

Altair Teknoloji Konferansı Türkiye
2023

24 Ekim 2023

Crowne Plaza, Bursa

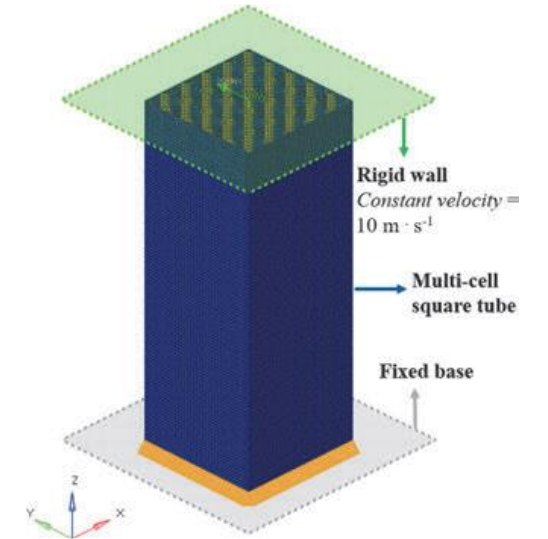
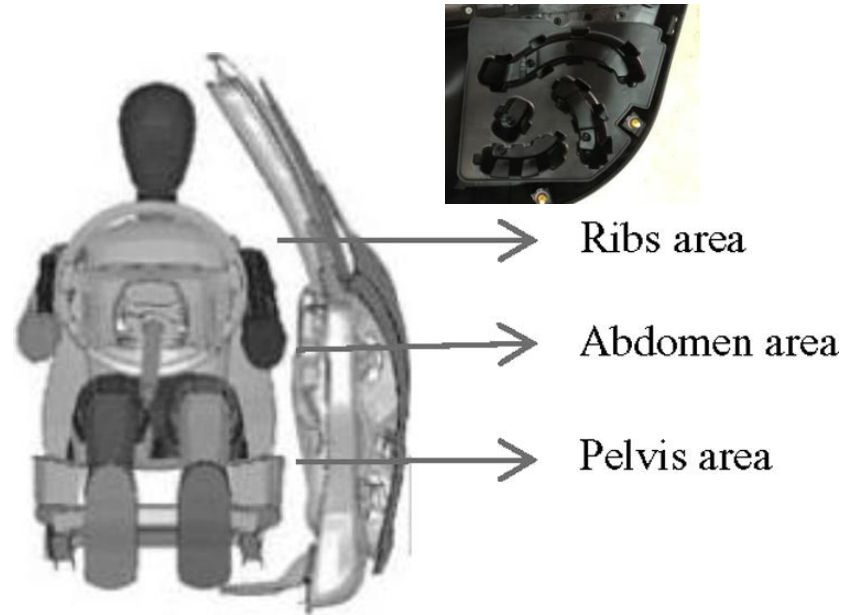
 **ALTAIR**
CHANNEL PARTNER



Farklı Yükleme Koşulları Altında Çok Hücreli İnce Cidarlı Yapıların Çarpışma Performanslarının Optimizasyonu

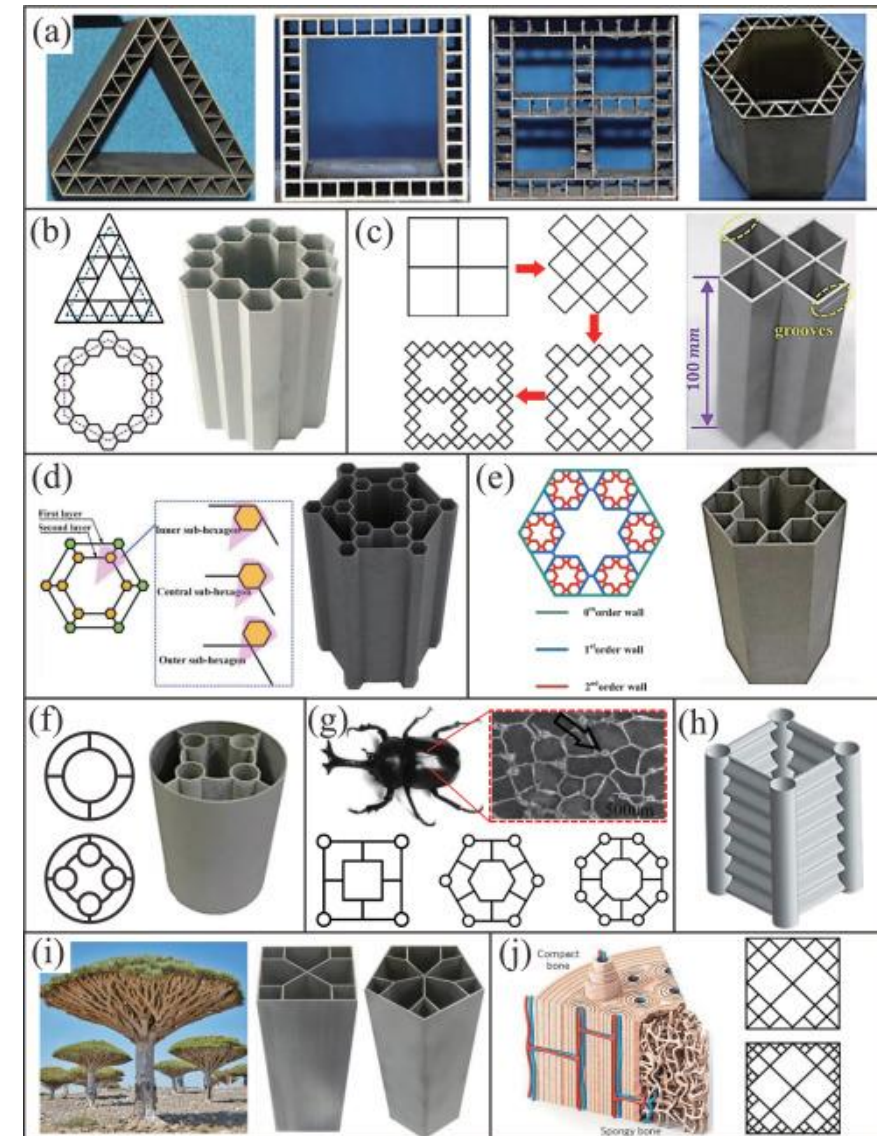
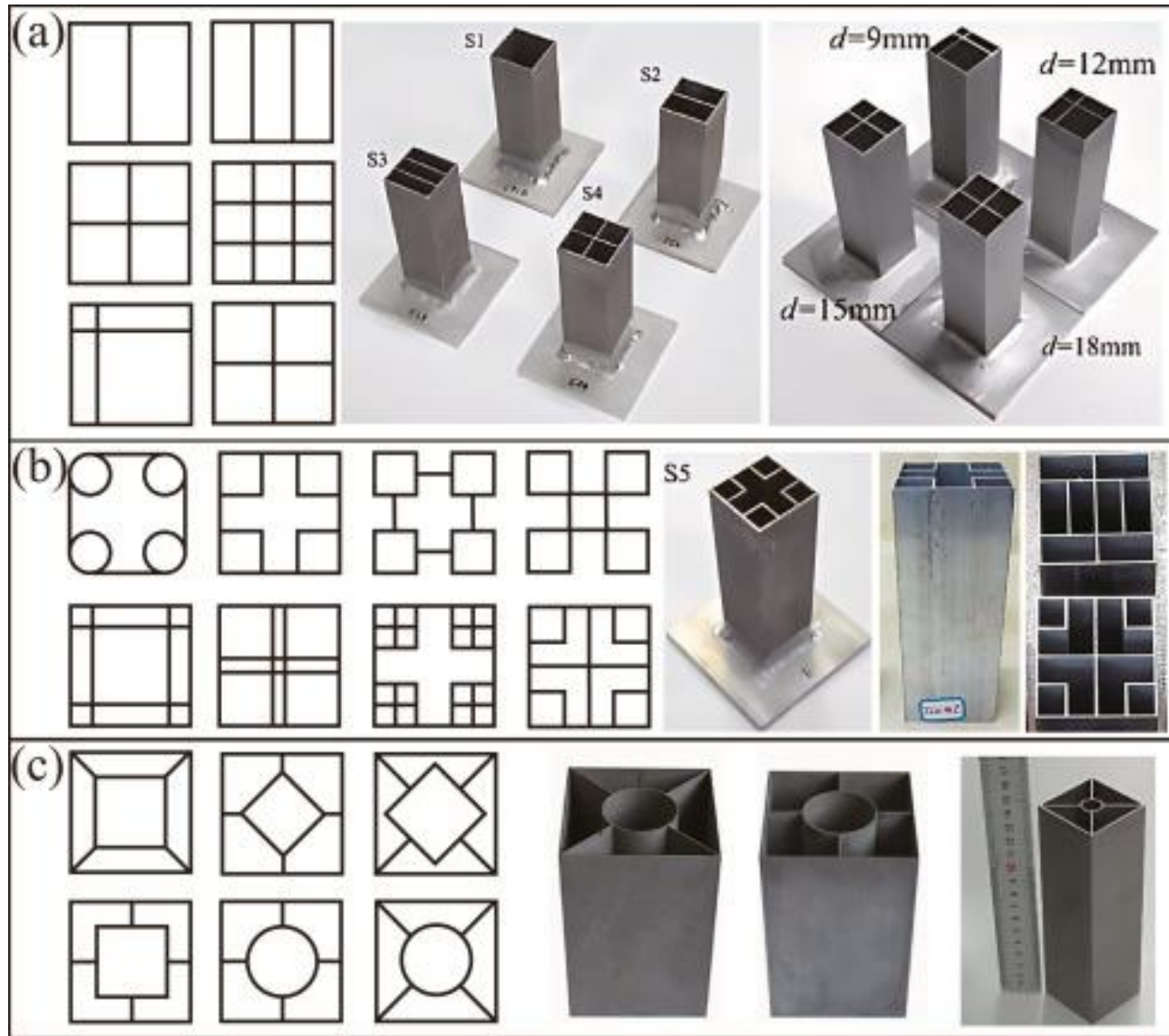
Doç. Dr. Emre İsa ALBAK
BUÜ - Otomotiv Mühendisliği

- ❖ *Taşıt Tasarım & Dinamiği*
- ❖ *Sonlu Elemanlar Analizi*
- ❖ *Çarpışma Analizleri*
- ❖ *Yapısal Tasarım ve Optimizasyon*
- ❖ *Yapay Zeka Optimizasyon Algoritmaları & Metamodelleme & Deneysel Tasarım*

