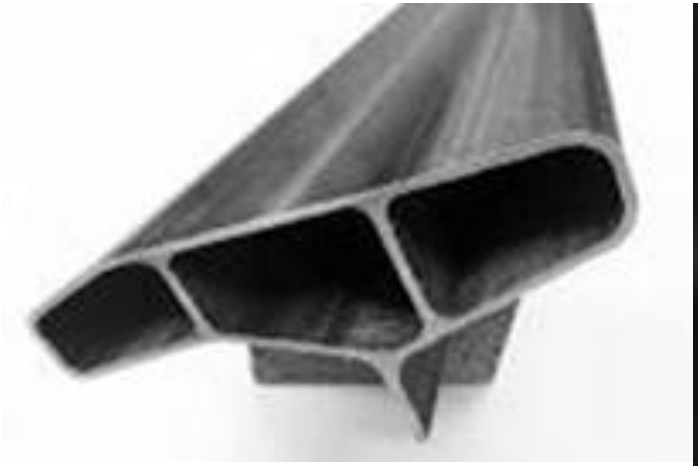
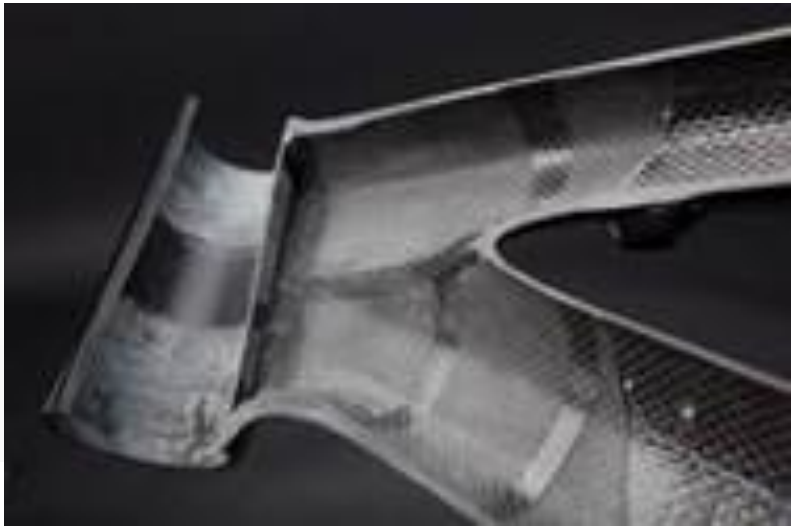
Kaj zamujamo pri neuporabi gradbenih proizvodov, ki vsebujejo FRP

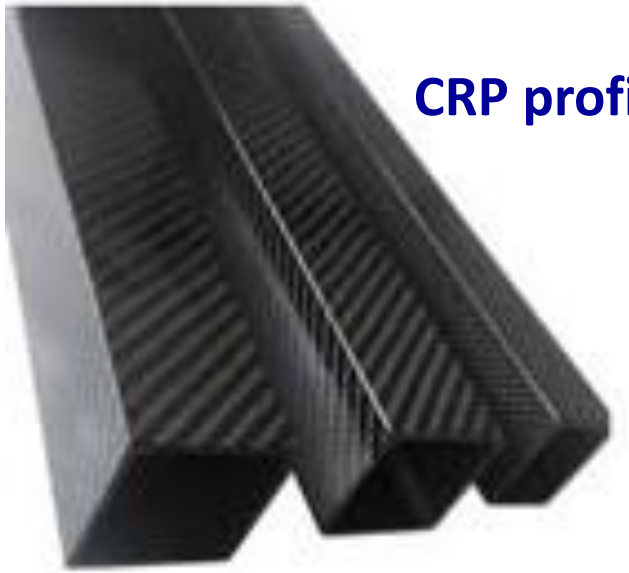
Uporaba ojačanih polimernih kompozitov v gradbeništvu krožnega gospodarstva

12. Oktober 2021

Janez Navodnik







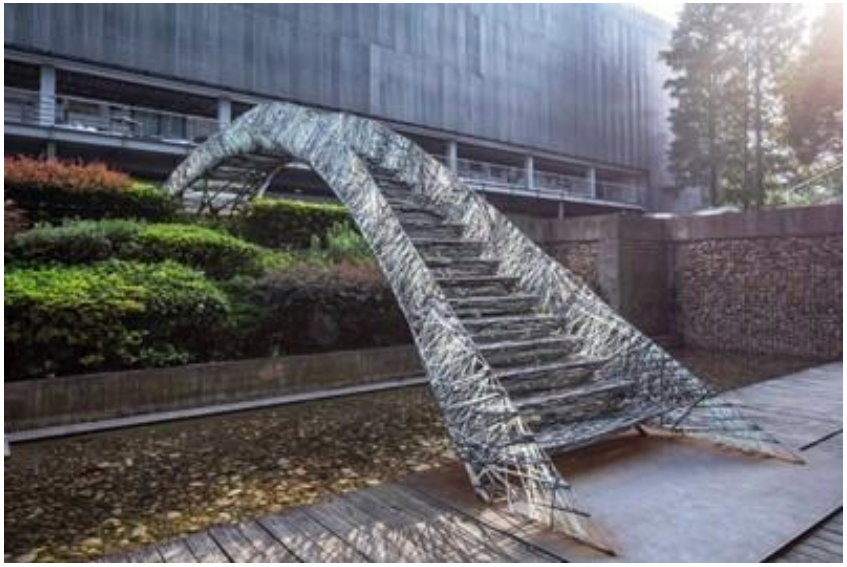
CRP profili

CRP v Uni Stuttgart

CRP trakovi za sanacijo betonskih preklad in plošč

Uni Dresden: FR/beton (FRC)

FRC zgradbe



Uni Tongji, 3D tiskana ojačitev mostu; FRP most

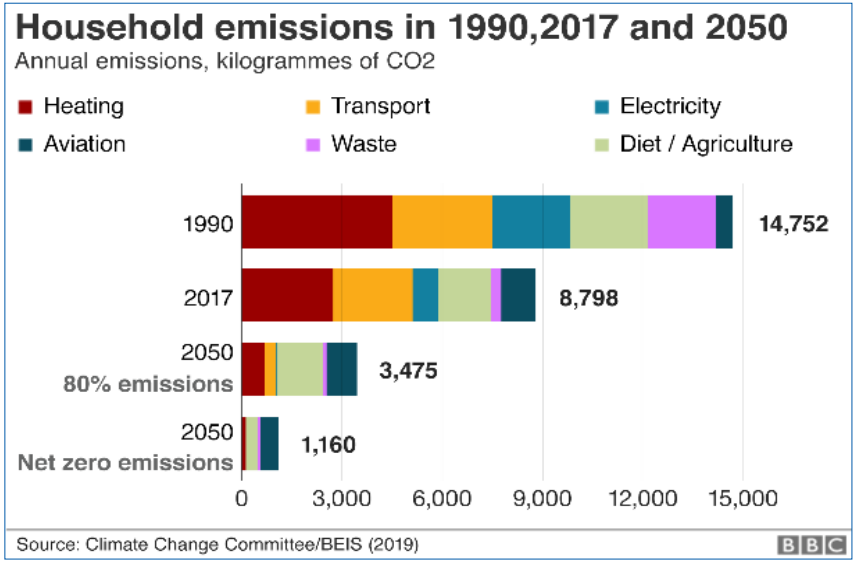
Vetrnice

Dubai, največja FRP jahta in nekaj zgradb

- ekonomske, okoljske, geopolitične, družbene, tehnološke.

1 Klimatske spremembe +1,5 °C, CO_2, metan

Zemlja se je segrela za 1 °C od industrijske revolucije, ko je bilo CO_2 280 ppm; zdaj je 412 ppm in narašča. Za zahtevano omejitev 1,5 °C je nujno zmanjšati emisije in zmanjševanje nivoja CO_2. Plastika ima med ind. surovinami najnižji CO_2 odtis.



Material	Vgrajena En MJ/kg	Vgrajen CO_2 Kg CO_2/kg
Inox	56.7	6.15
Aluminij	155	8.24
HDPE rec	47	1.7
PVC rec	54	1.8

Povečanje CO2 emisij po onesnaževalcih (transport …);

Cilj za zmanjšanje emisij za 80 % v letih 1990–2050.

Globalni problemi:

Zdravje, gibanje
CO_2, segrevanje
Pitna voda
Hrana
Energija
Samozadostne hiše
Lahki avtomobili
Krožna ekonomija
Redke kovine
Mikroplastika
Fosfor-atrofikacija morij

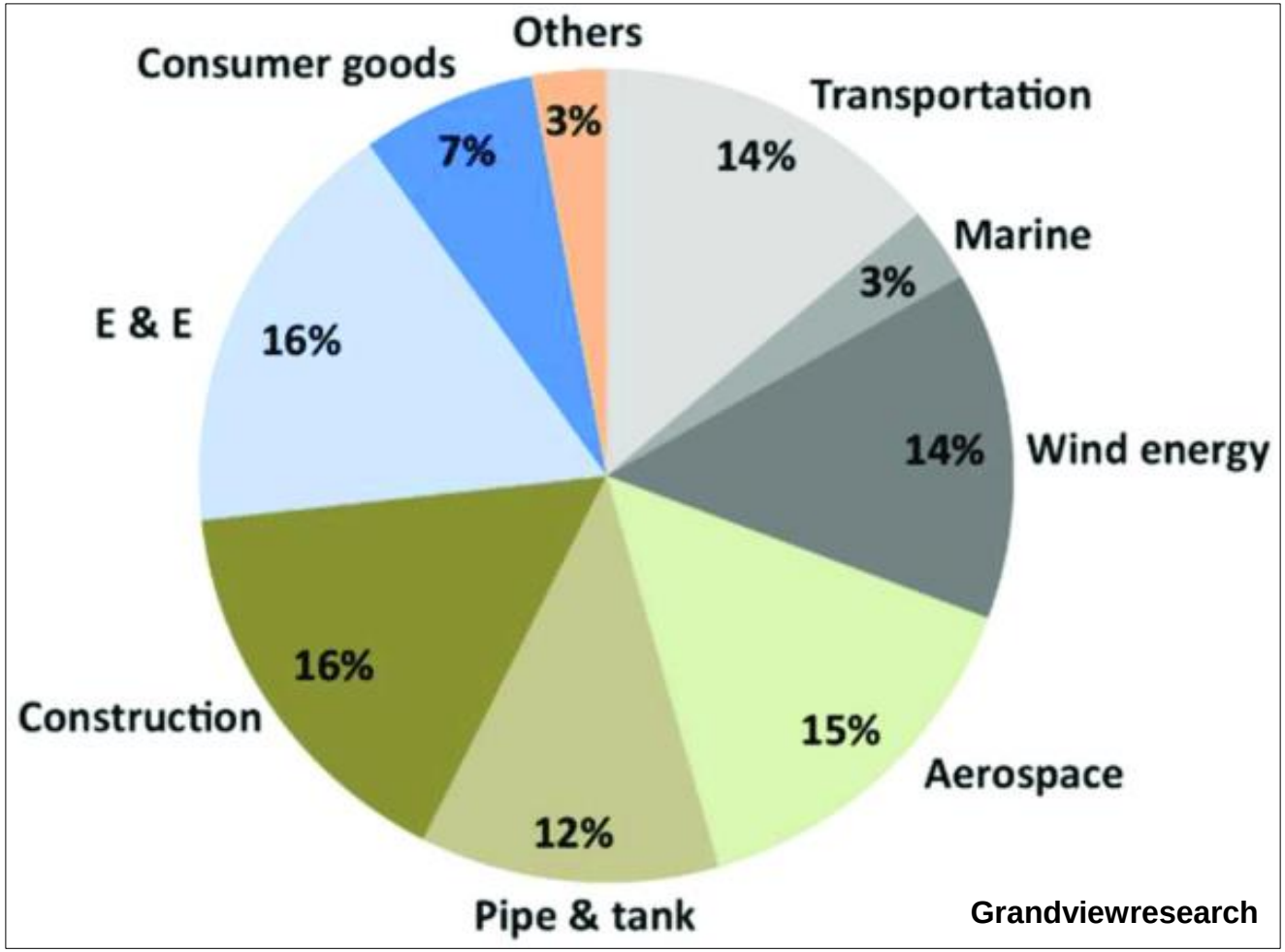
Prebojne teme:

