

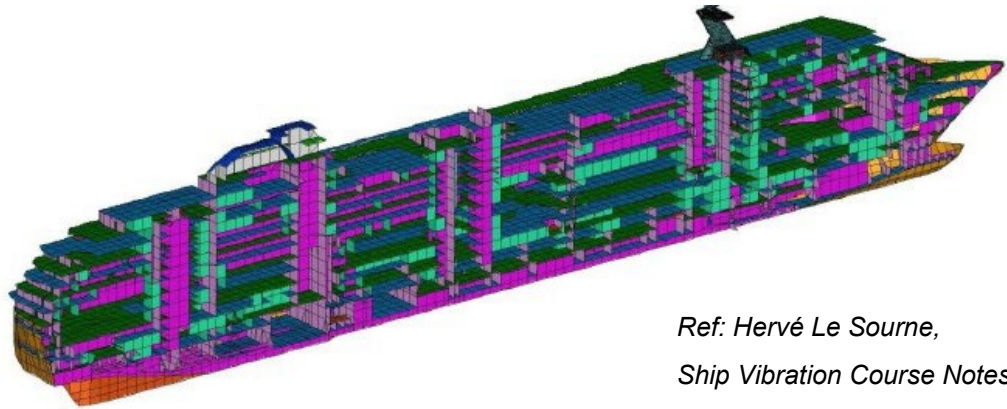
Orthotropic Elements for an Idealized Representation of Complex Structures in Ship Global Strength Analysis

Supervisor: Dr.-Ing. Thomas Lindemann, University of Rostock
Internship tutor: Dipl.-Ing. Stefan Griesch, MV WERFTEN GmbH
Reviewer: Prof. Hervé Le Sourne, ICAM, France

Min Htin Kyaw

Motivation

For Large Cruise Vessels,



*Ref: Hervé Le Sourné,
Ship Vibration Course Notes*

- Global strength analysis **impact** → Other design aspects such as GA, Stability, Pipes, HVAC, Production, etc.
- FEA, the de facto standard for structural strength analysis of ships
- Needs to be performed quickly due to the interdisciplinary nature
- Idealize the structural components in FEM ✓ fast
✓ efficient

Idealization of Structural Components

★ Idealization of Stiffened Panels

- Conventional Modelling Approach
 - Plates - Shell Elements
 - Stiffeners - Beam Elements
 - Girders - Shell Elements, etc.
- Requires mesh boundaries at the stiffener locations
- Mesh coarseness limited by the stiffener spacing

★ Idealization of Side Openings

- Side balcony openings also require modelling efforts
- Beneficial to represent them as intact plates with equivalent strength