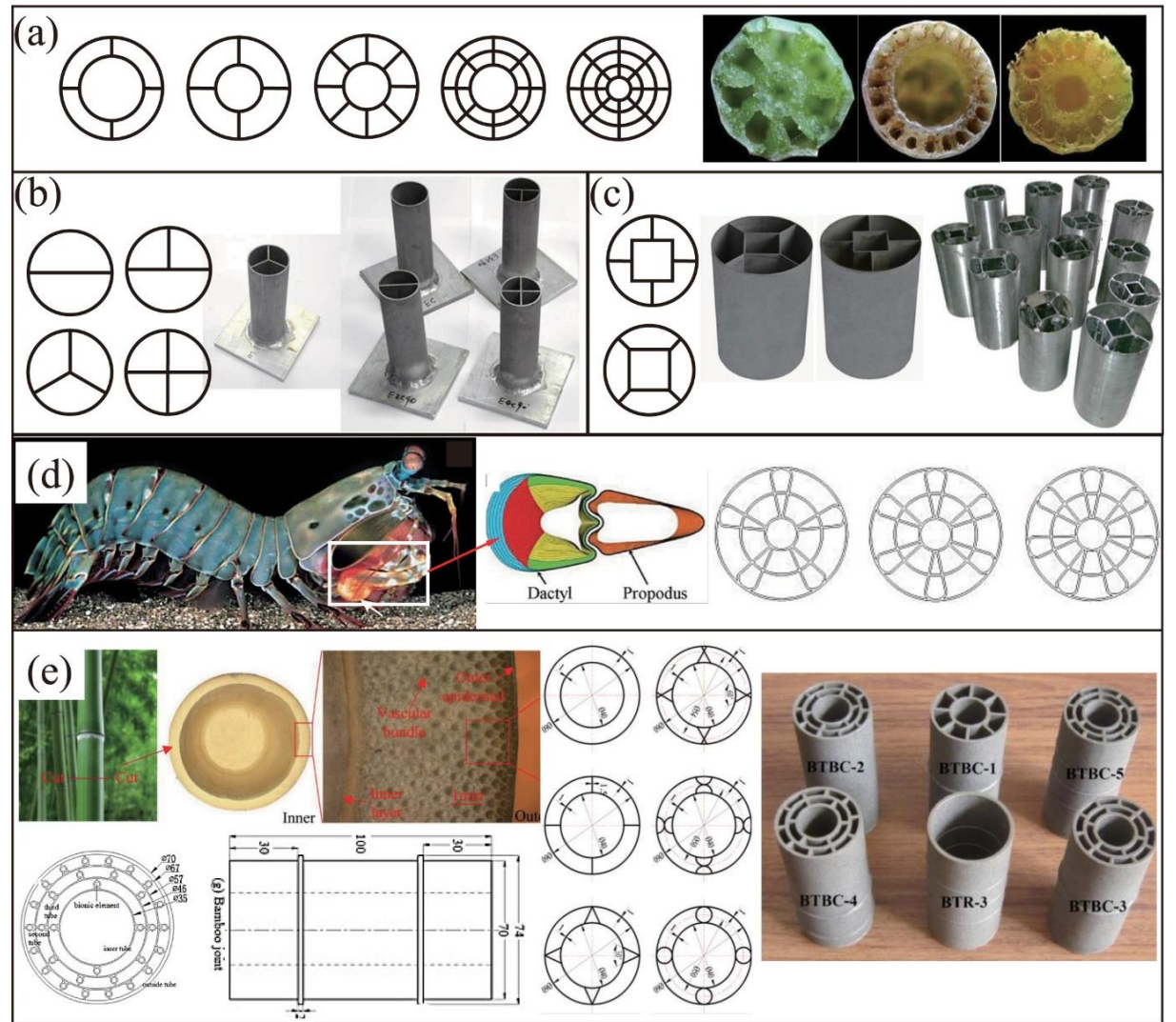
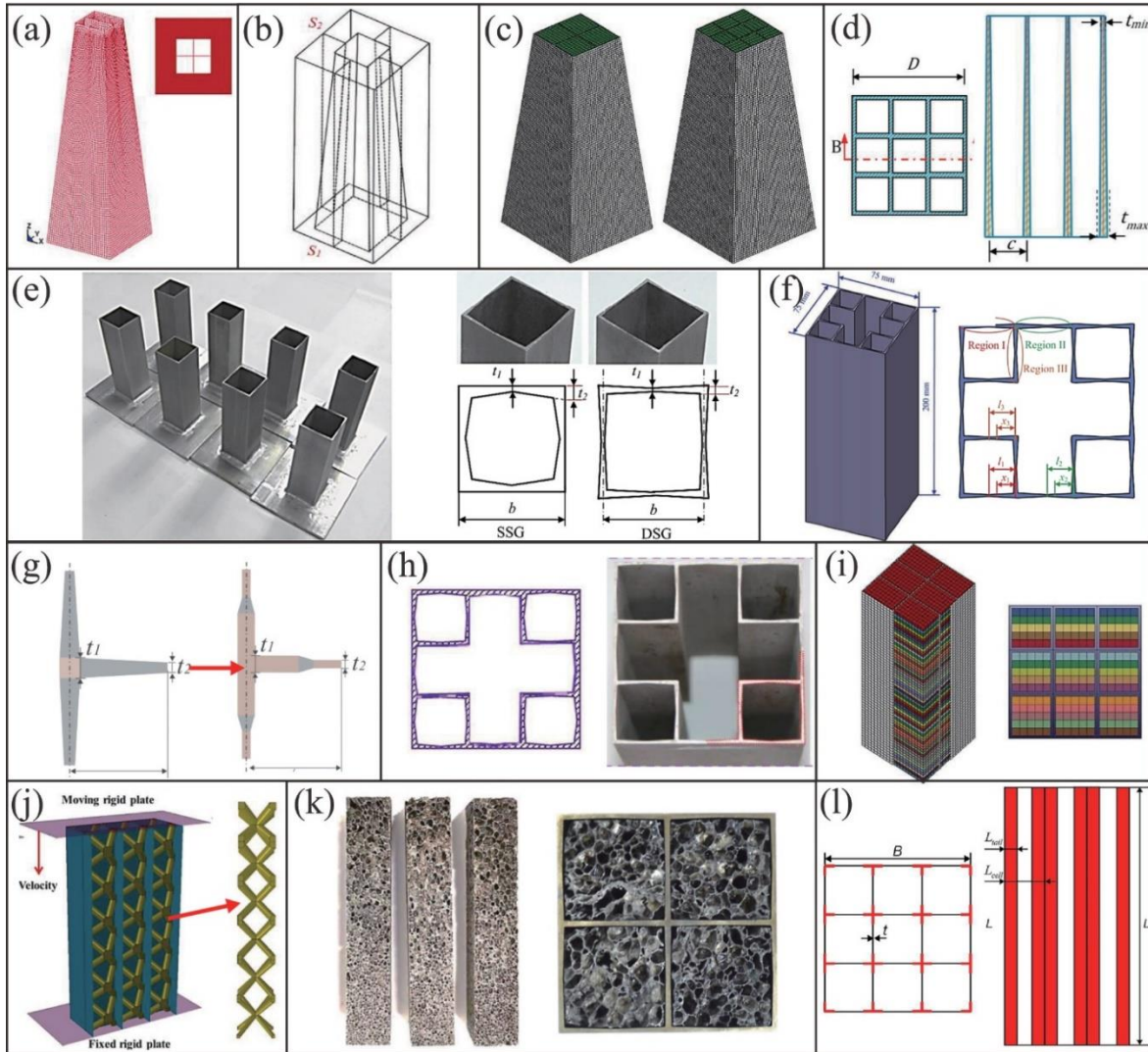


- ❖ *İnce Cidarlı Darbe Emiciler*
- ❖ *İncelenen Çok Hücreli İnce Cidarlı Yapı*
- ❖ *Çarpışma Performansı Kriterleri*
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- ❖ *Yapıların Çarpışma Performansı Değerleri*
- ❖ *Çok Amaçlı Optimizasyon*
- ❖ *Sonuçlar*

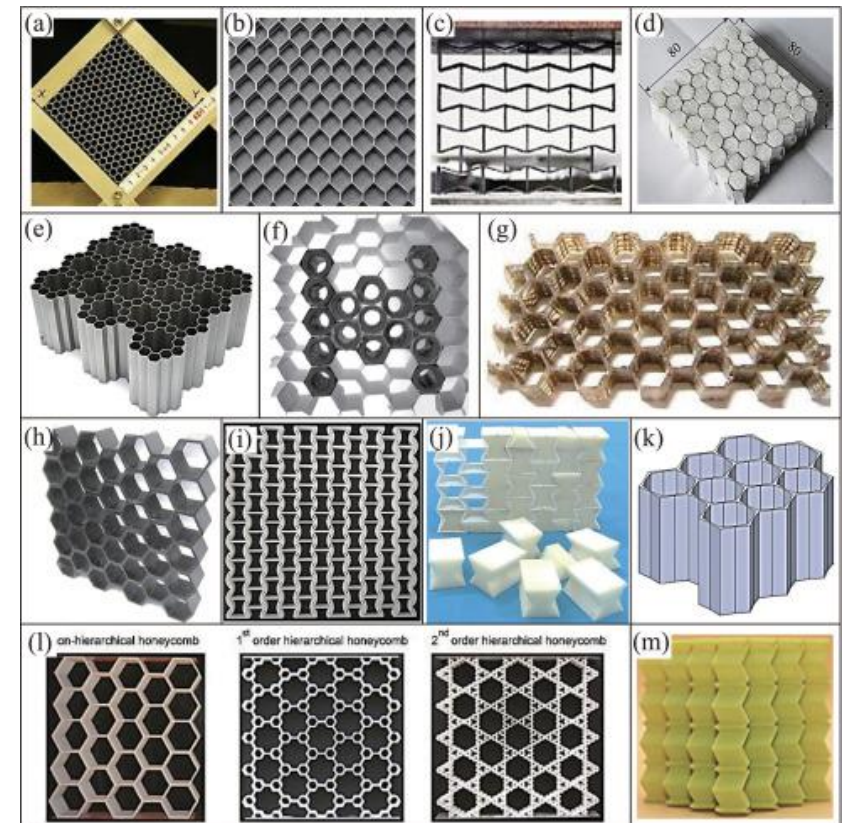
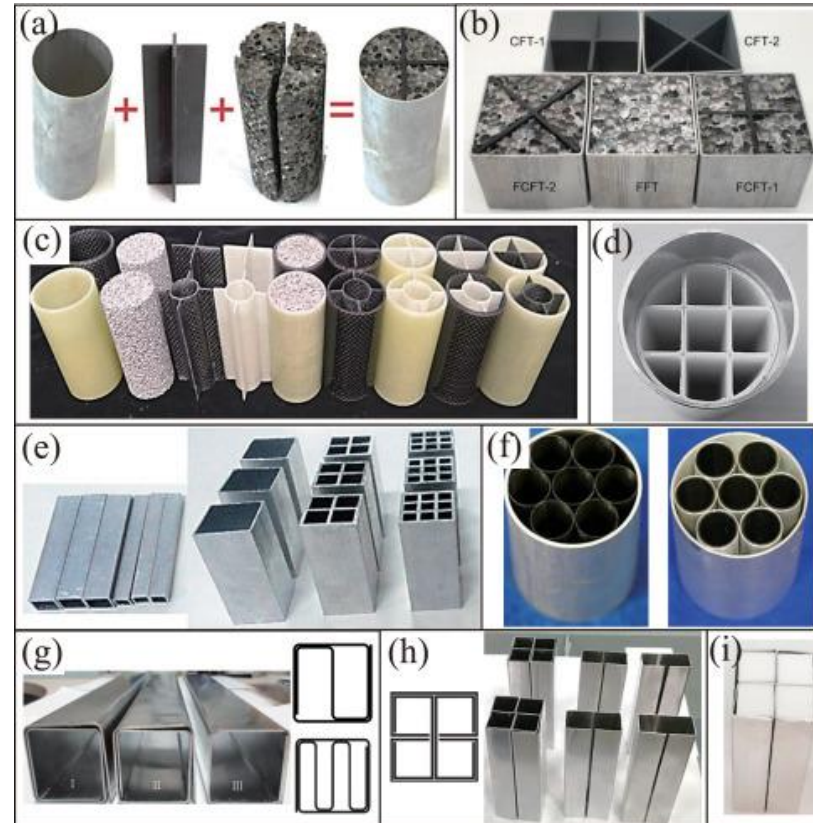
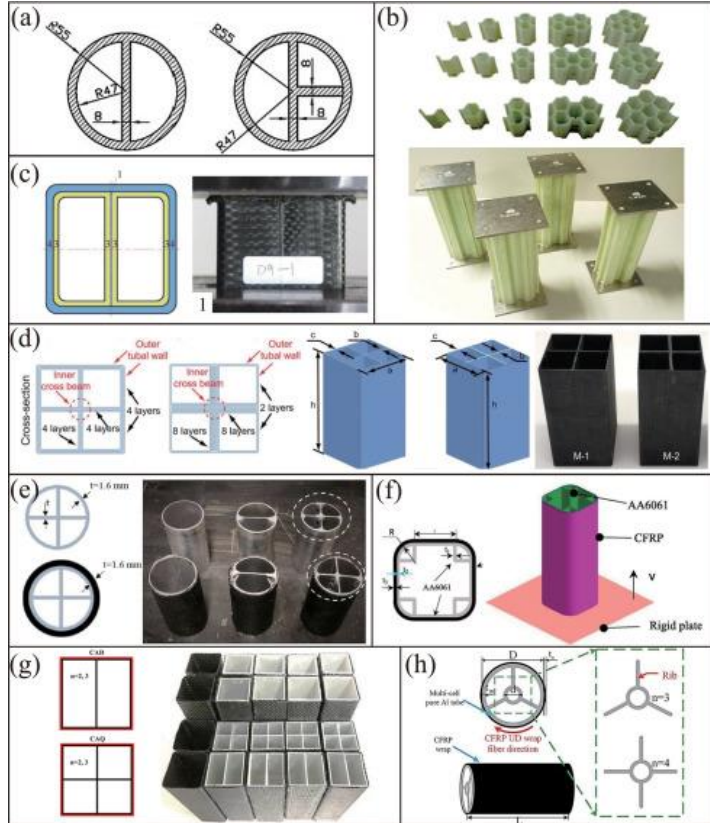
İnce Cidarlı Darbe Emiciler



