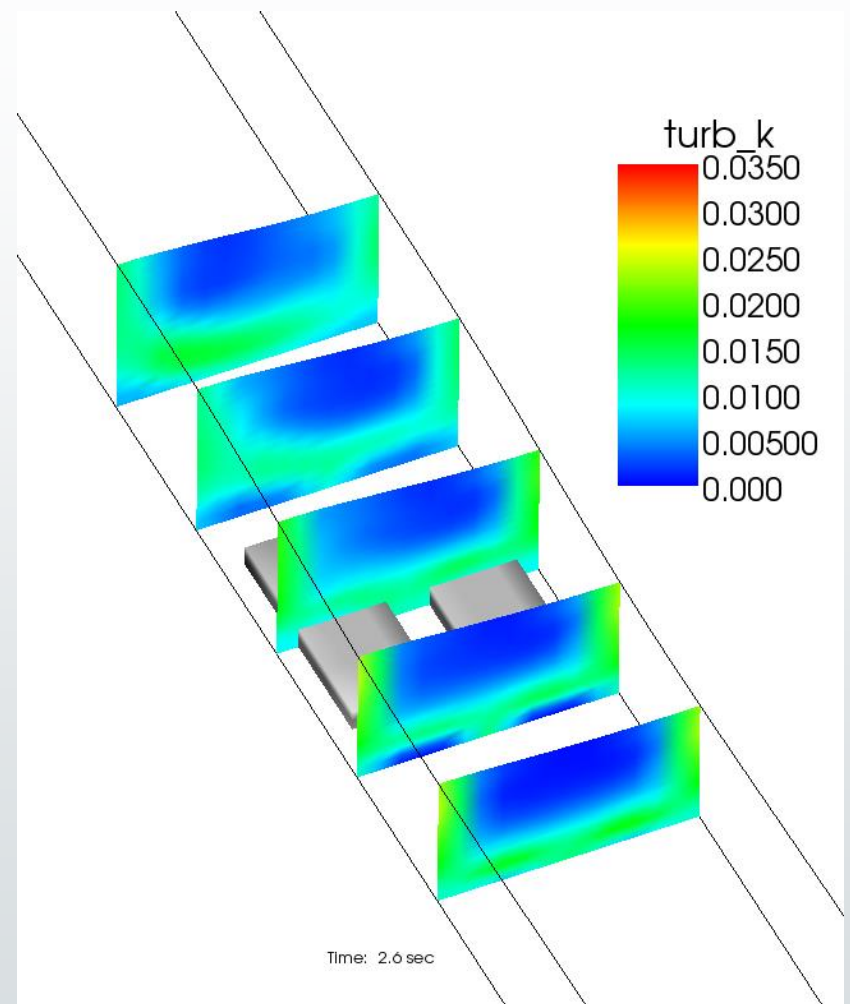


Varijanta II.1, t=2,6s

# Poređenje rezultata - k



Varijanta I.2, t=2,6s



Varijanta II.2, t=2,6s

# Zaključci

- Kod duže prelaznice (varijanta I) postoje značajne razlike u strujanju u nizvodnoj deonici za različite oblike krivine
- Kod kratke prelaznice (varijanta II) NE postoje značajne razlike u strujanju u nizvodnoj deonici za varijante prelaznice - **pretpostavka da oblik kratke prelaznice ne utiče na stujanje onoliko koliko je to slučaj kod duže prelaznice**
- Poklapanje sa analitičkim izrazom je solidno za kružne prelaznice, za prave prelaznice je odstupanje veće

# Zaključci

- Različiti načini diskretizacije advektivnih članova i tip  $k-\varepsilon$  modela (L ili NL) daju slične rezultate (testirano samo na kanalima varijante II)
- Sonde za merenje, iako im je visina skoro red veličine manja od dubine vode, **bitno utiču na strujno polje** delujući kao potopljeni prelivni prag i smanjujući zakrivljenost strujnica nizvodno od mernog mesta!

# Komentari

- Generalne zamerke na softver/solver:
  - „Problemi“ sa formiranjem pada dna kanala!
  - Hidraulički skok???
  - Optimizacija kôda - kapaciteti računara neiskorišćeni
  - 3D rotacija u postprocesiranju je problematična