Biopolimeri,
(Bio) kompoziti
Izolacije VIP
Nano pene
Bariere (VIP)
Absorberji
Fotovoltaika
Vetrnice
Reciklati
Redke kovine
Funkcionalni, odzivni materiali
Brizganje-integrirano
Površinske tehnologije
3D print
Implantati
Čistilne naprave

EU RAZPISI

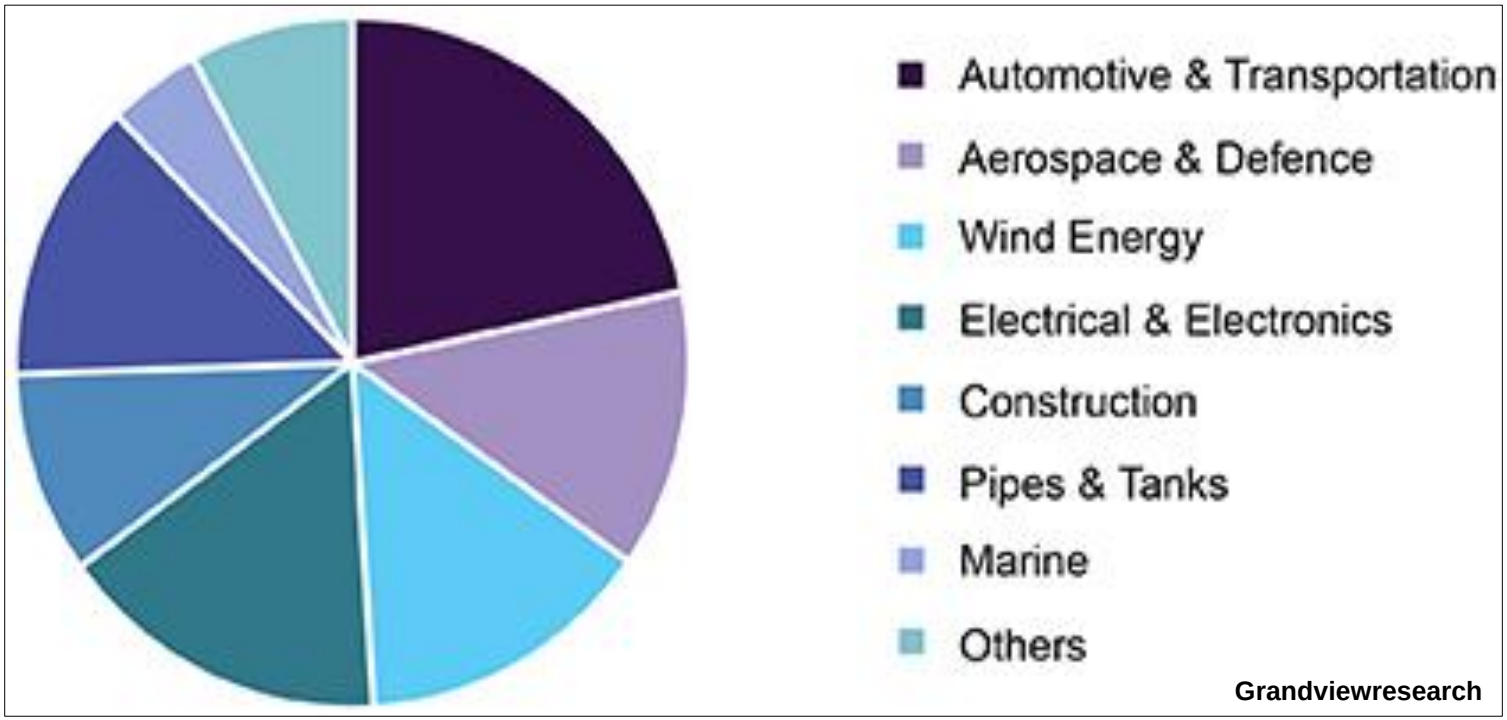
H-MISS-2021-NEB-01-01 Support the deployment of lighthouse demonstrators for the New European Bauhaus initiative in the context of H Europe missions	25 Jan 2022
H-CL5-2021-D4-01-02 Industrialisation of deep renovation workflows for energy-efficient buildings	19 Oct 2021
H-CL5-2021-D4-02-01 Demonstrating integrated technology solutions for buildings with performance guarantees (Built4People)	25 Jan 2022
H-CL5-2021-D4-02-03 Strengthening European coordination and exchange for innovation uptake towards sustainability, quality, circularity and social inclusion in the built environment as a contribution to the new European Bauhaus (Built4People)	25 Jan 2022
H-CL5-2022-D4-01-02 Renewable-intensive, energy positive homes	06 Sep 2022
H-CL5-2022-D4-01-03 Smarter buildings for better energy performance	06 Sep 2022
H-CL5-2022-D4-01-01 Demand response in energy-efficient residential buildings	06 Sep 2022
H-CL5-2022-D4-02-01 Designs, materials and solutions to improve resilience, preparedness & responsiveness of the built environment for climate adaptation (Built4People)	24 Jan 2023
H-CL5-2022-D4-02-02 Solutions for the sustainable, resilient, inclusive and accessible regeneration of neighbourhoods enabling low carbon footprint lifestyles and businesses (Built4People)	24 Jan 2023
H-CL5-2022-D4-02-03 Sustainable and resource-efficient solutions for an open, accessible, inclusive, resilient and low-emission cultural heritage: prevention, monitoring, management, maintenance, and renovation (Built4People)	24 Jan 2023
H-CL5-2022-D4-02-04 Smart-grid ready and smart-network ready buildings, acting as active utility nodes (Built4People)	24 Jan 2023
H-CL5-2022-D4-02-05 More sustainable buildings with reduced embodied energy / carbon, high life-cycle performance and reduced life-cycle costs (Built4People)	24 Jan 2023
H-CL5-2021-D2-01-08 Emerging technologies for a climate neutral Europe	19 Oct 2021
H-CL5-2021-D3-02-04 Novel tandem, high efficiency Photovoltaic technologies targeting low cost production with earth abundant materials	05 Jan 2022
H-CL5-2021-D3-03-13 Demonstration pilot lines for alternative and innovative PV technologies (Novel c-Si tandem, thin film tandem, bifacial, CPV, etc.)	23 Feb 2022
H-CL5-2021-D3-03-12 Innovation on floating wind energy deployment optimized for deep waters and different sea basins (Mediterranean Sea, Black Sea, Baltic Sea, North-Ocean)	23 Feb 2022
H-CL5-2021-D3-03-11 Development of hydropower equipment for hidden hydropower	23 Feb 2022
H-CL5-2021-D3-03-06 Novel approaches to concentrated solar power (CSP)	23 Feb 2022
H-CL5-2021-D3-03-07 Stable high-performance Perovskite Photovoltaics	23 Feb 2022
H-CL5-2021-D3-03-05 Wind energy in the natural and social environment	23 Feb 2022
H-CL5-2022-D3-01-06 Novel Agro-Photovoltaic systems	26 Apr 2022
H-CL5-2022-D3-01-03 Advanced manufacturing of Integrated PV	26 Apr 2022
H-CL5-2022-D3-01-02 Demonstration of innovative materials, supply cycles, recycling technologies to increase the overall circularity of wind energy technology and to reduce the primary use of critical raw materials	26 Apr 2022
H-CL2-2022-HERITAGE-01-10 The New European Bauhaus – shaping a greener and fairer way of life in creative and inclusive societies through Architecture, Design and Arts	20 Apr 2022
H-CL2-2021-HERITAGE-01-01 Green technologies and materials for cultural heritage	07 Oct 2021
H-CL4-2022-RESILIENCE-01-11 Advanced lightweight materials for energy efficient structures (RIA)	30 Mar 2022
H-CL4-2022-RESILIENCE-01-20 Climate Neutral and Circular Innovative Materials Technologies Open Innovation Test Beds (IA)	30 Mar 2022
H-CL4-2021-RESILIENCE-02-32 Social and affordable housing district demonstrator (IA)	25 Jan 2022
H-CL4-2022-RESILIENCE-01-07 Innovative solutions for efficient use and enhanced recovery of mineral and metal by-products from processing of raw materials (IA)	30 Mar 2022
H-CL4-2022-DIGITAL-EMERGING-02-20 2D-material-based composites, coatings and foams (IA)	16 Nov 2022
H-CL4-2022-RESILIENCE-01-16 Building and renovating by exploiting advanced materials for energy and resources efficient management (IA)	30 Mar 2022
H-CL4-2022-TWIN-TRANSITION-01-02 Products with complex functional surfaces (Made in Europe Partnership) (RIA)	30 Mar 2022
H-CL4-2022-TWIN-TRANSITION-01-10 Circular flows for solid waste in urban environment (Processes4Planet Partnership) (IA)	30 Mar 2022
H-CL6-2022-CIRCBIO-02-01-two-stage Integrated solutions for circularity in buildings and the construction sector	15 Feb 2022

EU subvencionira gradbeništvo.



