# Joint Stiffness 해석

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• 예제 문제

Joint stiffness analysis

- 해석 프로세스
  - ▶ Component-geometry 생성
  - > Materials and properties
  - ▶ Component-mesh 생성
  - ▶ Load collectors-boundary conditions 설정
  - ▶ Load collectors-load 설정
  - ▶ Load steps 정의 및 해석
  - ▶ 후처리

#### 차체구조

### 예제: JOINT STIFFNESS (1)

How to calculate rotational joint stiffness?

- F = 6680 N  $\rightarrow \delta$  = 6.4 mm
  - K = 1044 N/mm per side = 2088 N/mm bending stiffness
  - 30% of 7000 N/mm target
  - Twice the actual stiffness: too stiff ?
- Modified model with flexible joints







- F = 6680 N  $\rightarrow \delta$  = 7.7 mm
  - K = 1735 N/mm bending stiffness

### 예제: JOINT STIFFNESS (2)

- Joint rigidity in-plane bending
  - Mass penalty
  - Additional load path

 Effect of added bulkhead on out-of-plane joint rigidity



# JOINT STIFFNESS 쉘 요소

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### 기하형상 생성 (2)



### 기하형상 생성 (3)



### 재료 물성 및 특성 입력

	Solver Keyword	MAT1
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### 요소망 생성



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# 구속조건 및 하중조건 설정







# JOINT STIFFNESS 빔 요소

# 기하형상 생성 (1)



### 기하형상 생성 (2)



'Geom' -> 'lines' 클릭 가로 세로 400 mm 인 ∟ 자 형상을 생성

#### 스프링을 부착할 부분을 0.5 mm 정도로 떨어트림

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### 재료 물성 및 특성 입력

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### 요소망 생성

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# 부쉬 생성(1)



### 부쉬 생성(2)



### 구속조건 및 하중조건 설정





	Contour Plot Displacement(Y) Analysis system — 6.089E-03 — 5.412E-03			최대 변역 로 기존 mm 보 <sup>[]</sup> 로 확인	위는 6.089e-3 mm 쉘 요소의1.261e-2 다 강성이 높은 것으
	4.059E-03 4.059E-03 3.383E-03 2.706E-03 2.030E-03 1.353E-03		1:1	따라서 : 시키면서 위를 갖 법으로 -	스프링 강성을 변화 1 기존 쉘 요소의 변 는 강성을 시행착오 구함
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### 해석 결과: 스프링 상수 변경



### 연습문제: BULKHEAD 효과

- Bulkhead 를 모델링하여 해석 수행 후 강성 비교
  - Effect of added bulkhead on out-of-plane joint rigidity



해석결과 (*T*/<del>0</del>) 1.06 1.84 1.86 1.94



# 비선형 거동을 고려한 조인트 설계

### 비선형 정적 해석 개요

#### 선형 거동이란?

▶ 유한요소 해석에서 가장 기본이 되는 식은 다음과 같다.

 $\{F\} = [K]\{U\}$ 

- {F}: 하중 벡터
- {U}: 변위 벡터
- [K] : 강성 행렬(Stiffness Matrix)

#### ▶ <u>강성행렬이 일정한 값</u>을 가지는 경우 하중과 변위는 선형 관계에 있다고 한다.

- 하중-변위 관계식이 선형 조건
- 변형 및 변형율이 미소한 경우에 적용
- 요소의 적합 및 구성 방정식이 선형
- 강성행렬이 항상 일정
- 항복강도 이하에서 해석
- 초기 모델이 평형조건식을 만족
- 경계조건이 변하지 않음
- 하중은 변위에 독립된 요소
- 변위는 하중에 선형 비례함
- 중첩의 원리 적용 가능



### 비선형 정적 해석 개요

#### 비선형 거동이란?

- 자연계의 현상은 정확히 말해서 모두 비선형 현상이라고 볼 수 있다.
- •비선형 현상을 포함하고 있는 구조물은 <u>하중과 변위의 관계가 선형 관계를 가지고 있지 않는 것</u>을 의미한다.
- 즉, 비선형성을 포함하고 있는 구조물의 기본적인 특성은 하중이 변함에 따라 <u>구조 강성이 변한다는 것</u>을 의미한다.