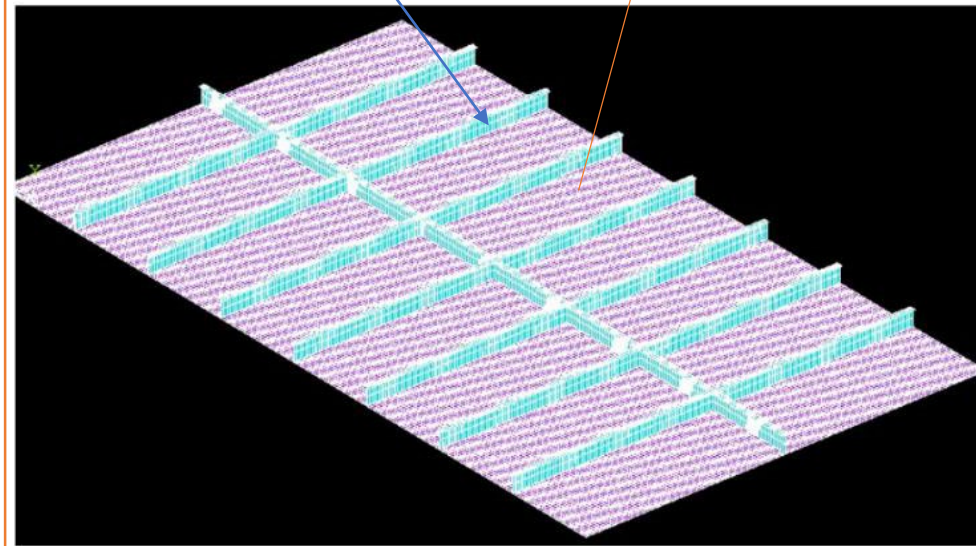
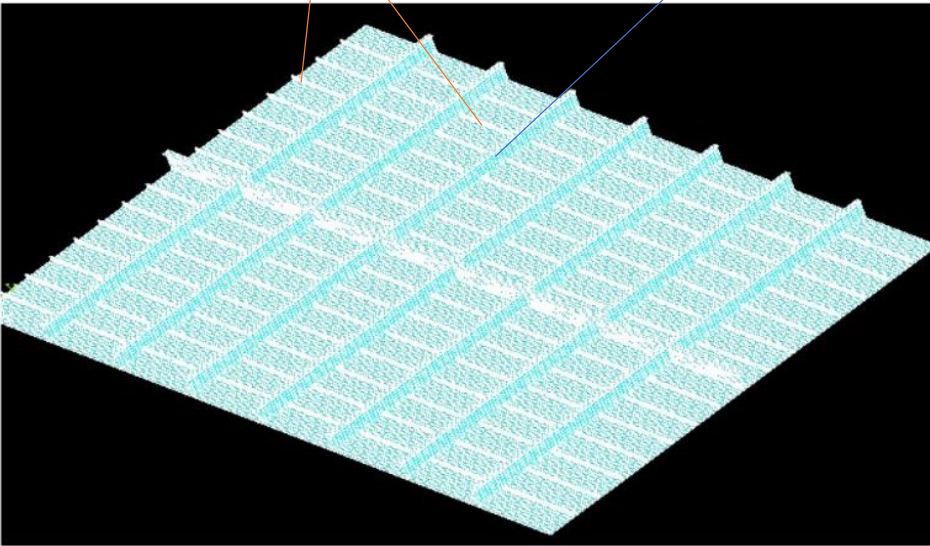


Idealization of Stiffened Panels

Stiffeners

Primary Supports
(Girders)

No Stiffener!



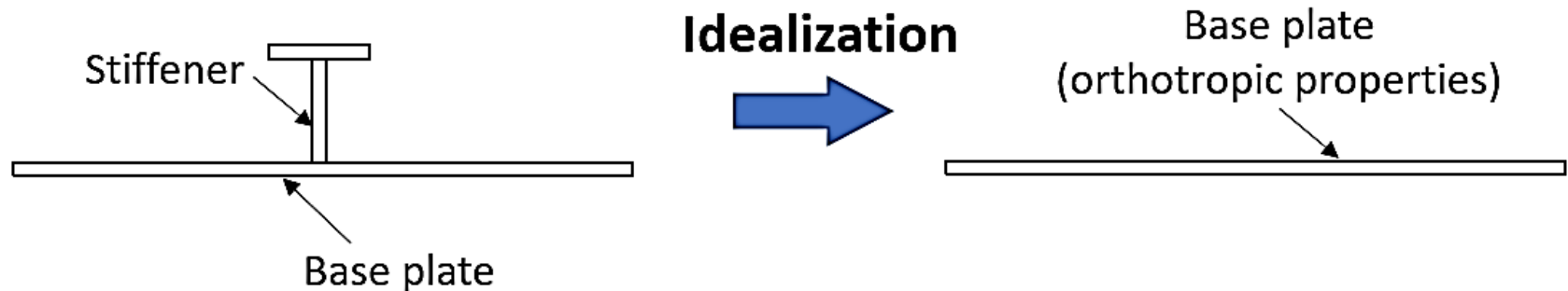
Unidealized Stiffened Deck Panel
F.E Model

Idealized Deck Panel F.E Model

Idealization of Stiffened Panels – Approach 1

➤ Orthotropic (One Layer) Approach

- Approach suggested by O. F. Hughes (1983)
- To smear the stiffeners into the base plating
- Stiffeners removed, Plate strength increased in stiffener direction