İnce Cidarlı Darbe Emiciler



İnce Cidarlı Darbe Emiciler



İncelenen Çok Hücreli İnce Cidarlı Yapı



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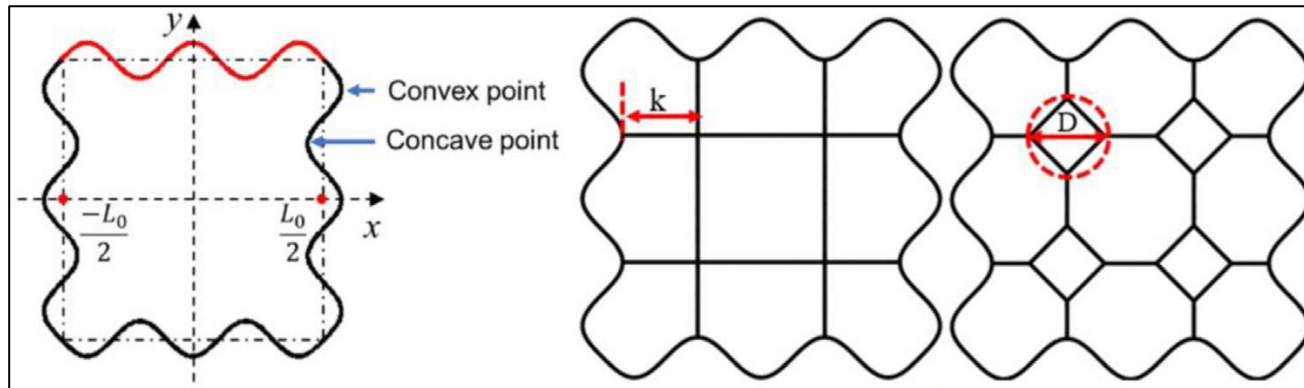


Full length article

Crashworthiness design for multi-cell circumferentially corrugated thin-walled tubes with sub-sections under multiple loading conditions

Emre İsa Albak

Hybrid and Electric Vehicle Technology, Vocational School of Gemlik Asım Kocabiyik, Bursa Uludağ University, Bursa, 16600, Turkey



$$y = (-1)^{N+1} \cdot \frac{L_0}{(2N-1)\pi} \cdot \cos\left(\frac{2N-1}{L_0} \cdot \pi x\right) + \frac{L_0}{2}, \quad x \in \left[-\frac{L_0}{2}, \frac{L_0}{2}\right]$$

Edge-junction type	Cs tube name		
None	C2	C3	C4
Square	C2S	C3S	C4S
Hexagon	C2H	C3H	C4H
Octagon	C2O	C3O	C4O
Circle	C2C	C3C	C4C
Cosine one	C2S1	C3S1	C4S1
Cosine two	C2S2	C3S2	C4S2

Çarpışma Performansı Kriterleri

1) PCF : maksimum kuvvet

$$2) EA = \int_0^d F(x)dx$$

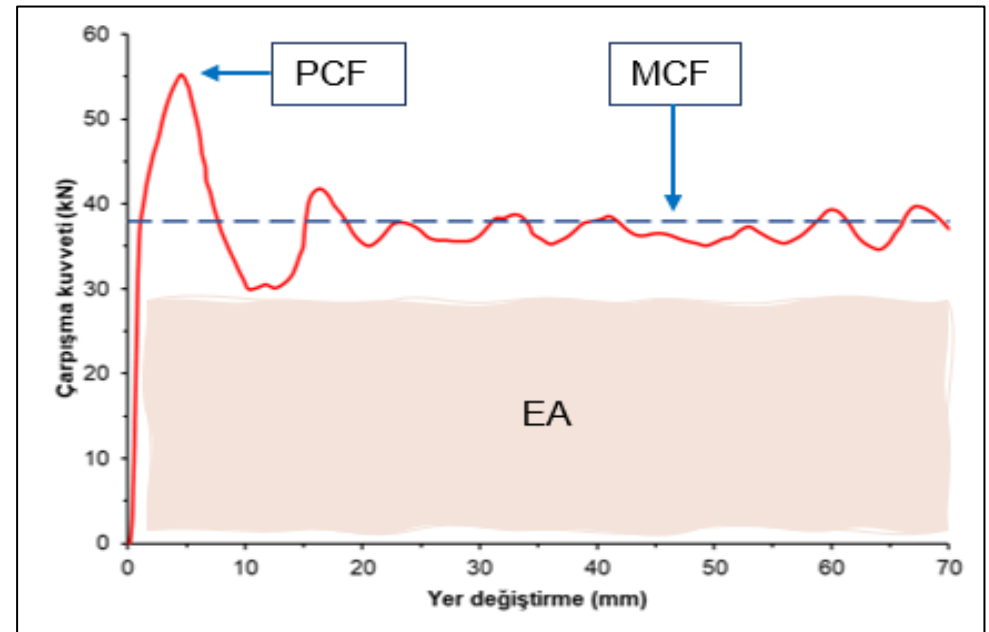
$$3) MCF = \frac{EA}{d}$$

$$4) SEA = \frac{EA}{m}$$

$$5) CFE = \frac{MCF}{PCF}$$

d : yer deęiřtirme

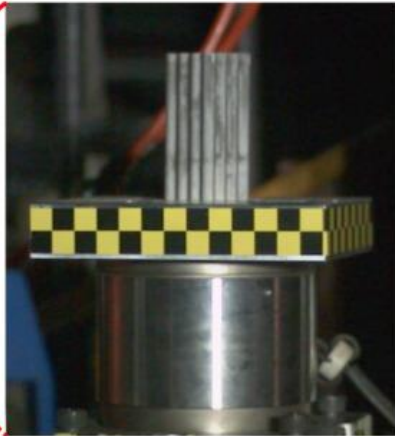
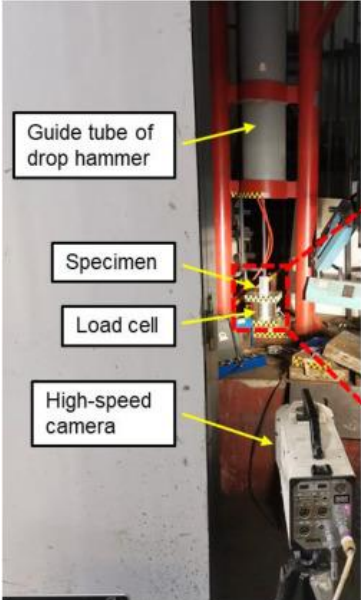
m : parça kütlesi



Sonlu Elemanlar Modeli Oluşturma

Fiziksel Deney

- AA6061O
- 181 kg ağırlığındaki kütle
- 1,80 m yükseklik
- **5,75 m/s çarpışma hızı**

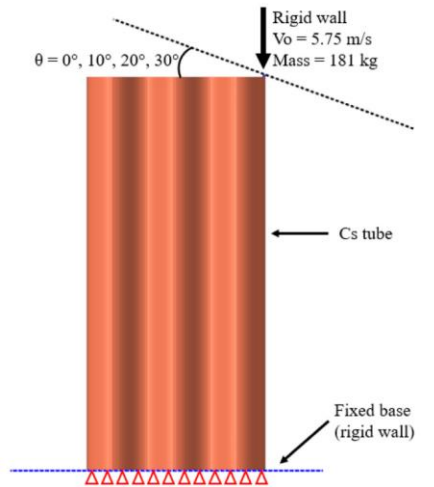
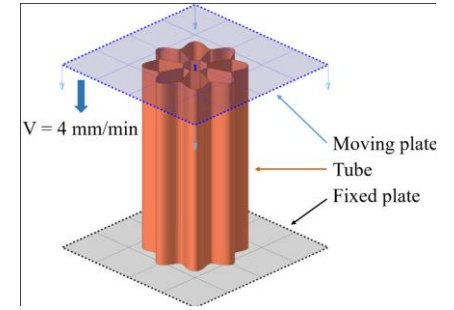
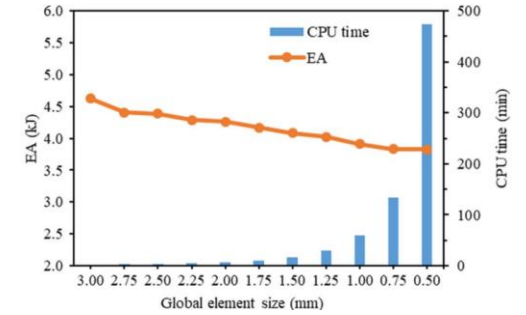
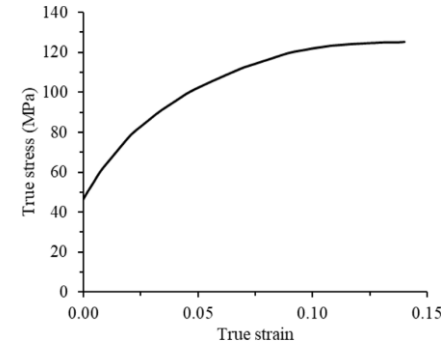


Sonlu elemanlar modeli

- Radioss
- 0,75 mm ortalama eleman boyutu
- Taban : Sabit rigid wall
- Üst plaka: Hareketli rigid wall
- Self contact TYPE7, friction 0.2

Card Image:	P1_SHELL
Ishell:	1:Q4, Visco-Elastic Hourglass Modes Orthogonal to Deformation and Rigid Modes (Belytschko)
Ismstr:	<OFF>
Ish3n:	0:Use Value in /DEF_SHELL
Idril:	1:Q4, Visco-Elastic Hourglass Modes Orthogonal to Deformation and Rigid Modes (Belytschko) 2:Q4, Visco-Elastic Hourglass without Orthogonality (Hallquist)
P_Thick_Fail:	3:Q4, Elasto-Plastic Hourglass with Orthogonality
Hm:	4:Q4 with Improved Type 1 Formulation
Hf:	12:QBAT Shell Formulation
..	24:QEPH Shell Formulation

Card Image:	M36_PLAS_TAB
Regular_OR_encry...	Regular
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Rho_Initial:	2.7e-09
E:	70040.0
Nu:	0.3



**Alüminyum malzemelerin strain rate duyarlılığı ihmal edilebilir.

Sonlu Elemanlar Modeli Doğrulama



Comparison of experimental [16] and FE simulation crashworthiness indicators.