### 비선형 정적 해석 개요

#### 비선형 정적 해석의 종류



### 예제: JOINT ANALYSIS

#### First Order Analysis for Automotive Body Structure Design –Part 2 : Joint Analysis Considering Nonlinear Behavior

Yasuaki Tsurumi, Hidekazu Nishigaki, Toshiaki Nakagawa, Tatsuyuki Amago, Katsuya Furusu

Toyota Central R&D Labs., Inc.

Noboru Kikuchi

The department of Mechanical Engineering at the University of Michigan

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예제의 형상을 바탕으로 A, B 파트 생성

(bulkhead 없는 형상)

### 기하형상 생성

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재료 물성치 및 특성 생성

두께 별 특성 각각 생성

### 요소망 생성







### 해석 케이스 정의

loadsten1	1	0	ame		Value
			Solver Keyword		SUBCASE
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2 Load Collectors	(4)	0			
2	(4) 1 🔳 2 🔲	0			
2 → ↓ Load Collectors → ↓ ⊕ ⊕ spc → ↓ ⊕ force → ↓ ⊕ nlparm	(4) 1 1 2 3	0 0			
Load Collectors	(4) 1 1 2 1 3 1 4 1	0 0 0 0			
2 Load Collectors Spc force nlparm Name	(4) 1 1 2 1 3 1 4 1 Value	0 0 0 0	ame	Value	
2 Load Collectors Solver Keyword	(4) 1 1 2 1 3 1 4 1 Value NLPARM	0 0 0 0 N	ame Solver Keyword	Value	
2 Load Collectors Solver Keyword Name	(4) 1 1 2 1 3 1 4 1 Value NLPARM nlparm	0 0 0 0	lame Solver Keyword Name	Value NLOUT nlout	
2 Load Collectors Spc Iniparm Iniparm Name Solver Keyword Name ID	(4) 1 1 2 1 3 1 4 1 Value NLPARM nlparm 3	0 0 0 0	ame Solver Keyword Name ID	Value NLOUT nlout 4	
2 - Collectors - Collectors	(4) 1 2 3 3 4 Value NLPARM nlparm 3	0 0 0 0	ame Solver Keyword Name ID Color	Value NLOUT nlout 4	
2 Solver Keyword Name ID Color Include	(4) 1 1 2 1 3 1 4 1 Value NLPARM nlparm 3 1 (Master Model)	0 0 0 0	ame Solver Keyword Name ID Color Include	Value NLOUT nlout 4 [Master Mo	odel]
2 Load Collectors spc force nlparm Name ID Color Include Card Image	(4) 1 1 2 3 4 Value NLPARM nlparm 3 [Master Model] NLPARM	0 0 0 0 0	ame Solver Keyword Name ID Color Include Card Image	Value NLOUT nlout 4 [Master Mo NLOUT	odel]
2 - Color Colo	(4) 1 1 2 1 3 1 4 1 Value NLPARM nlparm 3 [Master Model] NLPARM Hide In Menu/Ex	0 0 0 0 0 N	ame Solver Keyword Name ID Color Include Card Image User Comments	Value NLOUT nlout 4 [Master Mo NLOUT Hide In Me	odel]
2 Color	(4) 1 1 2 3 3 4 Value NLPARM nlparm 3 [Master Model] NLPARM Hide In Menu/Ex	0 0 0 0 0 0	ame Solver Keyword Name ID Color Include Card Image User Comments NINT	Value NLOUT nlout 4 [Master Mo NLOUT Hide In Me	odel] enu/Export