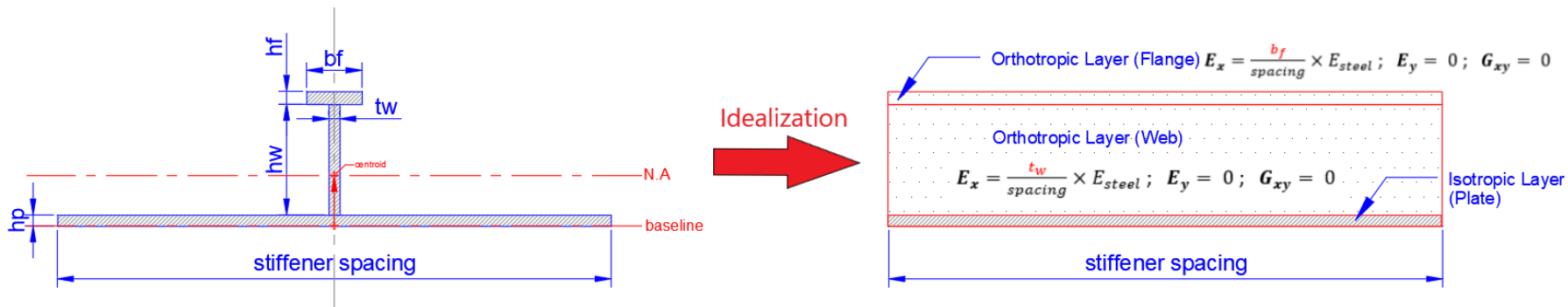


- Cross-section 'Area' only considered in idealization
- ONLY membrane strength is retained in idealized plate,
- NOT actual bending strength of the stiffened panel is retained.

Idealization of Stiffened Panels – Approach 2

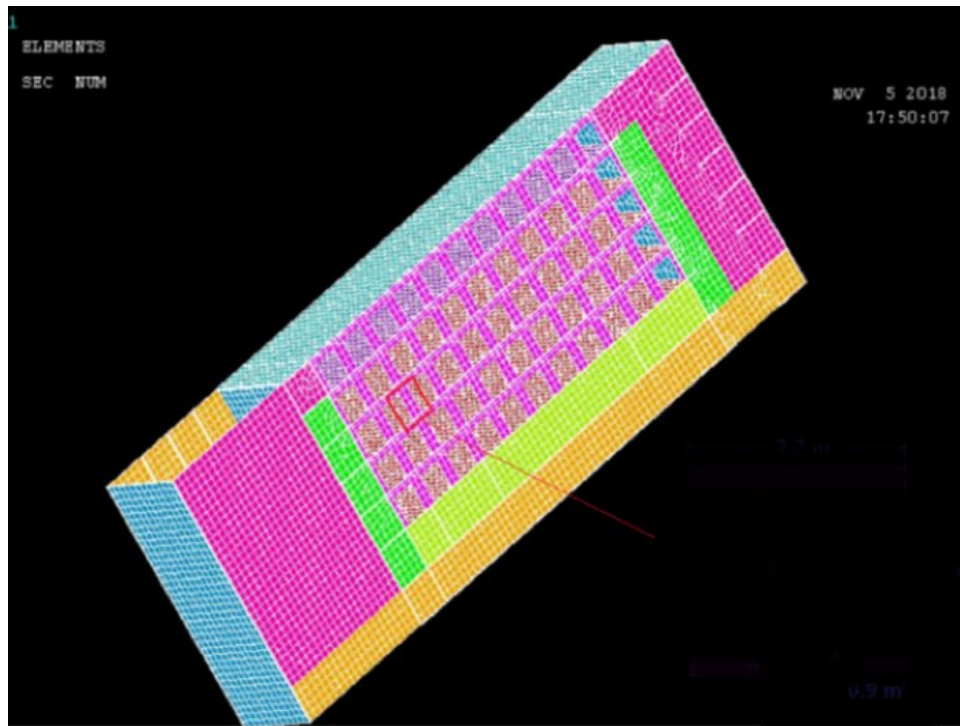
➤ Laminate Approach

- Approach introduced by J. Romanoff et al (2013)
- To represent the stiffened panel with laminate shell of equivalent strength