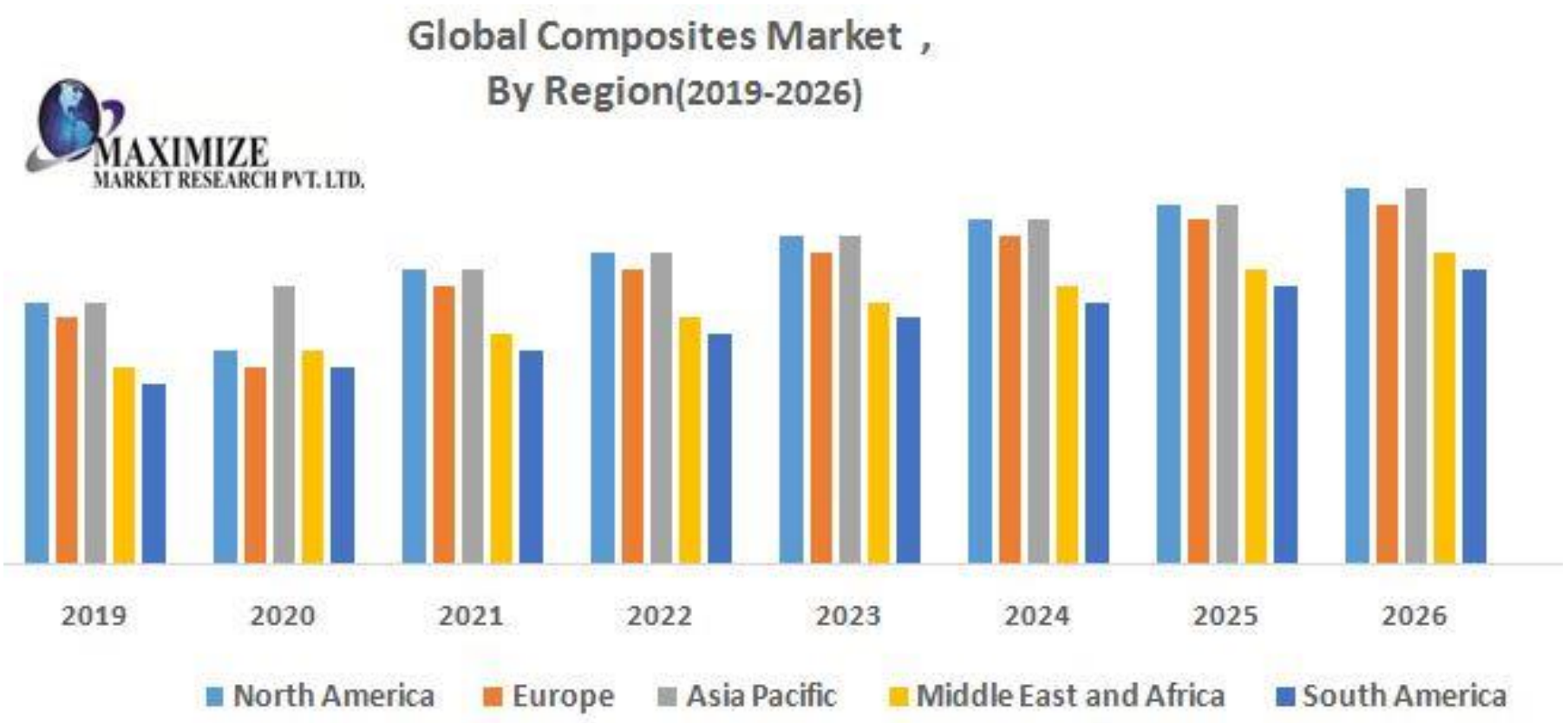
Globalni trg kompozitov 2020:

12.9 mil. t, 103 md $, CAGR 5%



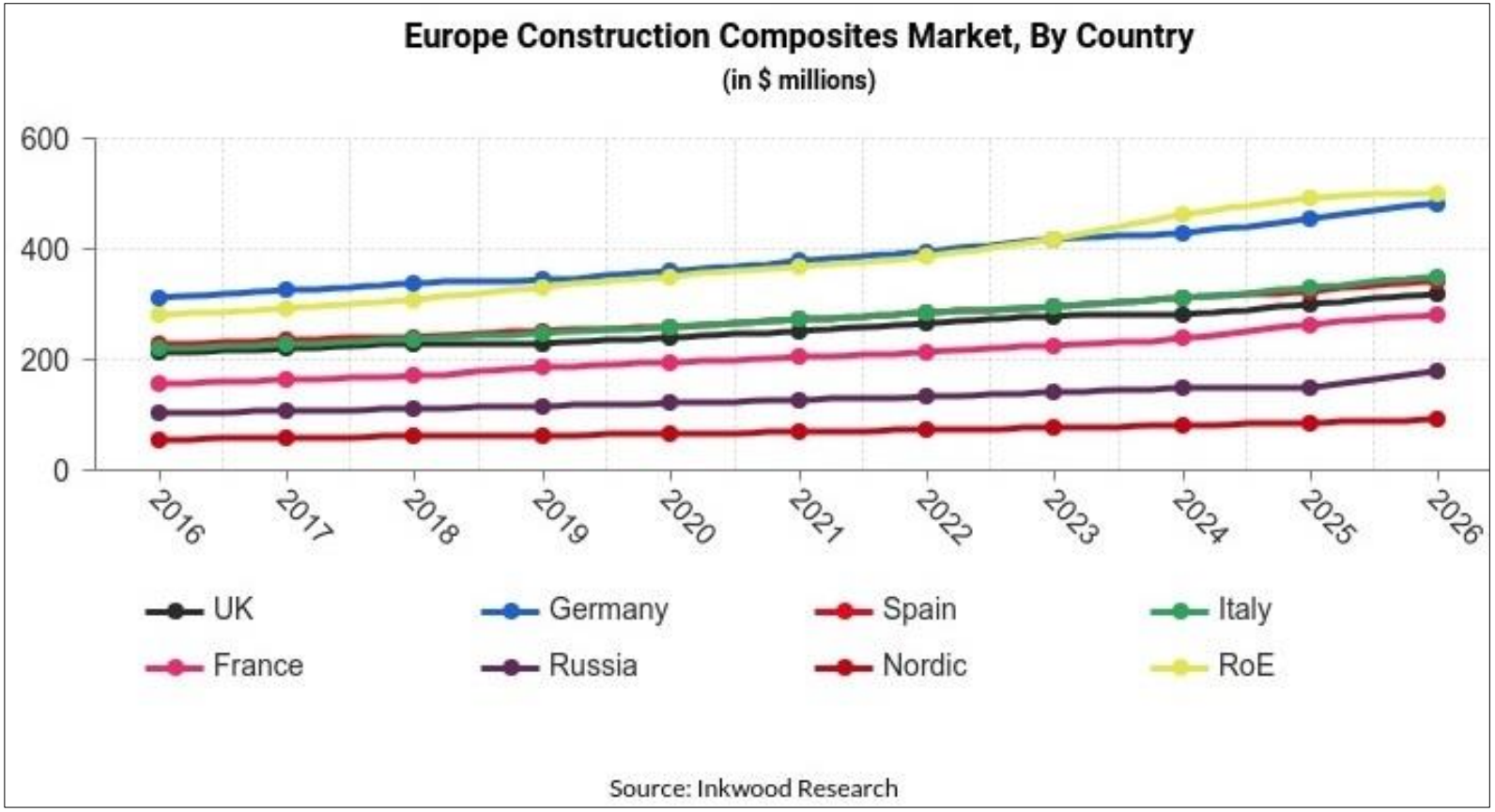
Trg kompozitov v Evropi 2018: 17,8 md$, CAGR 7,5%