Tube		PCF (kN)	MCF (kN)
C2	Experimental	9.63	4.84
	FEA	9.30	4.82
	Difference (%)	3.41	0.33
C3	Experimental	14.02	7.97
	FEA	13.18	8.33
	Difference (%)	5.99	4.55
C4	Experimental	19.37	12.43
	FEA	18.63	12.78
	Difference (%)	3.82	2.82

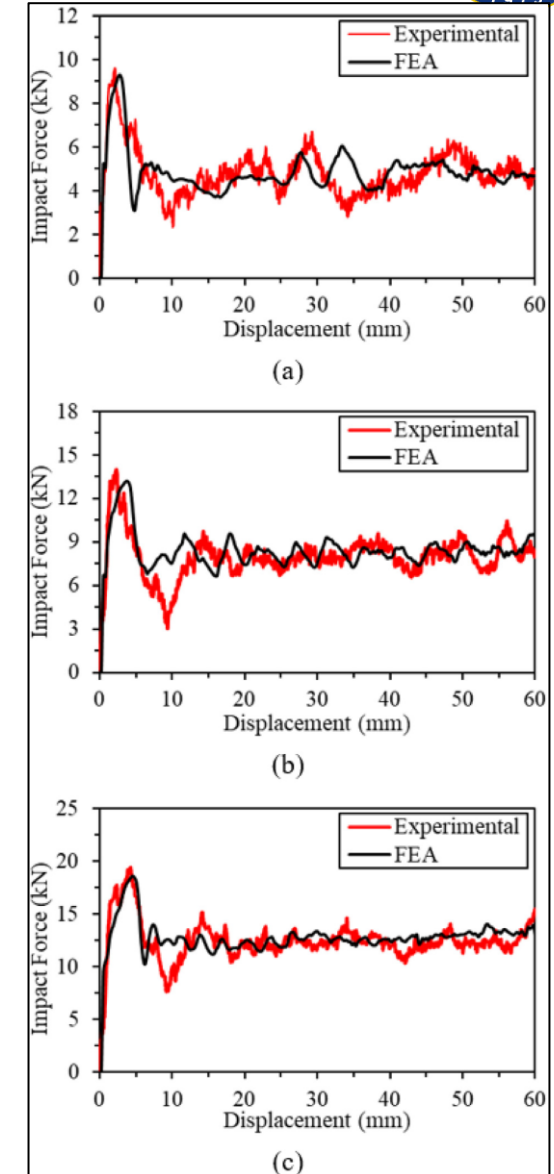
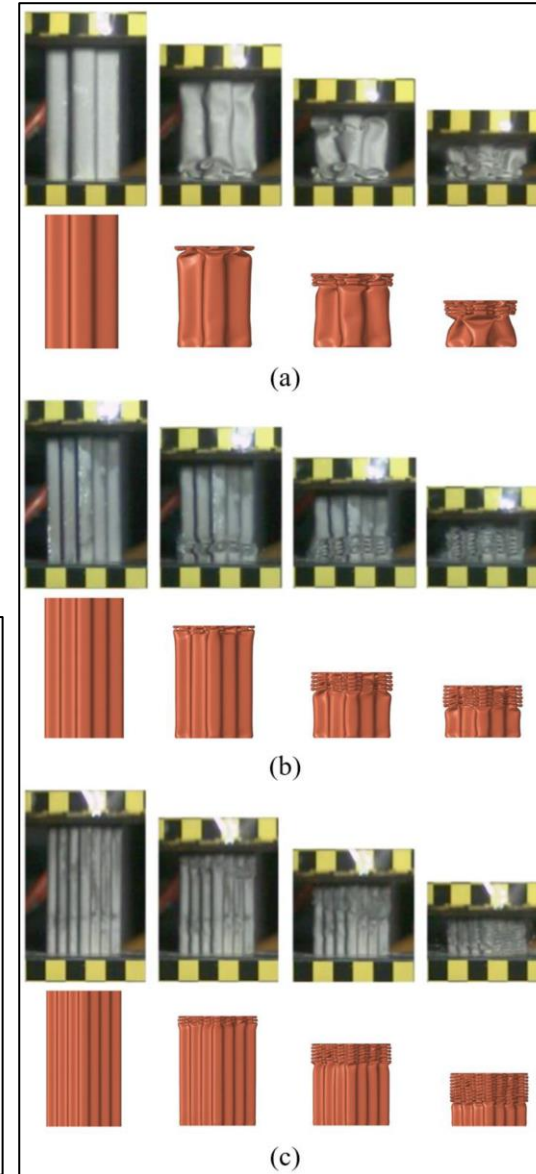
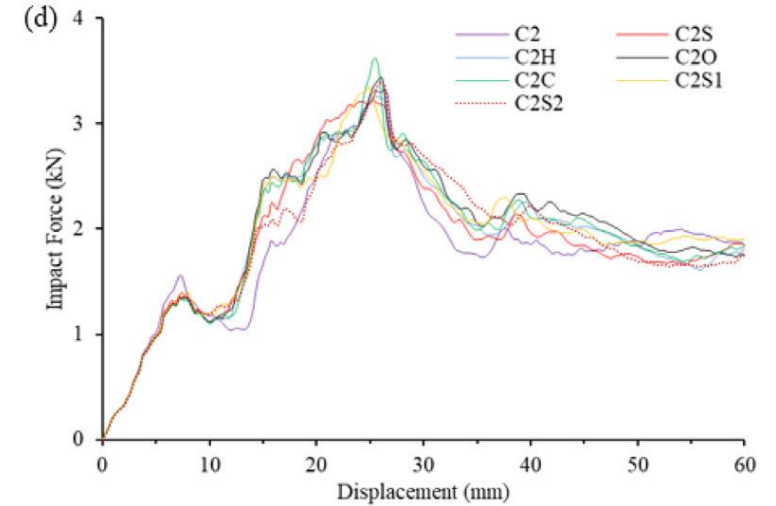
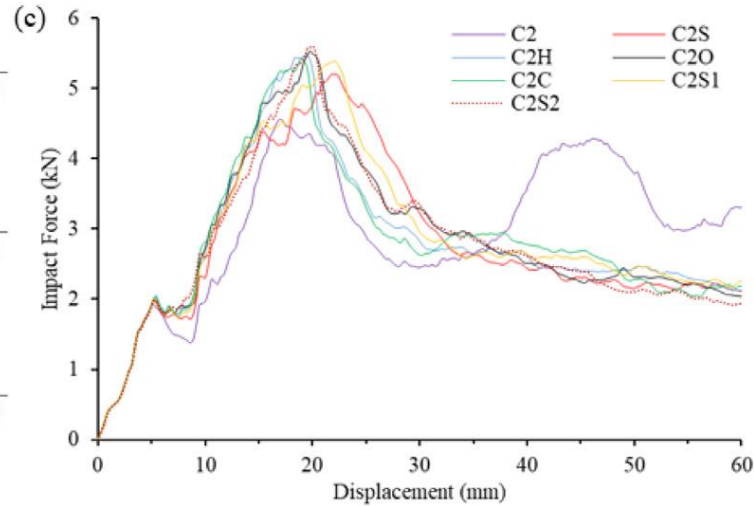
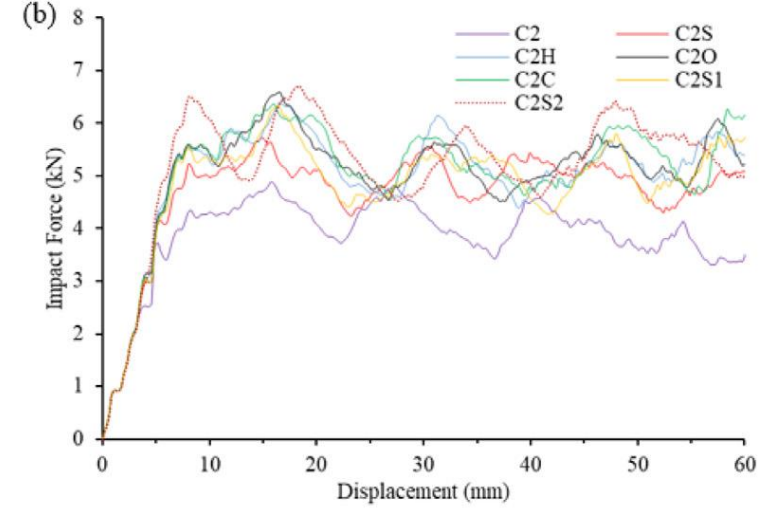
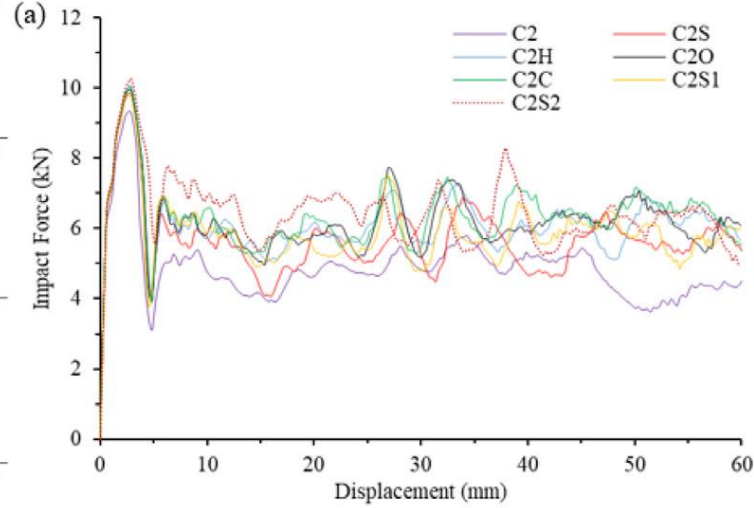
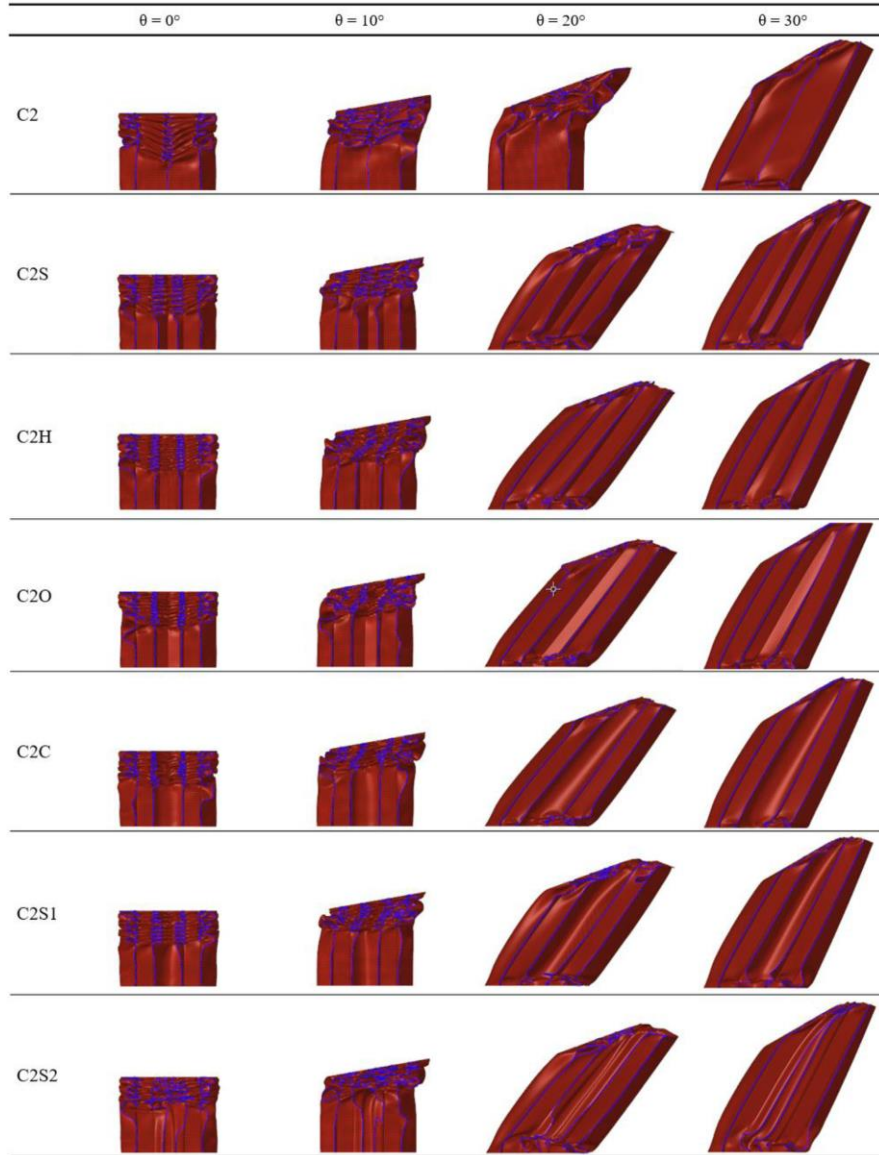