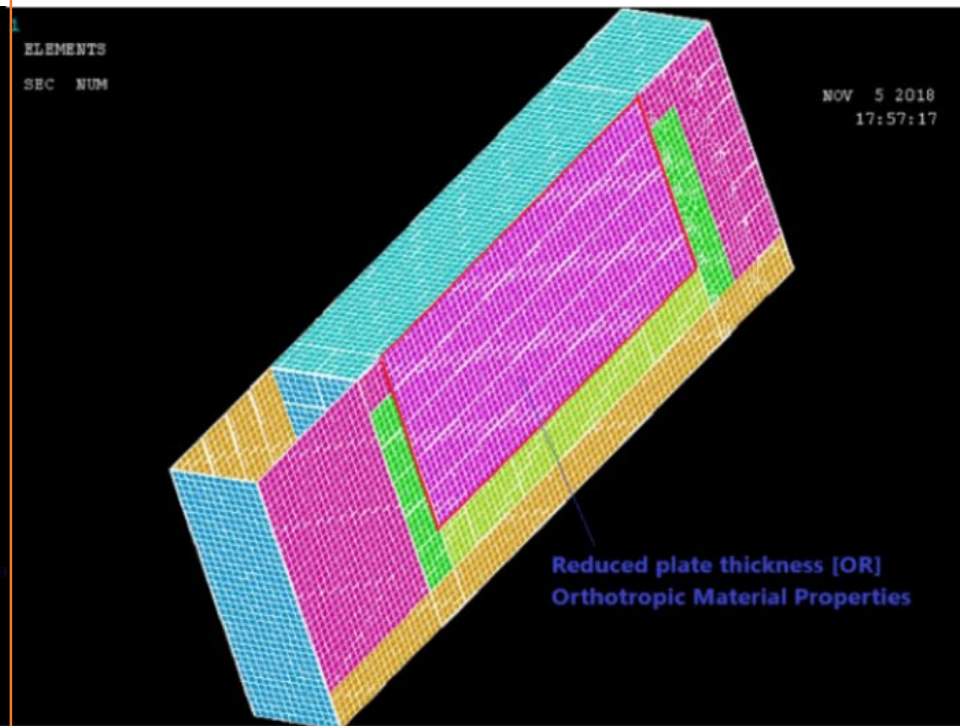


- Both Membrane and Bending strengths maintained in idealized laminate shell

Idealization of Side Openings



Unidealized Model with Actual Openings



Idealized Side Openings

Idealization of Side Openings – Approach 1

➤ Reduced Plate Thickness Approach

➤ DNV-GL FEA Class Guideline

Larger areas with cut outs, e.g. wash bulkheads, and walls with doors and windows:

