*SECTION_SHELL_EFG (1)

Card 1

Variable	SECID	ELFORM	SHRF	NIP	PROPT	…		
Type	F	F	F	I	F			
Default								

ELFORM EQ. 41: EFG shell (local projection)
EQ. 42: EFG shell (iso-parametric mapping)
EQ. 43: EFG 2D plane strain
EQ. 44: EFG 2D axisymmetric (y-axis of symmetry)

Card 3 define only for the EFG option

Variable	DX	DY	ISPLINE	IDILA	IEBT	IDIM
Type	F	F	I	I	I	I
Default	1.1	1.1	0	0	1	2

```
*SECTION_SHELL_EFG
6, 41
1.1, 1.1, , , 4, 1,
```

*SECTION_SHELL_EFG (2)

DX, DY, ISPLINE same as in *SECTION_SOLID_EFG
IDILA: not available

Essential boundary condition treatment

Variable	DX	DY	ISPLINE	IDILA	IEBT	IDIM
Type	F	F	I	I	I	I
Default	1.01	1.01	0	0	-1	2

IEBT EQ. 1: Full transformation (default)
EQ.–1: (w/o transformation)
EQ. 3: Coupled FEM/EFG = Smoothed Finite Element Method (SFEM)

Wu et. al. IJNME (2014); Comp. Mech. (2014)

*SECTION_SHELL_EFG (3)

Domain integration method

Variable	DX	DY	ISPLINE	IDILA	IEBT	**IDIM**
Type	F	F	I	I	I	I
Default	1.01	1.01	0	0	-1	0

ELFORM = 41

IDIM EQ.1: first-kind Local boundary condition method

EQ.2: Gauss integration (default)

ELFORM = 42

IDIM EQ.1: first-kind Local boundary condition method (default)

EQ.2: second-kind Local boundary condition method

- ELFORM = 41 is more suitable for crashworthiness analysis
- ELFORM = 42 is more suitable for metal forming analysis

Meshfree Shell Surface (1)

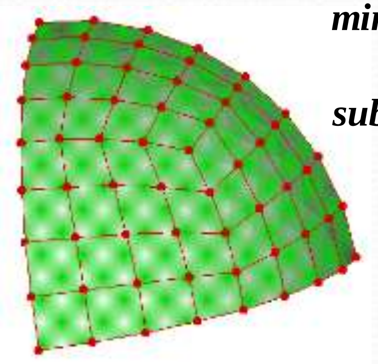
ELFORM = 41: Global Approach

Meshfree Shell Surface Representation

$$\mathbb{E}_0 := \left\{ \boldsymbol{X}_{mid} \in \mathbb{R}^3 \,\middle|\, \boldsymbol{X}_{mid}(\xi,\eta) = \phi(\xi,\eta) \right\}$$

- Surface parameterization based on FE mesh + MLS [Krysl and Belystchko 1996]
- Lagrange polynomials + MLS [Noguchi et al. 2000]
- 3D RKPM with extra constraints [Chen and Wu 2001]

- Angle-based triangular flattening [Sheffer and Sturler, 2001] + MLS

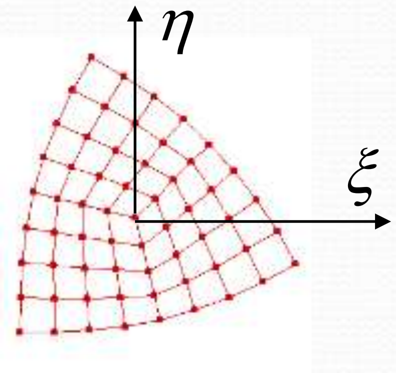


$$\textit{minimize } F(\alpha) = \sum_{i=1}^{N}\sum_{j=1}^{3}(\alpha_i^j - \varphi_i^j)^2 w_i^j$$

$$\textit{subject to } g_{i,j}^{(1)} \equiv \alpha_i^j \geq \varepsilon_2 > 0, \text{ for } i = 1 \ldots N,$$
$$j = 1 \ldots 3, \text{ and some } \varepsilon_2 > 0$$