Table 2

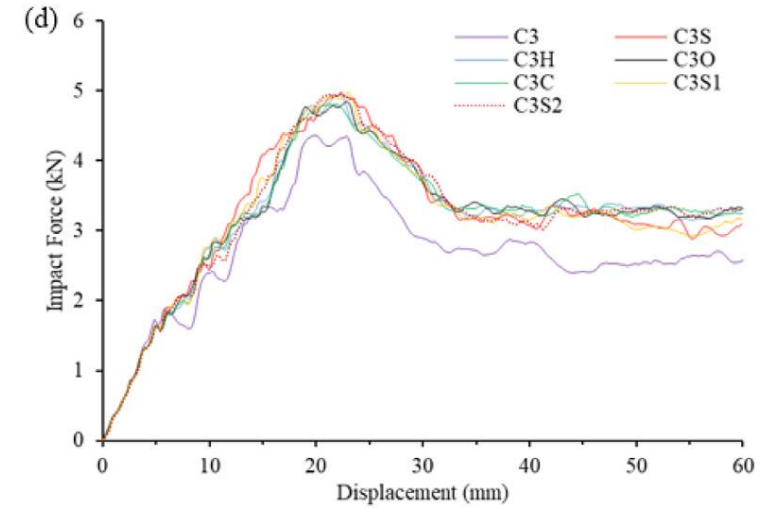
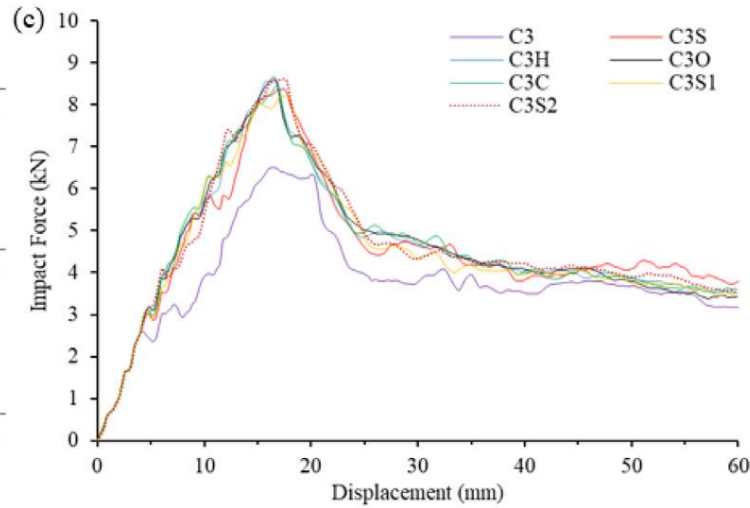
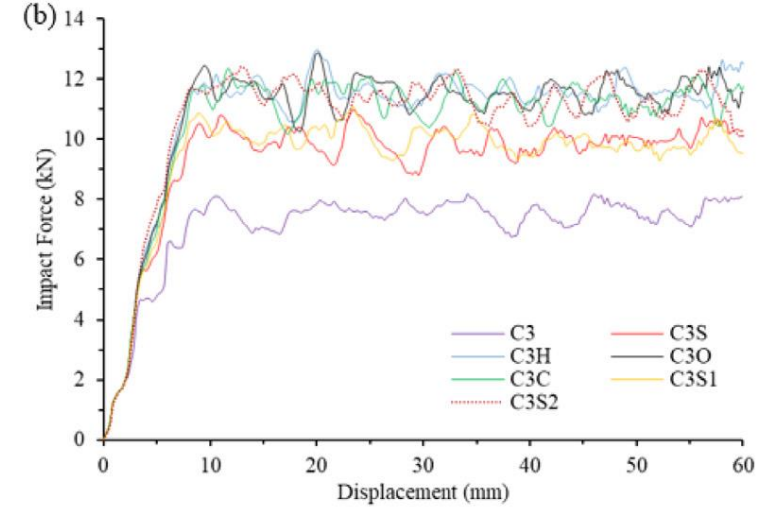
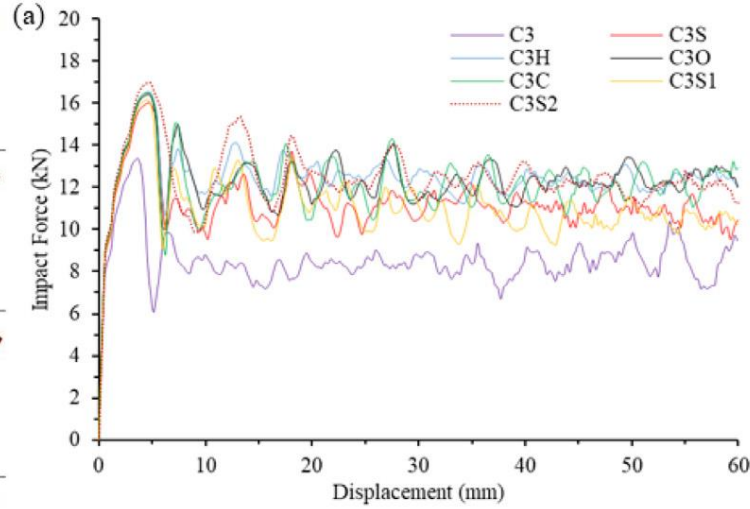
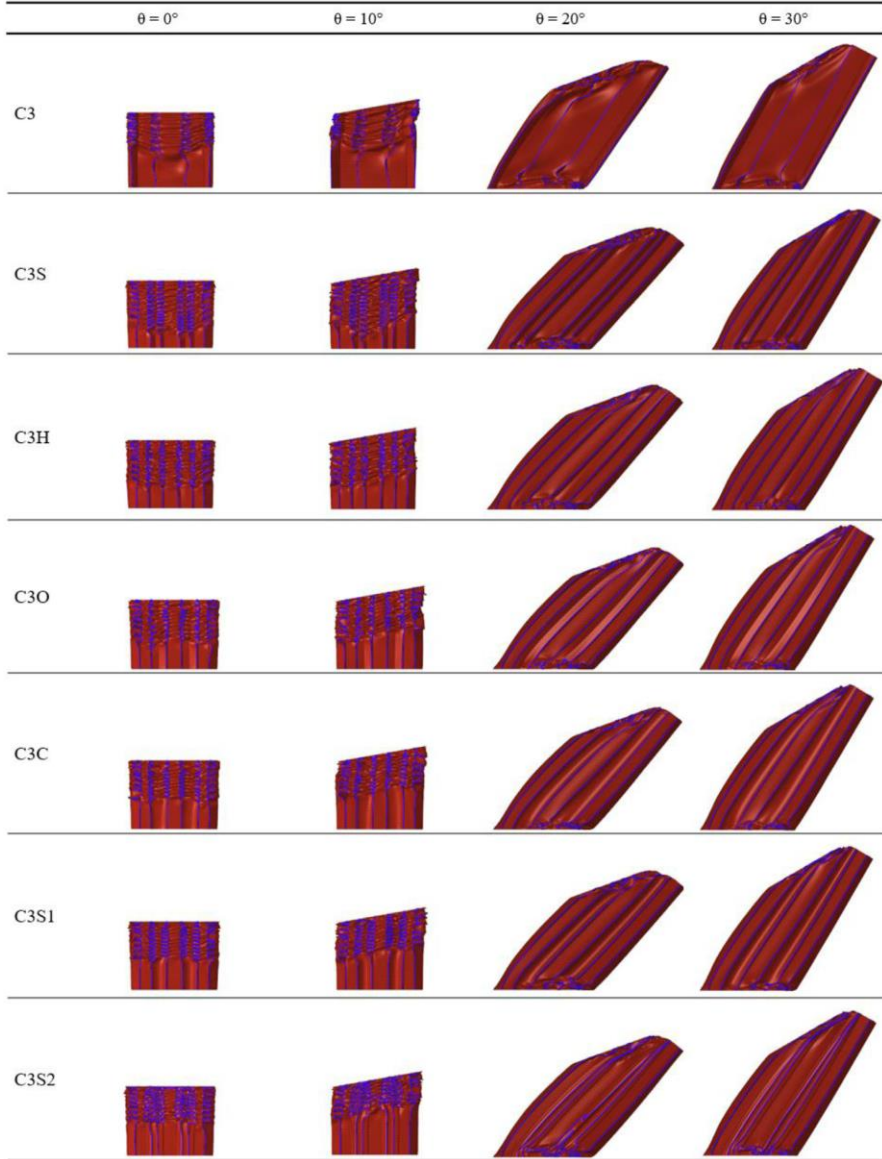
Comparison of FE simulations and theoretical predictions.