Manjši delež za gradbeništvo



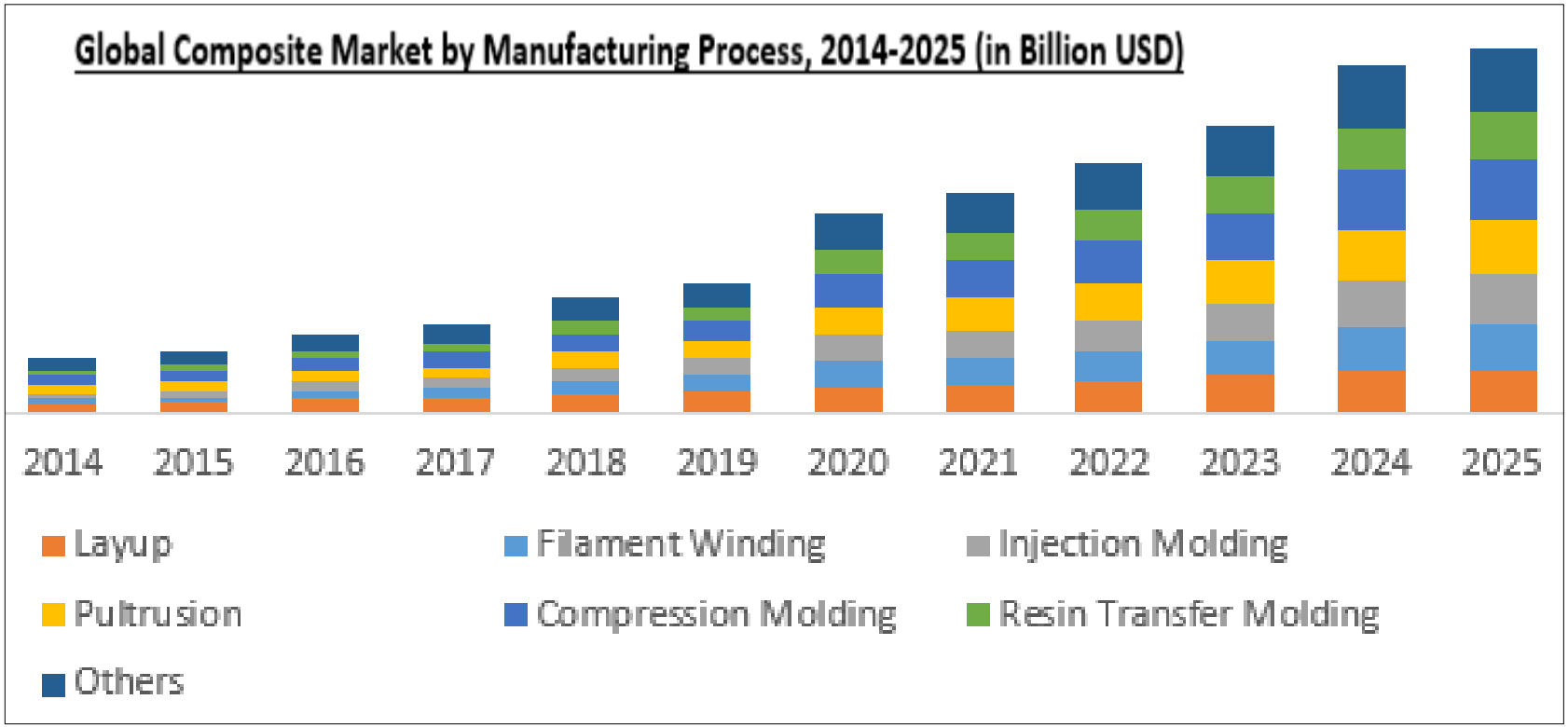
Trg kompozitnih materialov po regijah

Evropa šele tretja

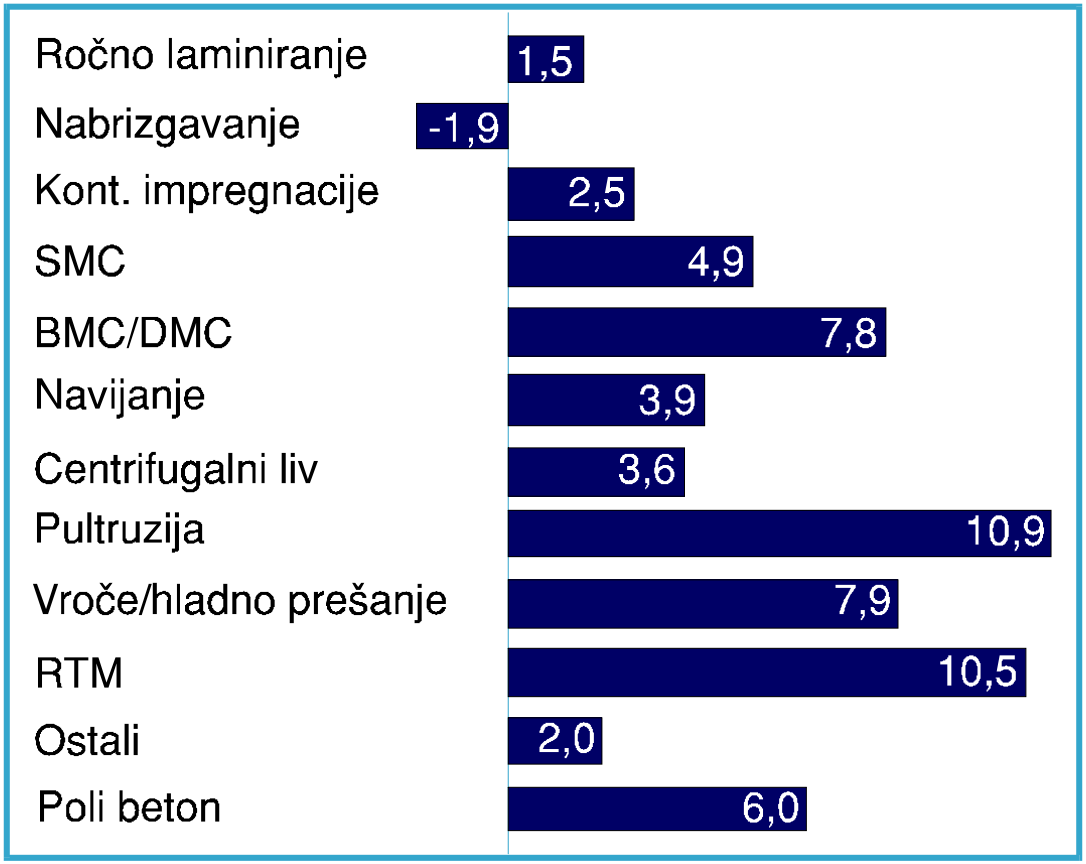


Kompoziti v gradbeništvu po državah:

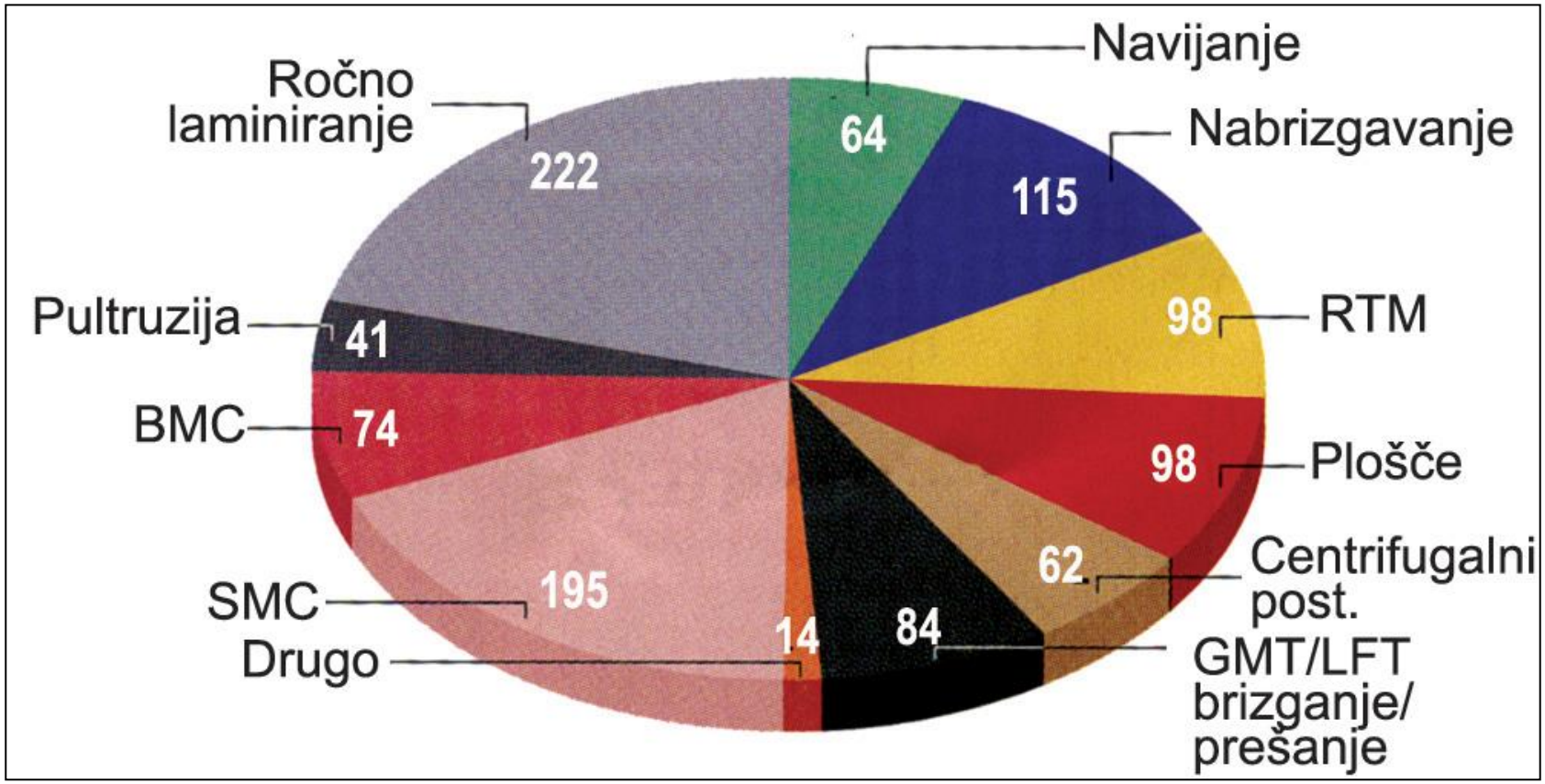
prednjači Nemčija



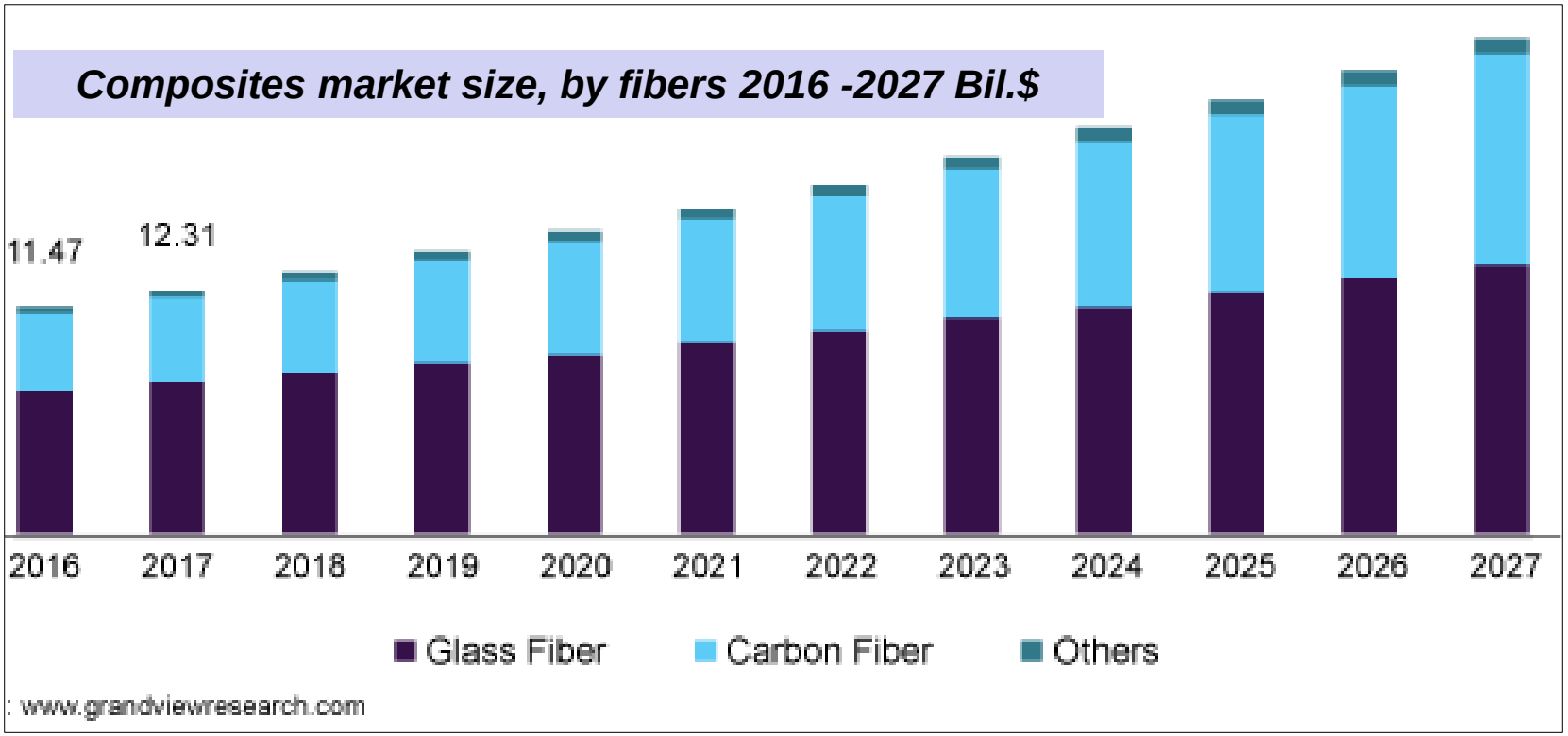
Tehnologije kompozitov v smer zaprtih, ekološko prijaznih postopkov