M

Projection

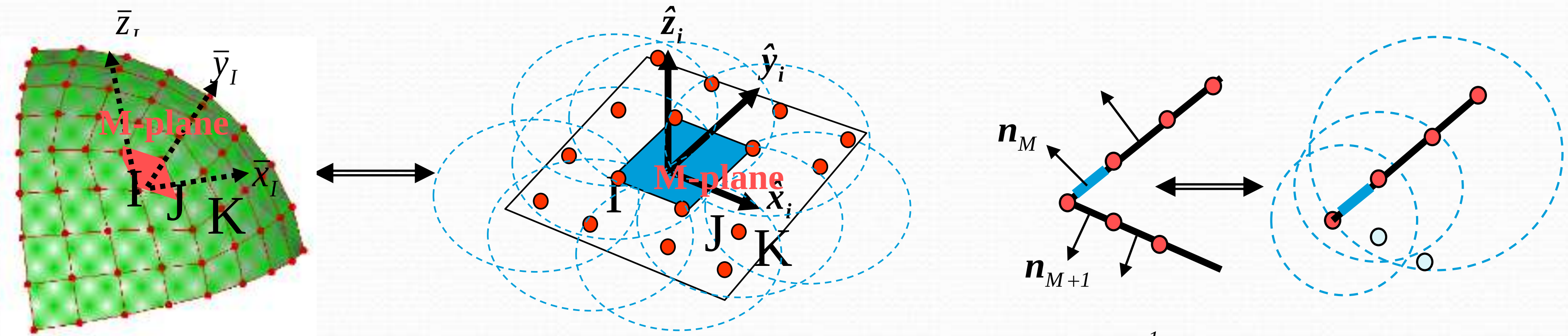


Advantage: Handle complex manifold surface; Conforming shape functions

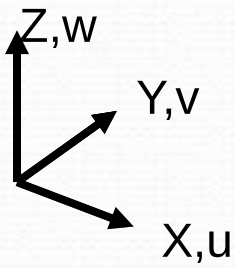
Disadvantage: Requires multiple parametric domains for spherical & cylindrical structures

Meshfree Shell Surface (2)

ELFORM = 42: Local Approach



$$\cos^{-1}(\boldsymbol{n}_M, \boldsymbol{n}_{M+1}) \le \theta_{Critical}$$



Advantage: Handle complex geometry

Disadvantage: Non-conforming shape functions

$$\Psi_I(\boldsymbol{X}_J)\Big/_{M-plane} \neq \Psi_I(\boldsymbol{X}_J)\Big/_{N-plane}$$

Remedy: (Area-weighed) smoothing

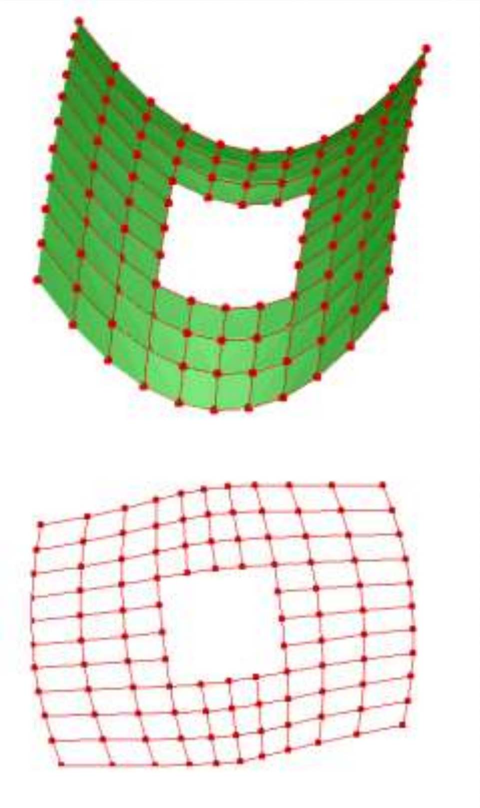
$$\tilde{\Psi}_I(\boldsymbol{X}_J) = \sum_{IE=1}^{NIE} \frac{\Psi_I(\boldsymbol{X}_J) \bullet A_{NIE}}{\sum A_{NIE}} \Rightarrow \sum_{I=1}^{NP} \tilde{\Psi}_I(\boldsymbol{X}) X_{iI}^N = X_i^N \; \forall \boldsymbol{X} \in E_0 / _{plate}$$

where

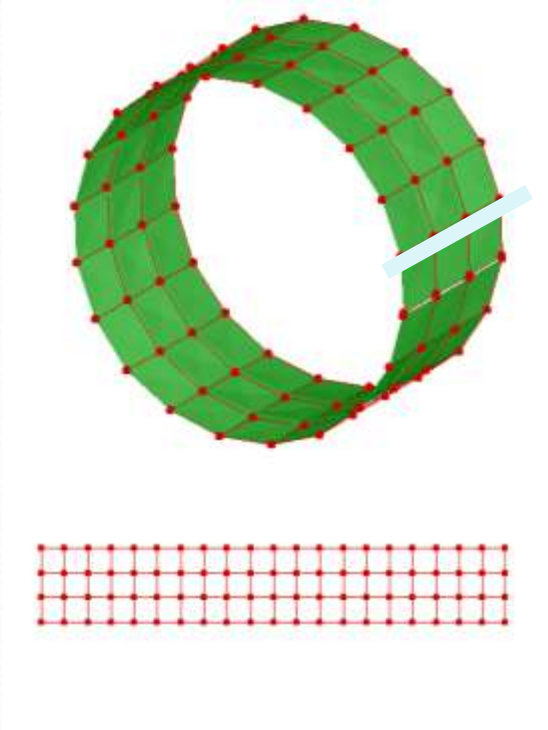
NIE is the number of surrounding projected planes evaluated at X_J

Constructed Meshfree Surface

Meshfree Global Approach
Meshfree Local Approach



Meshfree Global Approach
Meshfree Local Approach



Meshfree Local Approach