	FEA	Full equation		Exclude corner element	
	MCF (kN)	Theoretical MCF (kN)	Relative error (%)	Theoretical MCF (kN)	Relative error (%)
C2	4.85	5.44	10.90	–	–
C3	8.53	9.08	6.06	–	–
C4	12.83	13.09	2.02	–	–
C2S	5.66	6.43	11.98	–	–
C3S	11.23	12.06	6.86	–	–
C4S	17.49	18.70	6.48	–	–
C2H	6.15	6.95	11.47	6.54	5.91
C3H	12.50	13.56	7.79	12.39	0.89
C4H	19.16	21.47	10.75	19.34	0.91
C2O	6.21	6.99	11.21	6.59	5.70
C3O	12.35	13.68	9.71	12.52	1.38
C4O	19.13	21.68	11.76	19.57	2.27
C2C	6.35	6.47	1.93	–	–
C3C	12.21	12.21	0.00	–	–
C4C	18.71	19.00	1.53	–	–
C2S1	5.90	6.44	8.43	–	–
C3S1	11.03	12.10	8.88	–	–
C4S1	17.59	18.79	6.37	–	–
C2S2	6.47	6.93	6.66	6.53	0.87
C3S2	12.48	13.52	7.71	12.36	0.96
C4S2	19.47	21.40	9.00	19.27	1.06

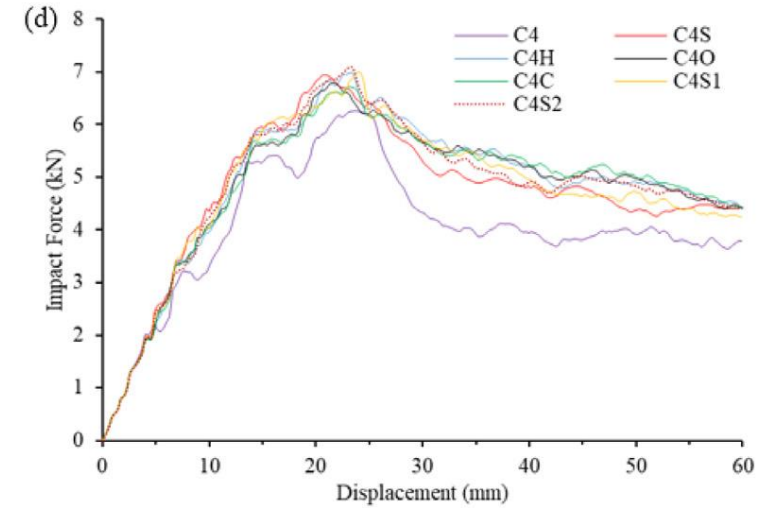
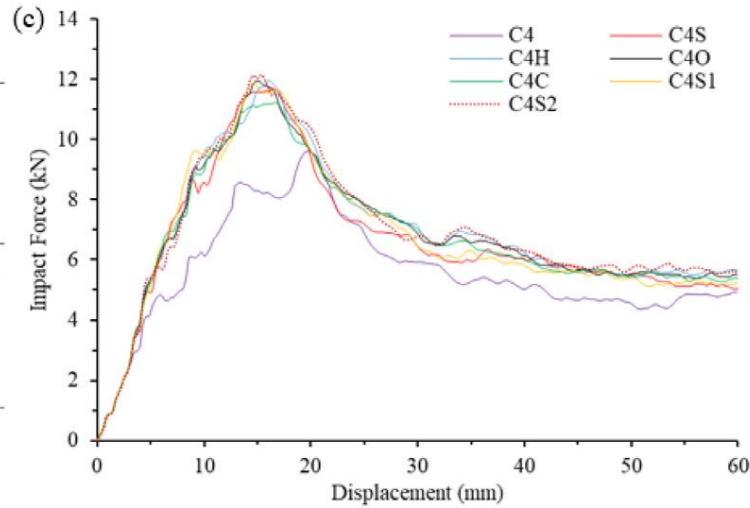
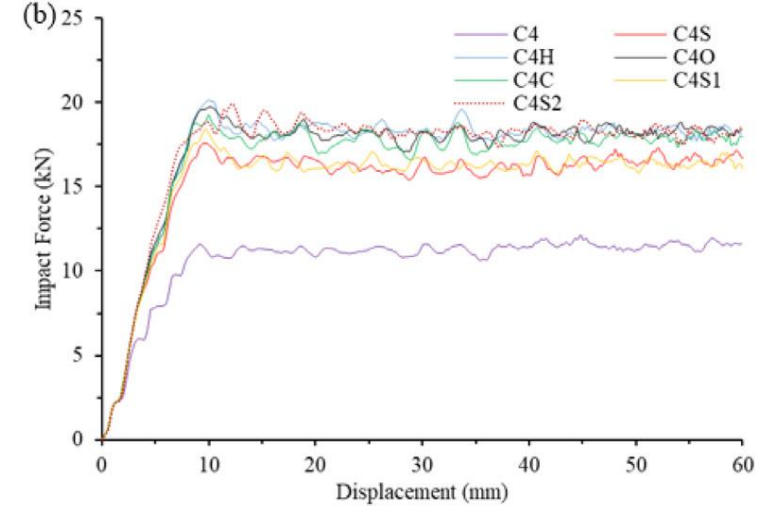
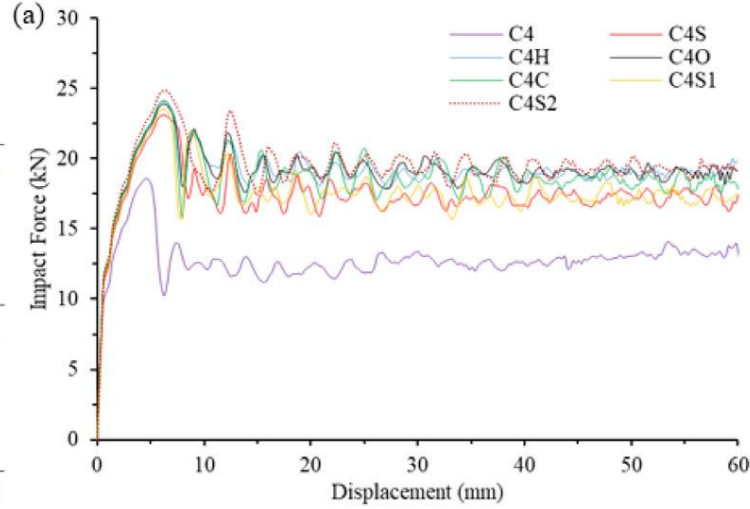
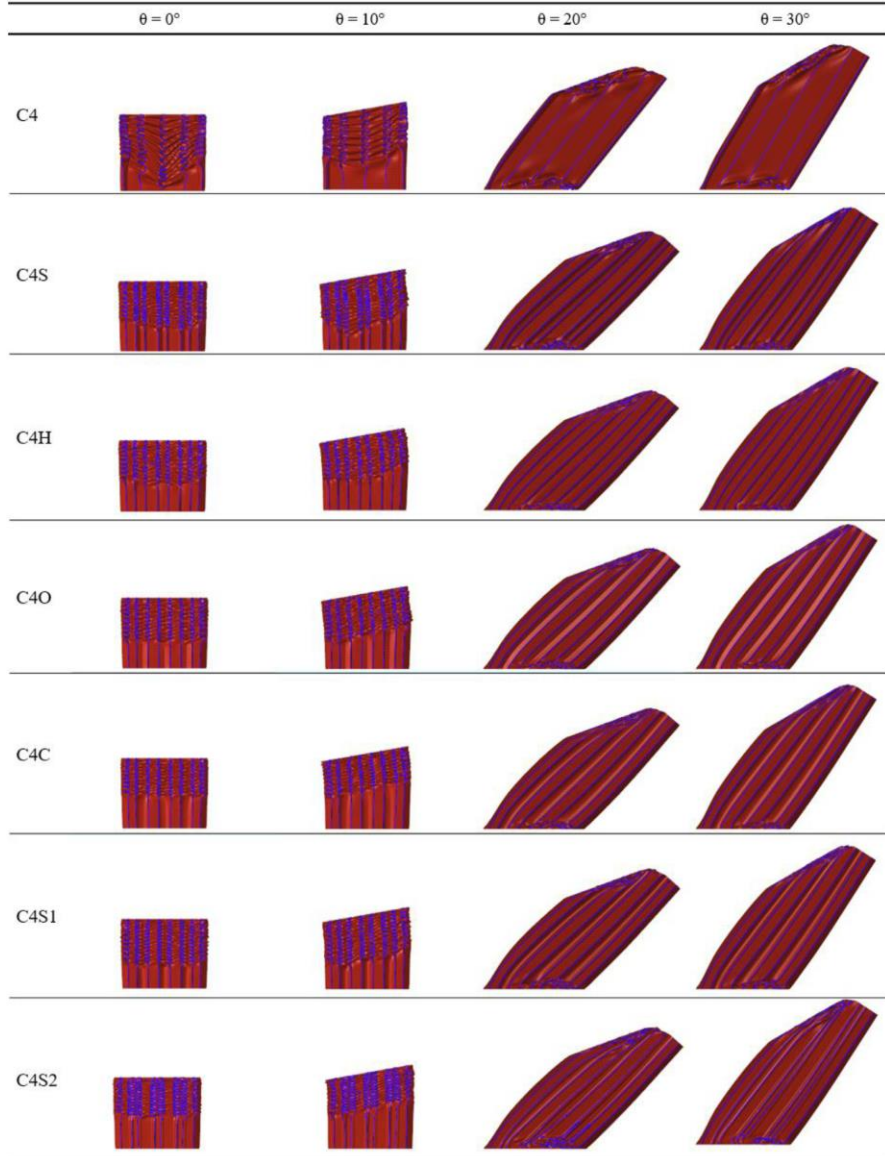
C2x Yapıları Katlanma Modları ve Kuvvet-Deplasman Eğrileri



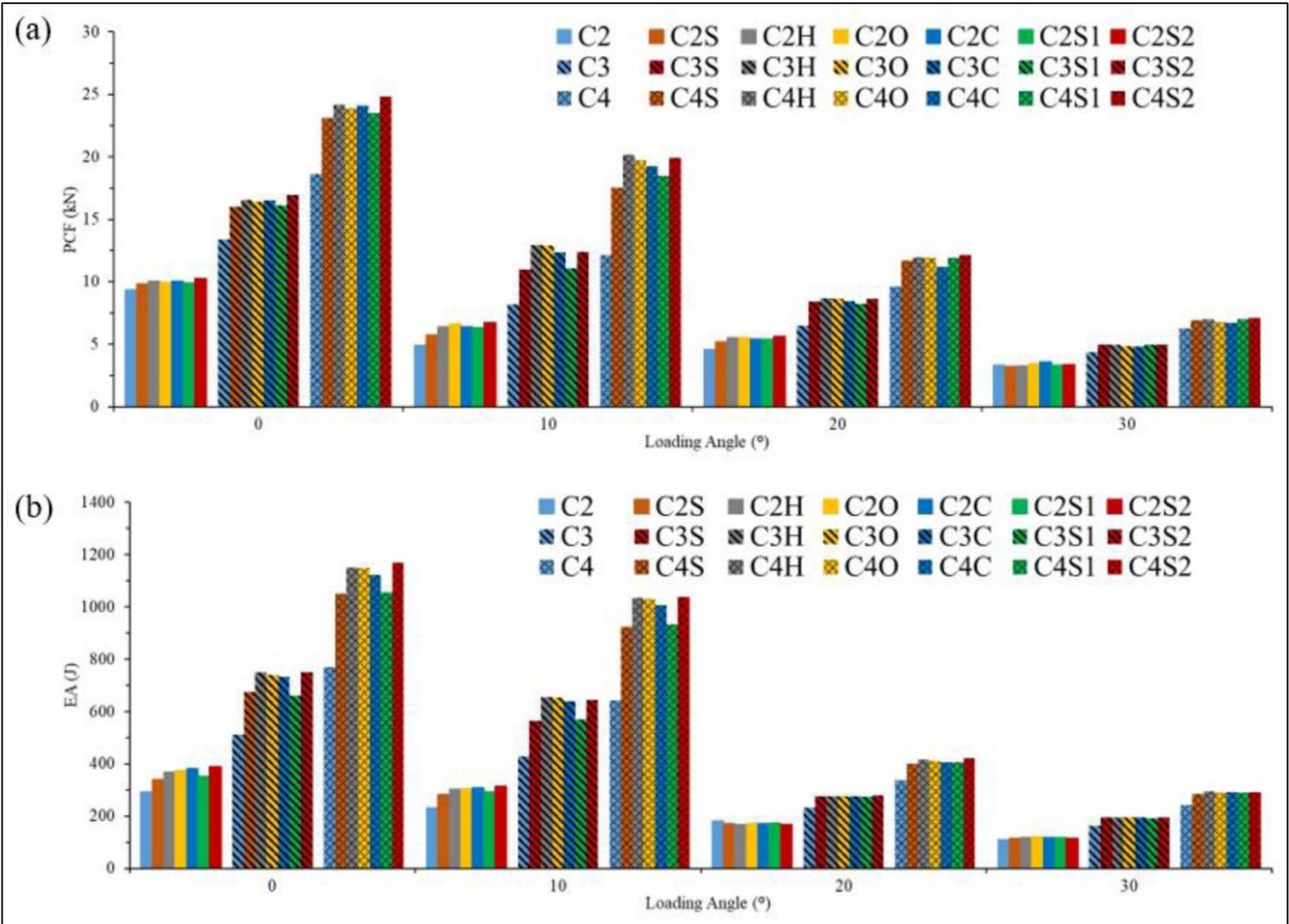
C3x Yapıları Katlanma Modları ve Kuvvet-Deplasman Eğrileri