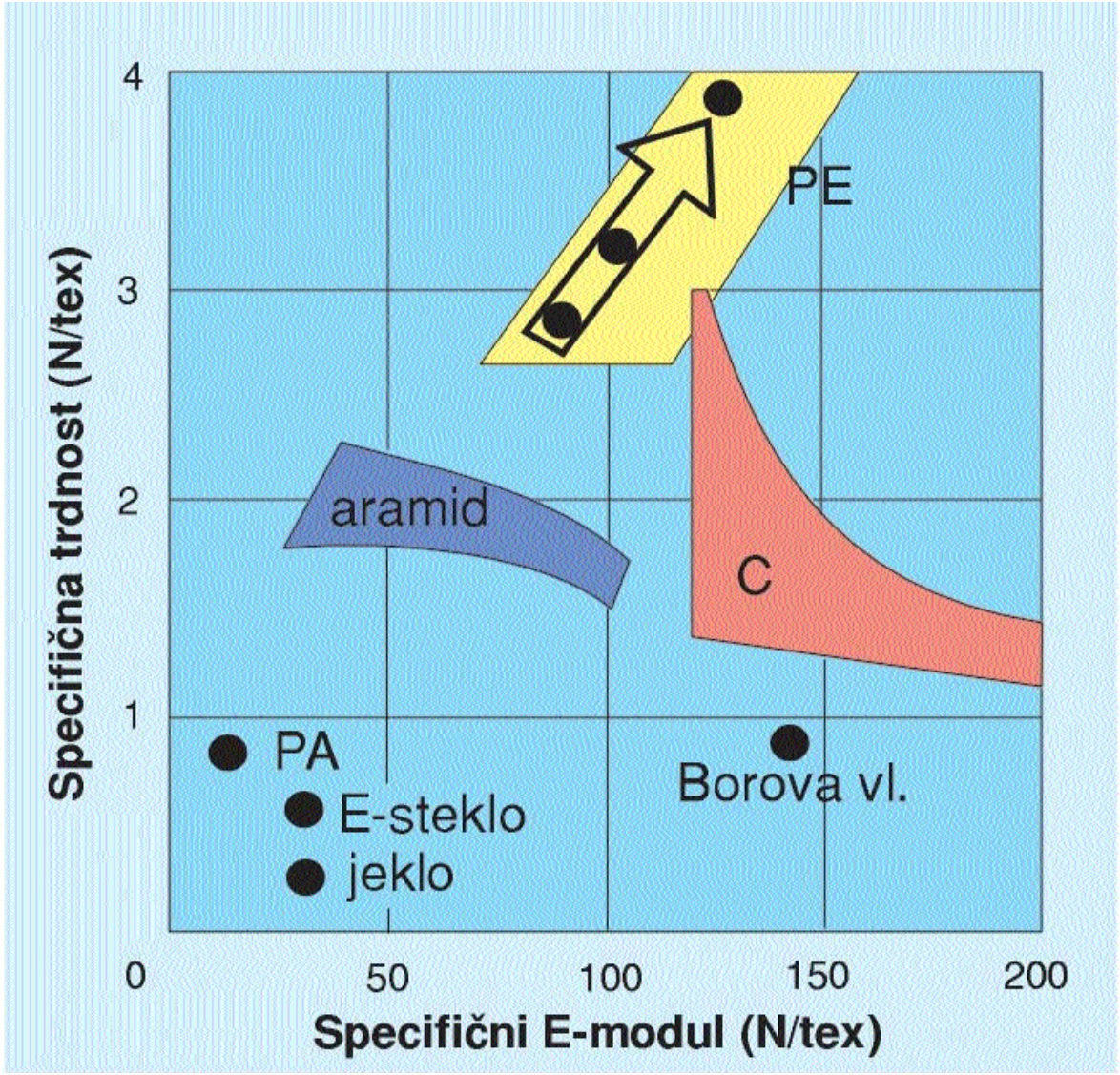
Shematski prikaz večanja uporabe RTM postopkov v primerjavi z ostalimi postopki izdelave kompozitov



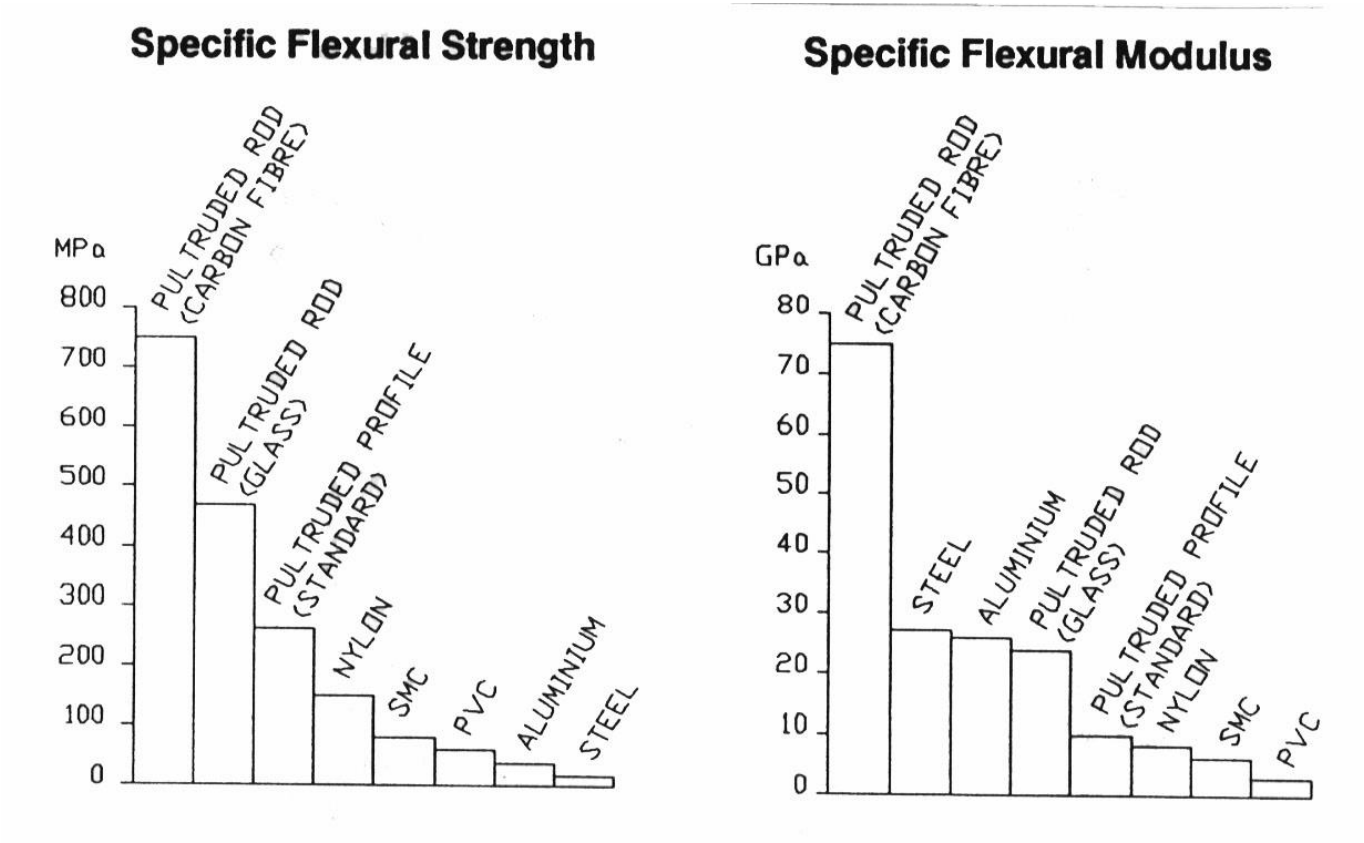
Postopki predelave kompozitov v Evropi (v 1.000 tonah)