$$t_{red} = \frac{1}{1 + 0.0025p^2} t_0$$

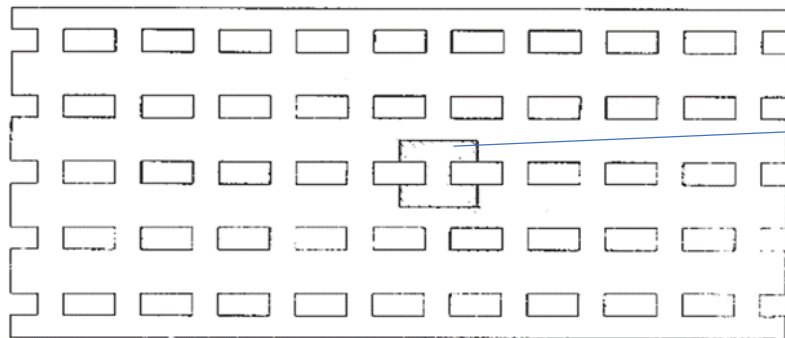
p = cut-out area in %

Ref: DNVGL-CG-0127

Idealization of Side Openings – Approach 2

➤ Equivalent Orthotropic Plate Approach

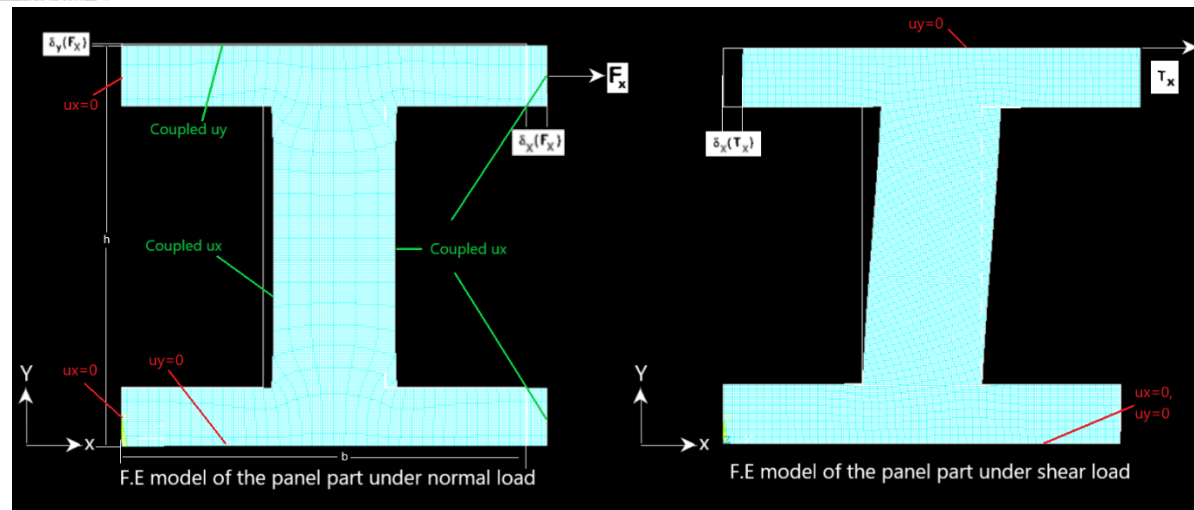
- Introduced by Heder and Ulfvarson (1991)
- Unique piece of openings analyzed with FEA under various load cases
- Deformation solutions from openings' FEA **determine** ➔ Equivalent Orthotropic Properties of opening panel



Unique Piece of Opening

FEA Analyses

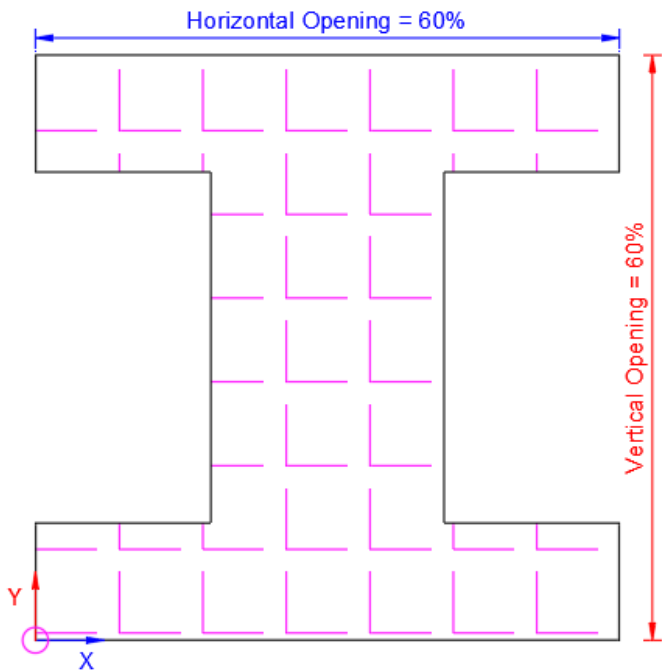
Ref: Heder et. al, Hull Beam
Behaviour of Passenger Ships



Catalogue of Equivalent Orthotropic Properties

- Equivalent Orthotropic Plate Approach requires beforehand 2D FE analyses of Opening Panels
- Beneficial to have a catalogue of equivalent orthotropic properties for various types of openings

💡 How to characterize the openings?



- Opening (%) in **Horizontal** and **Vertical** Directions
- Nomination : **OH****OV** – **60****60** for the example shown
- Opening types - 1010, 1020, 1030,....., 9090.