C4x Yapıları Katlanma Modları ve Kuvvet-Deplasman Eğrileri

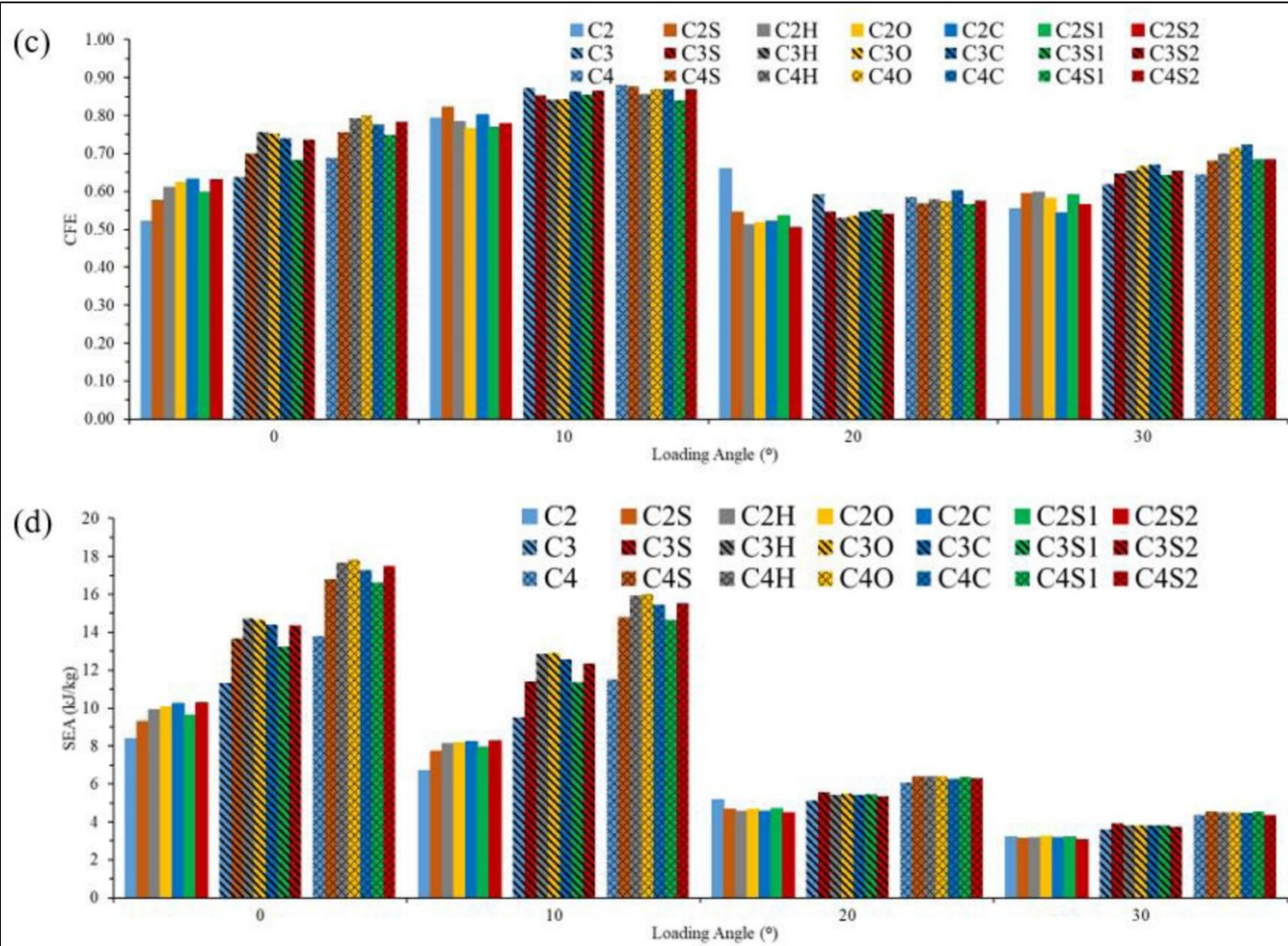


Yapıların PCF & EA Değerleri



Edge-junction type	Cs tube name		
None			
Square			
Hexagon			
Octagon			
Circle			
Cosine one			
Cosine two			

Yapıların CFE & SEA Değerleri



Edge-junction type	Cs tube name		
None	C2	C3	C4
Square	C2S	C3S	C4S
Hexagon	C2H	C3H	C4H
Octagon	C2O	C3O	C4O
Circle	C2C	C3C	C4C
Cosine one	C2S1	C3S1	C4S1
Cosine two	C2S2	C3S2	C4S2

Table 4
Decision matrix.

Loading angle (°)		0°			10°			20°			30°		
Tubes		PCF (kN)	CFE	EA (J)	PCF (kN)	CFE	EA (J)	PCF (kN)	CFE	EA (J)	PCF (kN)	CFE	EA (J)
C2	C2	9.32	0.52	291.27	4.89	0.79	232.31	4.56	0.66	180.14	3.33	0.55	110.66
	C2S	9.83	0.58	339.68	5.73	0.82	282.39	5.21	0.55	170.31	3.22	0.59	114.66
	C2H	10.06	0.61	368.73	6.41	0.78	301.72	5.49	0.51	168.60	3.26	0.60	117.08
	C2O	9.96	0.62	372.40	6.58	0.77	302.43	5.54	0.52	171.94	3.44	0.58	119.90
	C2C	10.04	0.63	381.03	6.37	0.80	306.56	5.42	0.52	169.58	3.62	0.54	117.89
	C2S1	9.87	0.60	353.76	6.33	0.77	292.05	5.39	0.54	173.56	3.35	0.59	118.38
	C2S2	10.26	0.63	388.18	6.71	0.78	312.80	5.59	0.50	169.21	3.40	0.57	115.40
C3	C3	13.38	0.64	511.74	8.19	0.87	428.97	6.51	0.59	231.18	4.37	0.62	162.40
	C3S	16.04	0.70	673.76	10.98	0.85	562.05	8.39	0.55	275.46	4.99	0.65	193.63
	C3H	16.54	0.76	749.80	12.97	0.84	654.62	8.67	0.53	276.21	4.95	0.65	194.53
	C3O	16.40	0.75	740.74	12.88	0.84	652.16	8.63	0.54	277.08	4.84	0.67	193.85
	C3C	16.51	0.74	732.49	12.35	0.86	639.75	8.46	0.55	276.94	4.81	0.67	193.64
	C3S1	16.15	0.68	661.67	11.08	0.86	568.27	8.23	0.55	272.44	4.98	0.64	191.91
	C3S2	16.97	0.74	749.04	12.42	0.87	645.16	8.62	0.54	279.83	4.96	0.65	194.67
C4	C4	18.63	0.69	769.72	12.15	0.88	641.64	9.63	0.58	337.87	6.26	0.65	242.63
	C4S	23.13	0.76	1049.37	17.56	0.88	923.51	11.70	0.57	399.65	6.94	0.68	284.24
	C4H	24.15	0.79	1149.73	20.15	0.86	1034.67	11.99	0.58	416.21	6.99	0.70	293.87
	C4O	23.91	0.80	1147.80	19.76	0.87	1029.82	11.94	0.57	411.62	6.78	0.71	290.46
	C4C	24.13	0.78	1122.56	19.26	0.87	1005.33	11.21	0.60	406.10	6.72	0.72	291.91
	C4S1	23.51	0.75	1055.55	18.47	0.84	931.27	11.89	0.57	404.58	7.01	0.69	288.14
	C4S2	24.85	0.78	1168.33	19.91	0.87	1037.85	12.15	0.58	419.83	7.08	0.69	291.15

Table 5

Weighting factors.

Loading	Parameter	Weighting methods			
		Entropy-1	Entropy-2	Entropy-3	Literature
0°	PCF	0.101	0.401	0.366	0.098
	CFE	0.011	0.038	0.041	0.053
	EA	0.163	0.561	0.592	0.098
10°	PCF	0.166	0.401	0.468	0.098
	CFE	0.002	0.038	0.005	0.053
	EA	0.187	0.561	0.527	0.098
20°	PCF	0.085	0.401	0.455	0.098
	CFE	0.003	0.038	0.018	0.053
	EA	0.099	0.561	0.527	0.098
30°	PCF	0.070	0.401	0.380	0.098
	CFE	0.006	0.038	0.031	0.053
	EA	0.108	0.561	0.588	0.098

Table 6

Result of multi-criteria decision approaches.

Tubes	TOPSIS				COPRAS			
	Ent. - 1	Ent. - 2	Ent. - 3	Lit.	Ent. - 1	Ent. - 2	Ent. - 3	Lit.
C2	0.403	0.362	0.389	0.442	85.6%	82.7%	85.1%	95.2%
C2S	0.402	0.360	0.386	0.439	82.7%	80.6%	82.4%	92.4%
C2H	0.398	0.357	0.382	0.435	80.7%	79.1%	80.7%	90.3%
C2O	0.396	0.355	0.380	0.432	80.0%	78.5%	80.1%	89.5%
C2C	0.400	0.356	0.382	0.432	80.4%	78.4%	80.1%	89.4%
C2S1	0.396	0.356	0.381	0.434	80.8%	79.2%	80.9%	90.5%
C2S2	0.397	0.355	0.380	0.431	79.6%	78.0%	79.6%	88.9%
C3	0.429	0.395	0.417	0.455	79.4%	78.9%	80.0%	88.3%
C3S	0.470	0.455	0.464	0.471	80.7%	80.8%	81.4%	87.6%
C3H	0.494	0.485	0.485	0.482	82.3%	82.4%	82.8%	88.5%
C3O	0.493	0.485	0.485	0.483	82.4%	82.5%	82.9%	88.8%
C3C	0.495	0.484	0.486	0.488	82.5%	82.6%	83.0%	89.1%
C3S1	0.467	0.452	0.460	0.468	80.4%	80.5%	81.1%	87.3%
C3S2	0.499	0.488	0.490	0.486	82.6%	82.6%	83.0%	88.8%
C4	0.519	0.526	0.528	0.498	84.6%	85.3%	85.8%	90.0%
C4S	0.579	0.602	0.587	0.525	95.3%	95.7%	95.8%	96.8%
C4H	0.578	0.610	0.591	0.529	99.7%	99.8%	99.8%	99.9%
C4O	0.582	0.613	0.594	0.533	99.6%	99.7%	99.7%	100.0%
C4C	0.583	0.616	0.599	0.537	98.8%	99.1%	99.1%	99.9%
C4S1	0.568	0.597	0.581	0.518	95.3%	95.9%	96.0%	96.5%
C4S2	0.580	0.608	0.591	0.528	100.0%	100.0%	100.0%	99.8%

Çok Amaçlı Optimizasyon

$$\left\{ \begin{array}{l} \min [PCF_w(t_1, t_2, d), -EA_w(t_1, t_2, d)] \\ s.t. \left\{ \begin{array}{l} 0.5 \text{ mm} \leq t_1 \leq 1.0 \text{ mm} \\ 0.5 \text{ mm} \leq t_2 \leq 1.0 \text{ mm} \\ 4.5 \text{ mm} \leq d \leq 9.0 \text{ mm} \end{array} \right. \end{array} \right.$$

$$\left\{ \begin{array}{l} PCF_w = \sum_{i=1}^k w_i PCF_i \\ EA_w = \sum_{i=1}^k w_i EA_i \\ \sum_{i=1}^k w_i = 1, w_i \geq 0 \end{array} \right.$$

Table 8
Value of weighting factor for all conditions.