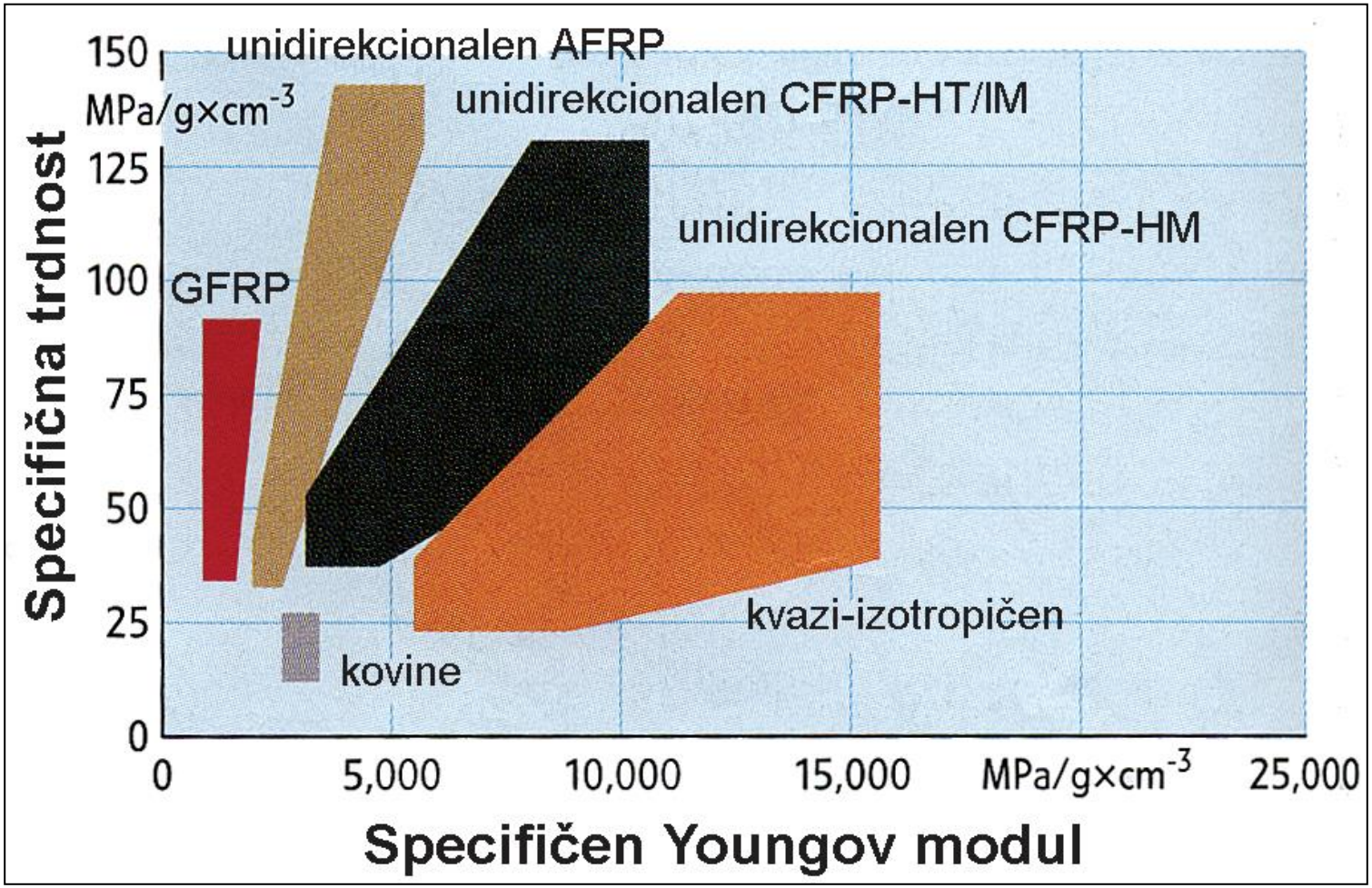
Narašča delež ogljikovih vlaken



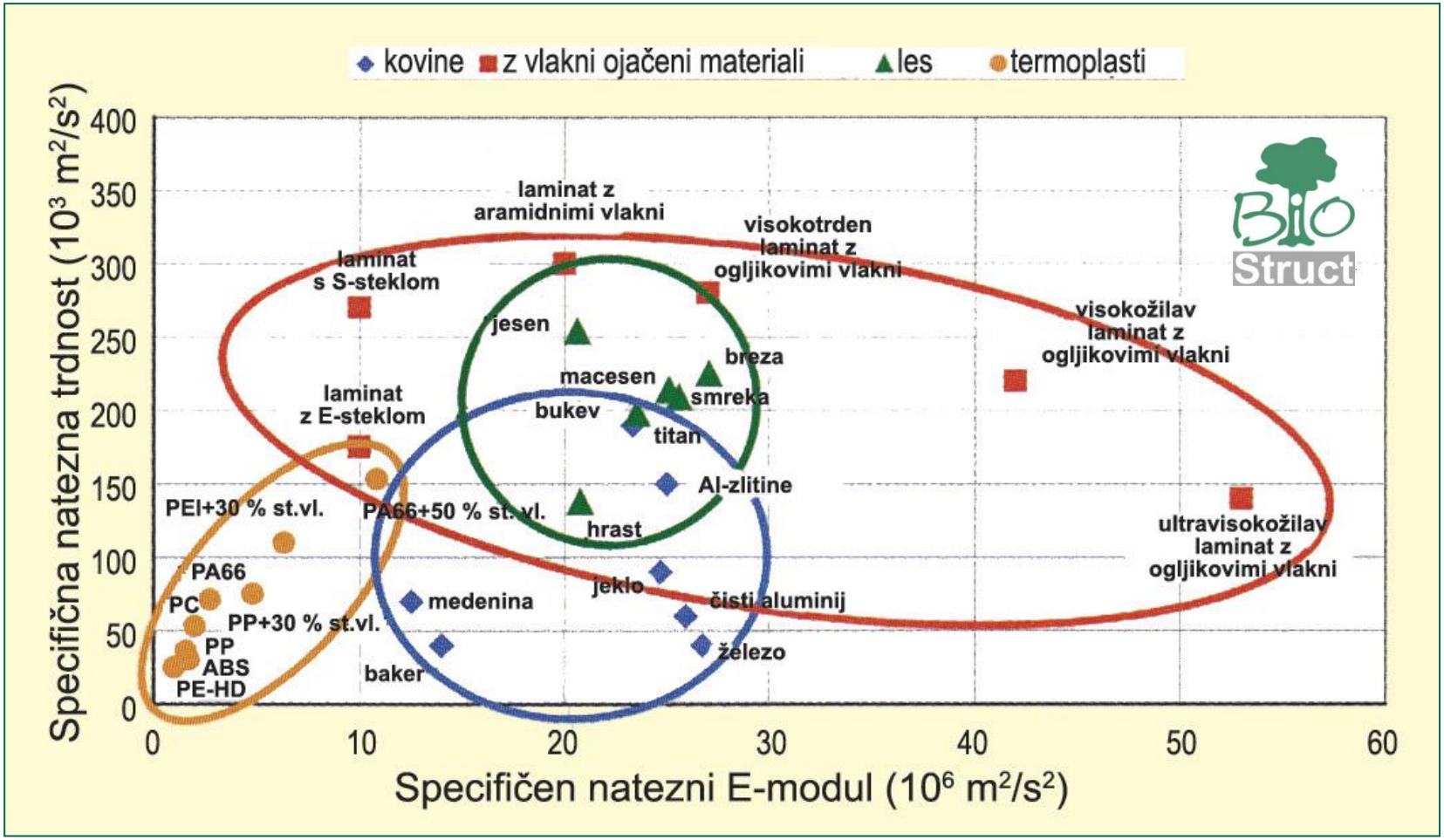
Specifična trdnost in E-modul vlaken močno presega jeklo



Kompoziti v specifični trdnosti močno presegajo druge materiale



Specifične lastnosti kompozitov nad kovinami



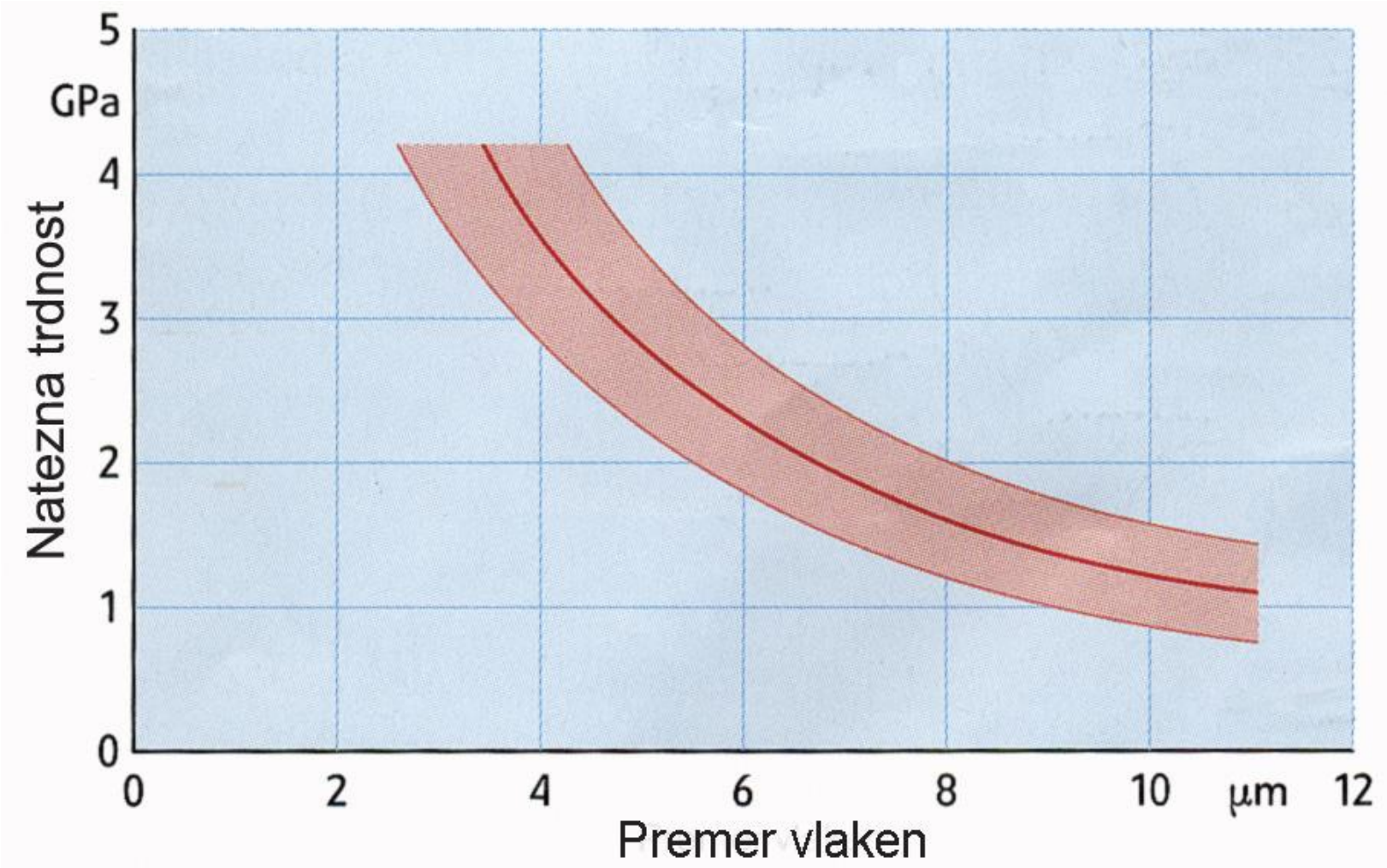
Specifične lastnosti kompozitov in lesa

Sestavina	Gostota ρ kg/dm^3	σ_{maks} v smeri vlaken MPa	E vzdolžno GPa	E prečno GPa	ε_{maks} %	T_{maks} ^{0}C	α vzdolžno 10^{-6} ^{0}C	α prečno 10^{-6} ^{0}C
S-steklena vlakna	2.48	4800	85	85	5,7	650		
E-steklena vlakna	2.54	3450	73	73	4.8	550	5	5
Ogljikova vlakna visoke togosti	1.78	5400	300	15	1.8	500	-1	10
Ogljikova vlakna visoke trdnosti	1.8	4090	241	20	1.65	500		
Aramid (Kevlar 49)	1.44	3170	138	5.4	2.3	160	-4	52
Aramid (Kevlar 29)	1.44	3780	97		3.9	160		
Poliesterska smola	1,12	80	3,5		3			
Vinilesterska smola	1,07	90	4		4			
Epoksi smola	1,1	65	4.6		6			