'loadstep1'은 선형 정적 해석 케이스

<sup>2</sup>비선형 정적 해석을 위한 'NLPARM', 'NLOUT' 설정

#### 'loadstep2'는 비선형 정적 해석 케이스

해석 수행

Control card 클릭

2 PARAM 클릭

'LGDISP' 체크

3

### 해석 케이스 정의

	🖞 😜 🛟 🕿 Auto 💿 🗸 💎 - 💎	• 🌍 👰 By Comp 💿 • 🎲 • 🦚 • .	< = = =		
Lington	loodt mee		interference 1		C. Coom
Veciois	l loau types		intenaces	control carus	C Geom
systems	constraints	accels	rigid walls	output block	C 1D
preserve node	equations	temperatures	entity sets	loadsteps	C 2D
	forces	flux	blocks		C 3D
	moments	load on geom	contactsurfs	optimization	Analysis
	pressures		bodies		C Tool
			nsm	OptiStruct	C Post

OSDIAG	PFMODE	RESTARTW	delete
OUTFILE	PFPANEL	RESULTS	disable
OUTPUT	PROPERTY	SCREEN	enable
P2G	PADPRM	SENSITIVITY	
PARAM	A RESPRINT	SENSOUT	next
PRETPRM	RESTART	SHAPE	prev
PFGRID	RESTARTR	SHRES	return



#### PARAM, LGDISP

#### **Bulk Data Entry**

Activates Large Displacement Nonlinear Analysis.

## 해석 결과 (1)



선형 해석의 경우 16.97 mm,

#### 비선형 해석의 경우 9.46 mm 의 변형 결과를 보임

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# 해석 결과 (2)



# 비선형 거동을 고려한 조인트 설계 : 1D 모델링

### 기하형상 생성



# 재료 물성/특성 입력 및 요소망 생성

Name	Value
Name	beamsection1
ID	1
Include	[Master Model]
Collector	(1) beamsectcol1
Config	Standard
Section Type	BOX1
Parameter Definitions	
Dimension DIM1	150.0
Dimension DIM2	150.0
Thickness DIM3	1.5
Thickness DIM4	1.5
Thickness DIM5	1.5
Thickness DIM6	1.3

Name	Value
Name	beamsection2
ID	2
Include	[Master Model]
Collector	(1) beamsectcol1
Config	Standard
Section Type	BOX1
Parameter Definitions	
Dimension DIM1	150.0
Dimension DIM2	150.0
Thickness DIM3	0.83
Thickness DIM4	0.83
Thickness DIM5	1.05
Thickness DIM6	0.83







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# 비선형 부쉬 특성 생성 (1)



## 비선형 부쉬 특성 생성



### 구속조건 및 하중조건 설정



### 해석 케이스 정의 및 해석 실행

🗄 😱 Load Collectors (4)		
🚺 🗖 🔡 table1	1 🔳	0
- 💋 🖽 spc	2 📃	0
- 💋 🗭 force	3 📘	0
🔤 🗖 🗭 nlparm	4 📃 .	0
Name	Value	
Solver Keyword	NLPARM	
Name	nlparm	
ID	4	
Color		
Include	[Master Model	]
Card Image	NLPARM	
User Comments	Do Not Export	
NINC		
DT	0.01	
KSTEP		
MAXITER		
CONV		
EPSU		

🕞 📸 Load Steps (1)		
🦾 👍 loadstep1	1 0	
Name	Value	
Solver Keyword	SUBCASE	
Name	loadstep1	
ID	1	
Include	[Master Model]	
User Comments	Do Not Export	
Subcase Definition		
🖃 Analysis type	Non-linear quasi-sta	itic
SPC	(2) spc	
LOAD	(3) force	
NLPARM	<unspecified></unspecified>	
NLPARM(LGDISP)	(4) nlparm	
SUPORT1	<unspecified></unspecified>	
DEFORM	<unspecified></unspecified>	
PRETENSION	<unspecified></unspecified>	
MPC	<unspecified></unspecified>	

비선형 정적해석을 위한 'NLPARM', 'NLOUT' 생성

2 Loadstep 설정 후 해석





기존 쉘 모델과 유사한 거동 을 하는지 확인



• 다음 모델에 대하여 비선형 정적 해석을 이용하여 1D 조인트 설계 수행