Design case	w_{a1}	w_{a2}	w_{a3}	w_{a4}
Case I of SLC	1.00	0.00	0.00	0.00
Case II of SLC	0.00	1.00	0.00	0.00
Case III of SLC	0.00	0.00	1.00	0.00
Case IV of SLC	0.00	0.00	0.00	1.00
Case I of MLC	0.10	0.20	0.30	0.40
Case II of MLC	0.25	0.25	0.25	0.25
Case III of MLC	0.40	0.30	0.20	0.10

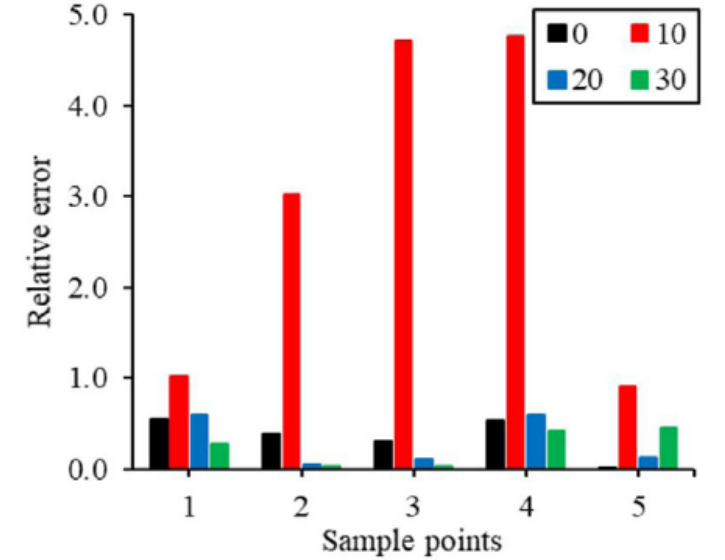
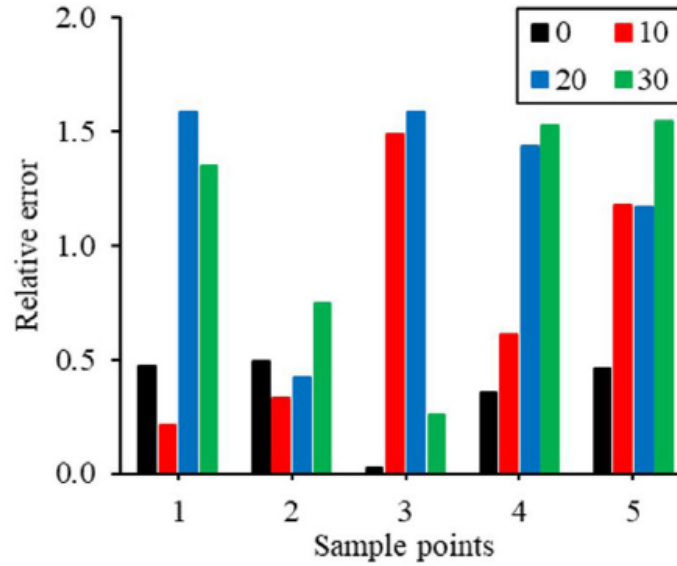
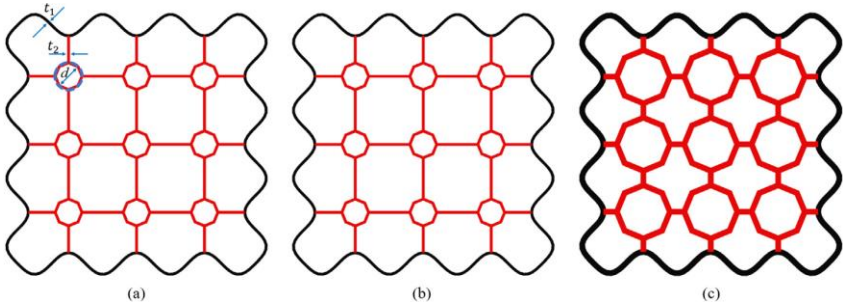


Fig. 18. Relative errors of RBF approximate models (a) PCF, (b) EA.

Pareto Eğrileri

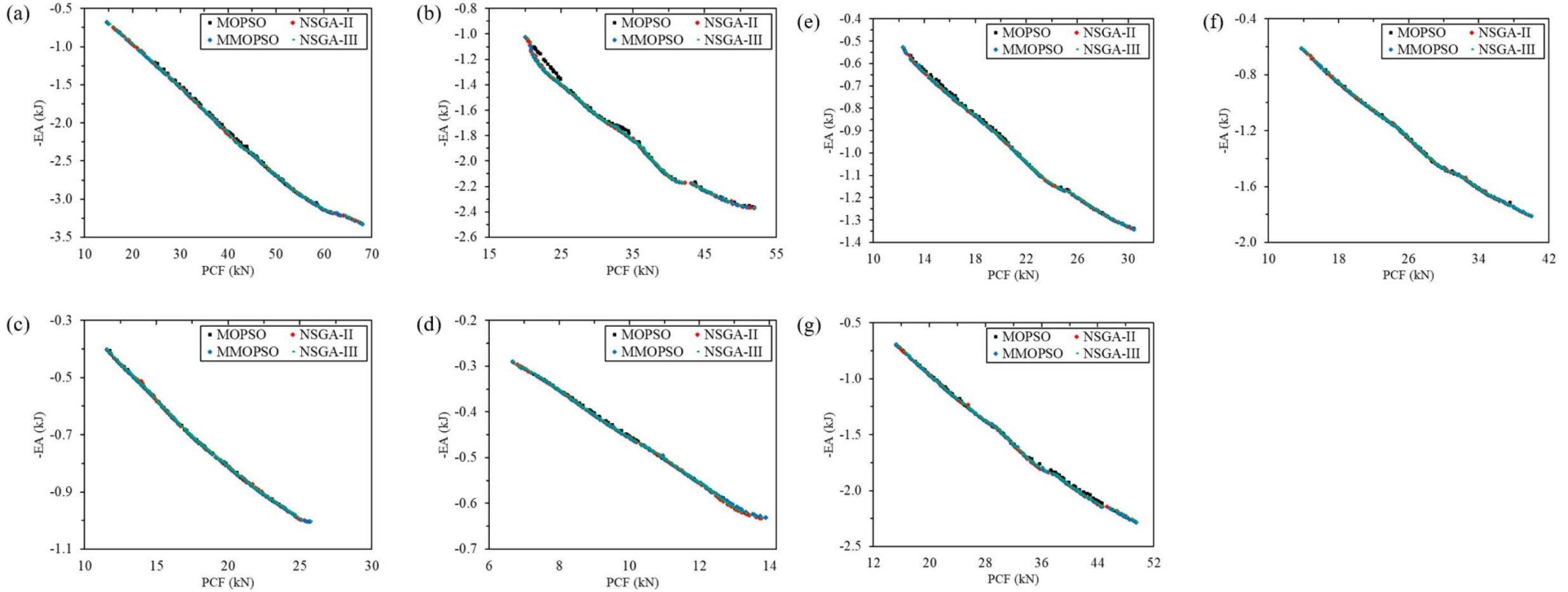


Fig. 19. Pareto frontiers for multiobjective optimizations (a) Case I of SLC, (b) Case II of SLC, (c) Case III of SLC, (d) Case IV of SLC, (e) Case I of MLC, (f) Case II of MLC, (g) Case III of MLC.

Table 9
Optimization results of all cases.

		Optimization results					FEA		Relative error	
		Design parameters			PCF (kN)	EA (kJ)	PCF (kN)	EA (kJ)	PCF (%)	EA (%)
		t_1 (mm)	t_2 (mm)	d (mm)						
Case I of SLC	MOPSO	0.87	0.96	5.52	50.99	2.75	50.42	2.71	1.11	1.20
	NSGAI	0.96	1.00	5.38	56.76	3.02				
	MMOPSO	0.95	0.99	5.60	56.12	2.99				
	NSGAI	0.92	1.00	5.45	55.45	2.97				
Case II of SLC	MOPSO	0.92	0.70	6.39	39.21	2.08	39.61	2.01	1.02	3.64
	NSGAI	0.95	0.72	6.64	40.84	2.15				
	MMOPSO	0.92	0.72	6.48	40.03	2.12				
	NSGAI	0.95	0.70	6.55	39.66	2.11				
Case III of SLC	MOPSO	1.00	0.57	6.42	17.97	0.73	17.90	0.70	0.36	4.38
	NSGAI	1.00	0.60	6.55	18.50	0.75				
	MMOPSO	1.00	0.62	6.52	18.79	0.76				
	NSGAI	1.00	0.59	6.46	18.19	0.74				
Case IV of SLC	MOPSO	0.79	0.77	8.93	11.19	0.51	11.37	0.51	1.61	1.47
	NSGAI	1.00	0.84	4.57	13.21	0.62				
	MMOPSO	0.91	0.94	9.00	13.32	0.62				
	NSGAI	1.00	0.50	8.99	10.49	0.48				
Case I of MLC	MOPSO	0.92	0.69	6.29	22.42	1.07	22.47	1.05	0.21	1.50
	NSGAI	0.93	0.72	6.32	23.25	1.11				
	MMOPSO	0.94	0.74	6.38	23.70	1.13				
	NSGAI	0.97	0.75	6.44	24.28	1.15				
Case II of MLC	MOPSO	0.88	0.71	6.27	27.98	1.37	28.03	1.36	0.18	0.95
	NSGAI	0.94	0.71	6.21	28.87	1.43				
	MMOPSO	0.94	0.72	6.52	28.98	1.43				
	NSGAI	0.94	0.70	6.36	28.49	1.41				
Case III of MLC	MOPSO	0.87	0.74	6.65	34.14	1.70	34.17	1.68	0.07	1.58
	NSGAI	0.93	0.73	6.37	35.11	1.77				
	MMOPSO	0.99	0.74	6.21	36.44	1.82				
	NSGAI	0.93	0.71	6.51	34.54	1.75				

- ❖ Çalışmada, sonlu elemanlar modelinin oluşturulmasında **HyperMesh**, çözücü olarak **Radioss**, sonuçların görüntülenmesinde **HyperView** ve **HyperGraph**, verilerin toplanması ve parametrik analizlerin gerçekleştirilmesinde **HyperMorph** ve **HyperStudy**, optimizasyonlar için ise **MATLAB** programı kullanılmıştır.
- ❖ Yüksek çarpışma performanslı yapılar için farklı kesitler ve malzemeler üzerinde çalışmalar yapılmaktadır,
- ❖ Sonlu elemanlar modelinin doğruluğu önemlidir,
- ❖ Teorik hesaplama ile MCF hesaplanabilir,
- ❖ Hücre sayısı, hücre tipi ve çarpışma açısının çarpışma performansı üzerinde önemli etkileri vardır,
- ❖ Farklı yapılar arasından en iyi olanı belirlemek için MCDM yöntemleri kullanılabilir,
- ❖ RBF ile yüksek doğruluklu metamodeller oluşturulabilmektedir,
- ❖ Çok amaçlı optimizasyonlar farklı şartları da görmek için kullanılabilir.

Teşekkürler & Sorular ...

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