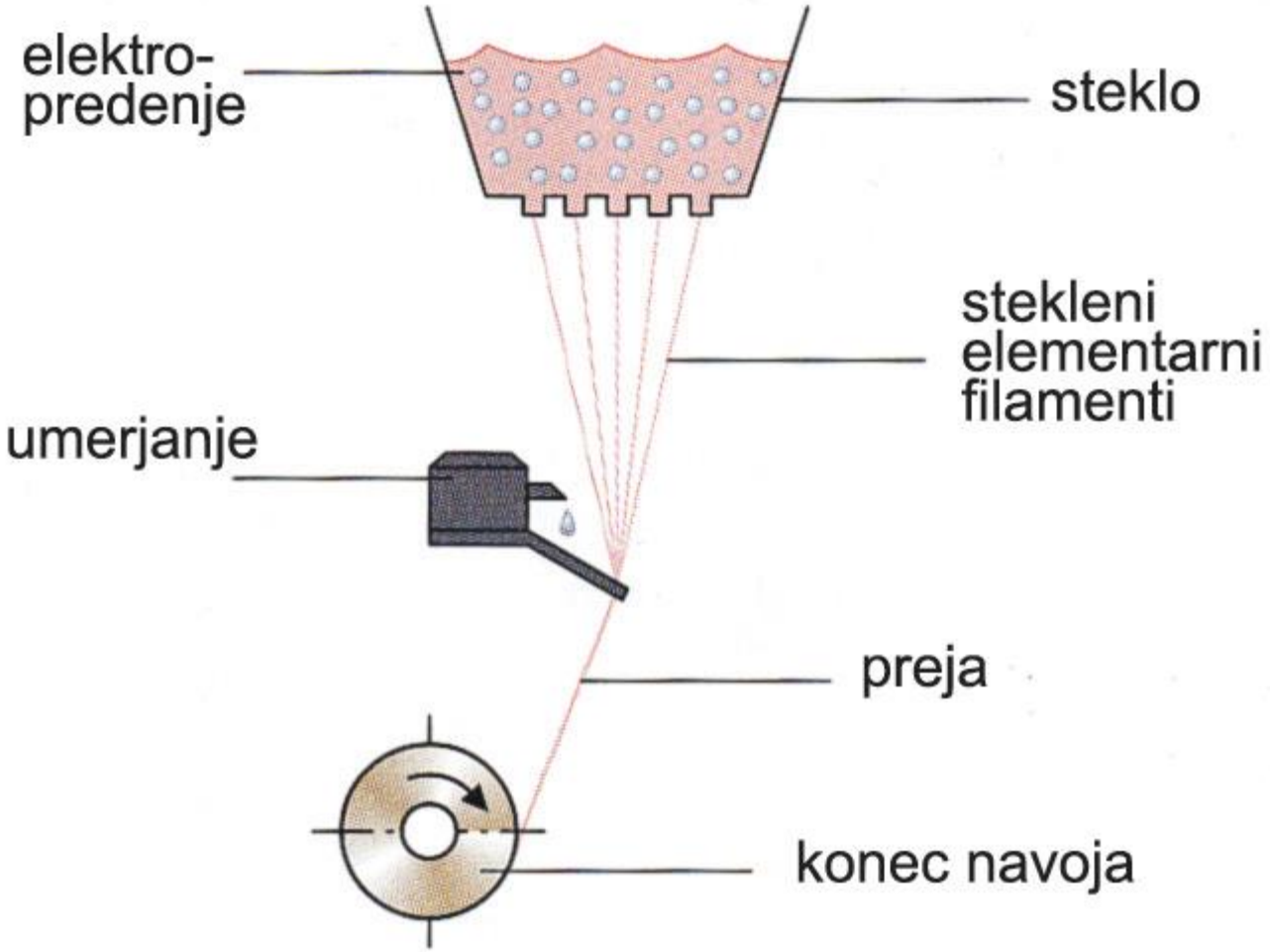
Nekatere lastnosti sestavin kompozitnih materialov

Značilnosti	Steklena vlakna			
	E	R/S	M	C
Natezna trdnost (GPa)	3.5	4.7	3.7	3.1
Youngov modul (GPa)	73	88	125	71
Raztezek do pretrga (%)	~4.5	5.0	~5.5	3.5
Spec. moč (GPa x cm^3/g)	1.38	1.8	2.8	1.3
Spec. Youngov modul (GPa x cm^3/g)	28.8	34	50.3	29
Premer vlaken (μm)	3–13	10	10	-
Gostota (g/cm^3)	2.55	2.49	-	2.45
Koef. topl. raztezanja (10^{-6} /K)	5–6	4	-	7.2

Lastnosti steklenih vlaken



Vpliv premera steklenih vlaken na trdnost



Proces predenja steklenih vlaken

Lastnost / Tip vlakna	Št. filamentov/ roving (K) *(1K = 1000 filamentov)*	Premer (µm)	Gostota (g/cm^3)	Natezna trdnost (MPa)	Modul elastičnosti (GPa)	Raztezek pri pretrgu (%)
Visokotrdno vlakno	1–24 (majhno/srednje predivo)	7	1.75–1.78	3,500–5,00	221–245	1.5–2.0
	48–600 (težko predivo)	7	1.76–1.8	3,500–4,000	225–240	1.5–1.6
Vmesno modulno vlakno (IM)	6–24	5	1.8	4,800–6,370	276–300	1.8–2.2
Visoko modulno vlakno (HM)	1–24	7	1.8–1.93	2,740–5,490	300–680	0.7–1.9
Visoko modulno/ visokotrdno vlakno (UM)		5				