Summary

★ Idealization of Stiffened Panels

- Orthotropic (One Layer) Vs Laminate approach
- Laminate approach – correct bending stiffness – secondary response ✓
- Laminate approach – modal analysis ✓
- Calculation of idealization parameters necessary
- Tool necessary for faster idealization

★ Idealization of Side Openings

- Reduced Plate Thickness Vs Equivalent Orthotropic Plate Approach
- Equivalent Orthotropic Plate Approach – more reliable ✓
- Beforehand FEAs of prospective opening panels necessary
- Catalogue of equivalent orthotropic properties – easier idealization process

Implementation of Idealization

★ Tool for idealization of stiffened panel (laminated approach)

=Information of the Panel (User Input)																					
=Equivalent Stiffener for Bulb Profiles (Calculation)																					
=Idealization Parameters (For FEM Input)																					
Panel Data														Material Properties				Sectional Properties			
No.	Panel Data													Mat Num	EX	GXZ	ρ	Sec Num	Sec Offset	DQX	DQY
1	Base Plate	Spacing (mm)	600	tkn (mm)	7	Angle (A)/ Bulb (B)	B	Eplate	206000	bp (mm)	600	tp (mm)	7	206000	79230.77	7.85					
	Angle	tw (mm)		hw (mm)		Bulb	b (mm)	140	Eweb	206000	tw (mm)	8	hw (mm)	126.7826	1	2746.667	1056.41	0.104667			
	Section	bf (mm)		tf (mm)		Profile	t (mm)	8	Eflg	206000	bf (mm)	26.89552	tf (mm)	13.21739		9234.129	3551.588	0.351883	1	49.08191	569802.7
2	Base Plate	Spacing (mm)	600	tkn (mm)	8	Angle (A)/ Bulb (B)	B	Eplate	206000	bp (mm)	600	tp (mm)	8	206000	79230.77	7.85					
	Angle	tw (mm)		hw (mm)		Bulb	b (mm)	140	Eweb	206000	tw (mm)	8	hw (mm)	126.7826	1	2746.667	1056.41	0.104667			
	Section	bf (mm)		tf (mm)		Profile	t (mm)	8	Eflg	206000	bf (mm)	26.89552	tf (mm)	13.21739		9234.129	3551.588	0.351883	2	51.00516	626569.3
3	Base Plate	Spacing (mm)	550	tkn (mm)	6	Angle (A)/ Bulb (B)	B	Eplate	206000	bp (mm)	550	tp (mm)	6	206000	79230.77	7.85					
	Angle	tw (mm)		hw (mm)		Bulb	b (mm)	100	Eweb	206000	tw (mm)	8	hw (mm)	91.13043	2	2996.364	1152.448	0.114182			
	Section	bf (mm)		tf (mm)		Profile	t (mm)	8	Eflg	206000	bf (mm)	25.80796	tf (mm)	8.869565		9666.254	3717.79	0.36835	3	36.38587	468021.5
4	Base Plate	Spacing (mm)	600	tkn (mm)	10	Angle (A)/ Bulb (B)	A	Eplate	206000	bp (mm)	600	tp (mm)	10	206000	79230.77	7.85					
	Angle	tw (mm)	8	hw (mm)	80	Bulb	b (mm)		Eweb	206000	tw (mm)	8	hw (mm)	80	3	2746.667	1056.41	0.104667			
	Section	bf (mm)	100	tf (mm)	12	Profile	t (mm)		Eflg	206000	bf (mm)	100	tf (mm)	12		34333.33	13205.13	1.308333	4	28.39796	879817.2

★ Catalogue for idealized orthotropic properties of side openings

No.	Item	EX (MPa)	EY (MPa)	EXY (MPa)	vxy
1	9090	20912	20912	231	0.037
2	9080	41505	21817	304	0.071
3	9070	62103	23237	427	0.103
4	9060	82702	25159	634	0.134
5	9050	103301	27662	999	0.165

No.	Item	EX (MPa)	EY (MPa)	EXY (MPa)	vxy
42	5040	131720	115200	31817	0.229
43	5030	152377	120338	37019	0.261
44	5020	172673	126525	42109	0.287
45	5010	191470	133961	46614	0.304
46	4090	30927	123901	1700	0.049

Orthotropic Elements for Idealization of Global FEM

- ❖ Ships' Global FEMs are usually idealized for faster and more efficient calculations.
- ❖ The analysis results from idealized models should be consistent with unidealized models' solutions.
- ❖ Preparations should be made to streamline the idealization process.

Thank you for your attention!!!