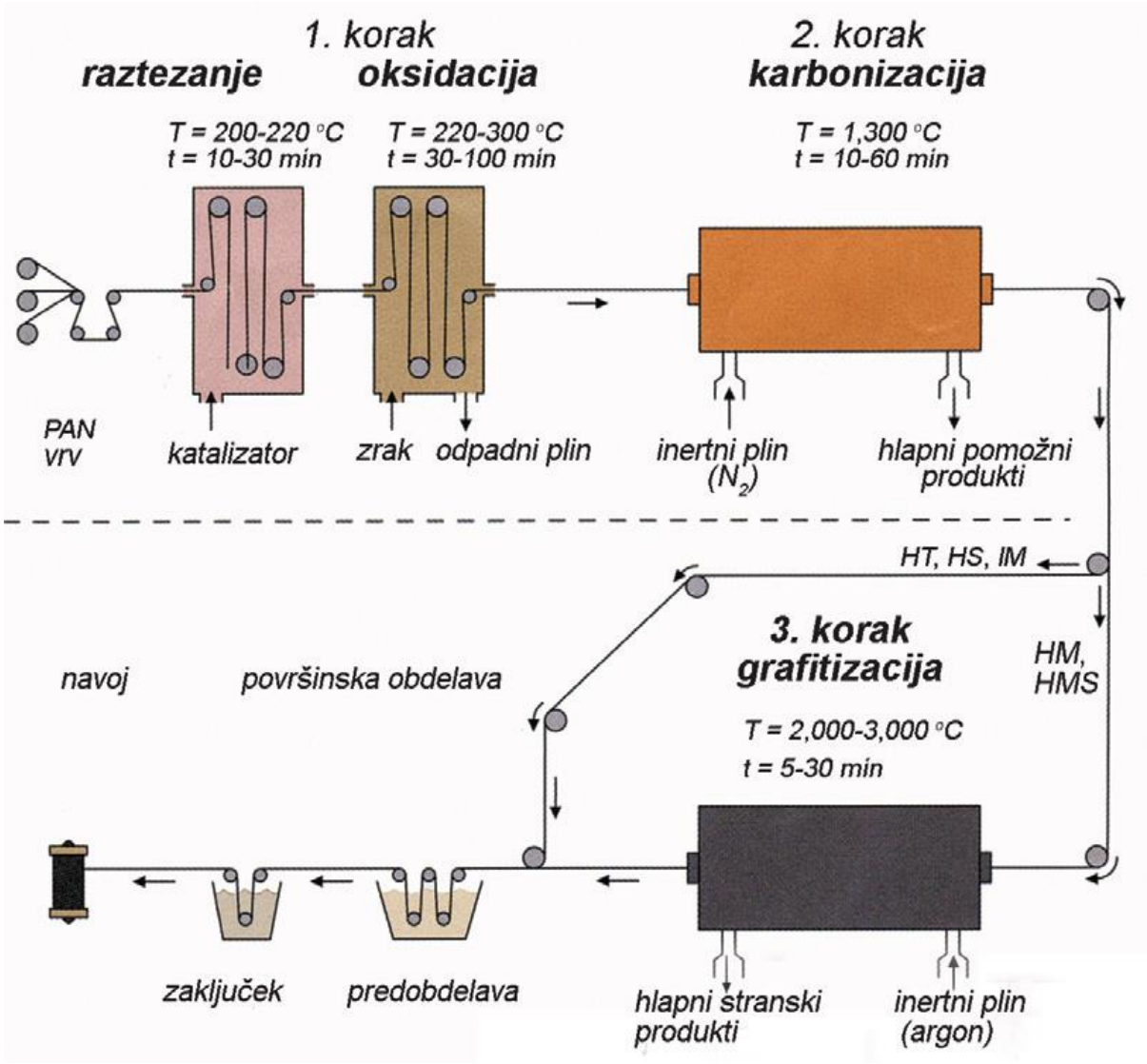
Trdnost karbonskih vlaken do 6370 N/mm²

Zelo trdna jekla do 1600 N/mm²

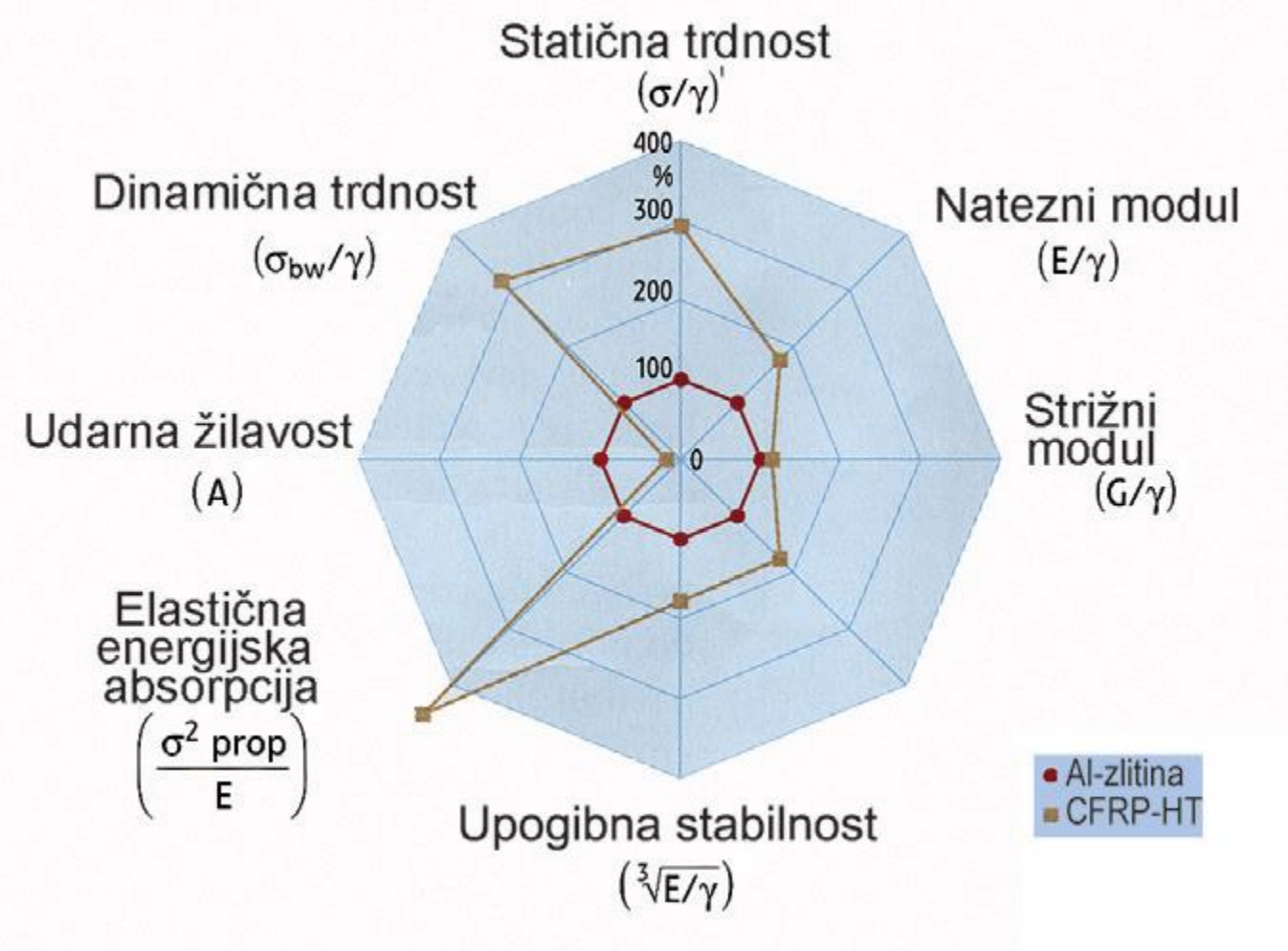
Lastnost / Tip vlakna	Premer (µm)	Gostota (g/cm^3)	Natezna trdnost (GPa)	Modul elastičnosti (GPa)	Raztezek do pretrga (%)
Standardno	12	1,44	2,8–3,6	65–83	3,4–4
Visoko modulno	12	1,44–1,47	3,1–3,6	121–124	2,0–2,9
UHMPE	13–25	0,97	2,7–3	87–170	2,7–3,5
PBO (preja)	-	1,56	5,8	180	3,5
PBO (visokomodulno	-	1,54	5,8	280	2,5

*poly(p-phenylene-2,6-benzobisoxazole)

Natezna trdnost polimernih vlaken do 5800 N/mm^2



Proizvodnja karbonskih vlaken na osnovi PAN



Primerjava specifičnih lastnosti aluminija in CRP

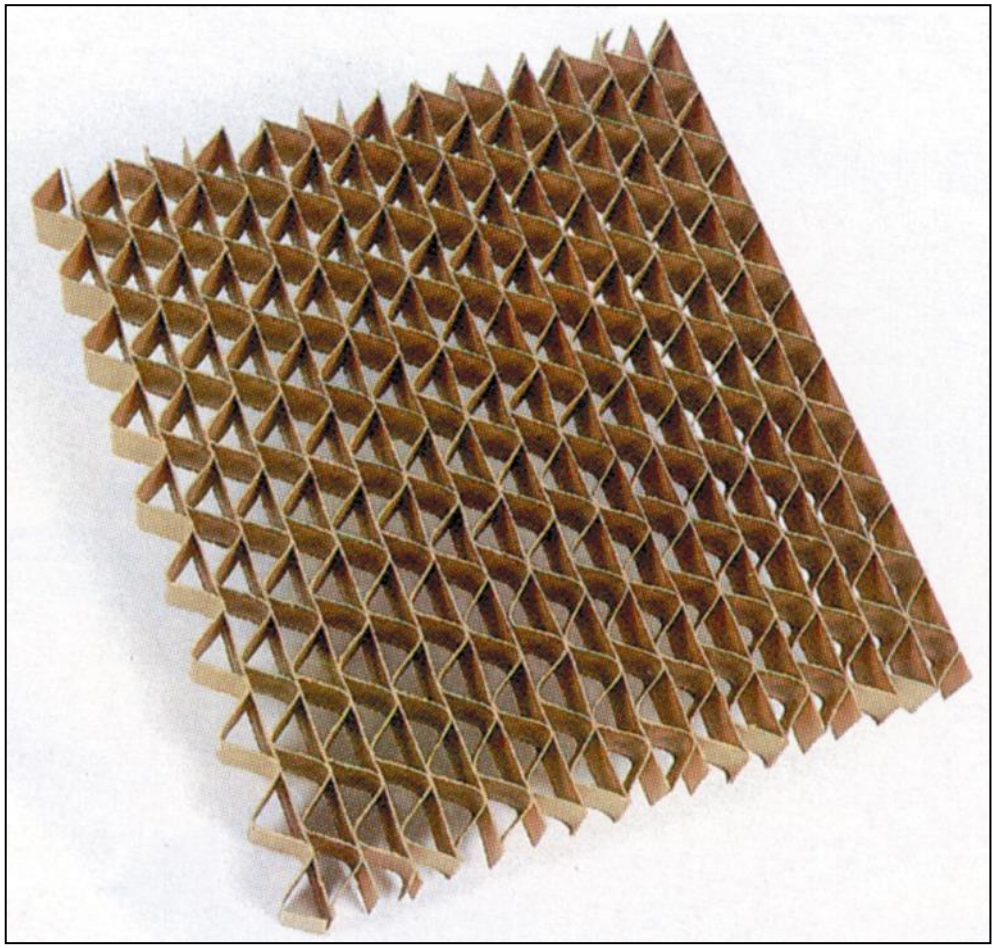
LASTNOSTI VLAKEN IN POLNIL

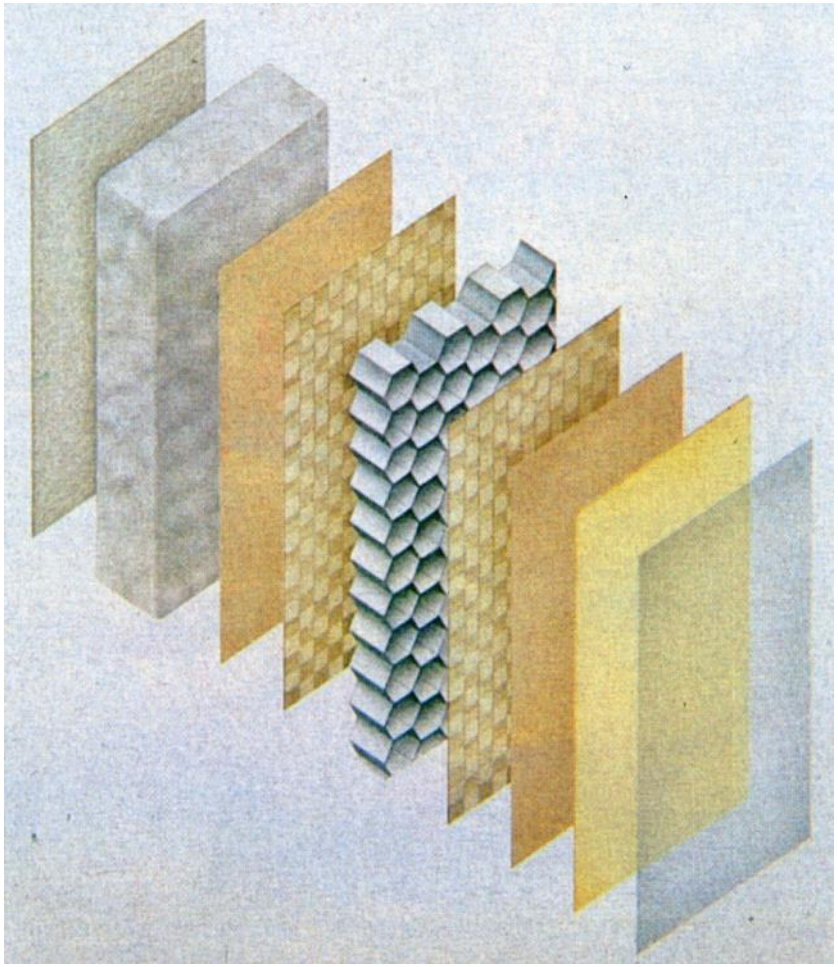
	Steklena vlakna	Wolastonit	C - vlakna	Whiskers	Sintetična vlakna	Celuloza	Sljuda	Talk	Grafit	Kremenčev prah	Silika	Kaolin	Steklene kroglice	Kalcijev karbonat	Kovinski oksidi	Saje
Natezna trdnost	++		+	+-			+	o					+			
Tlačna trdnost	+							+		+			+	+		
E-modul	++	++	++	+			++	+		+	+		+	+	+	+
Udarna žilavost	-+	-	-	-	++	+	-+	-		-	-	-	-	-+	-	+
Znižanje termičnega raztezka	+			+			+	+		+	+	+			+	
Znižanje skrčka	+	+	+				+	+	+	+	+	+	+	+	+	+
Boljša toplotna prevodnost		+	+					+	+	+	+			+		+
Boljša oblikovna obstojnost	++	+	++				+	+				+		+	+	
Električna prevodnost			+						+							+
Električna upornost		+					++	+			+	++			+	
Toplotna obstojnost		+					+	+		+	+	+			+	+
Kemijska obstojnost		+					+	o	+			+	+			
Manjša obraba			+				+	+	+			+				
Hitrost ekstrudiranja	-+						+					+		+		
Abrazija strojev	-			o	o	o		o	o	-			o	o		o
Pocenitev	+	+				+	+	+	+	++	+	+	+	++		
	vlaknata polnila in ojačala						**lamelni delci**			**kroglasti delci**						

++ močan učinek, + srednji učinek, o brez učinka, - negativni učinek

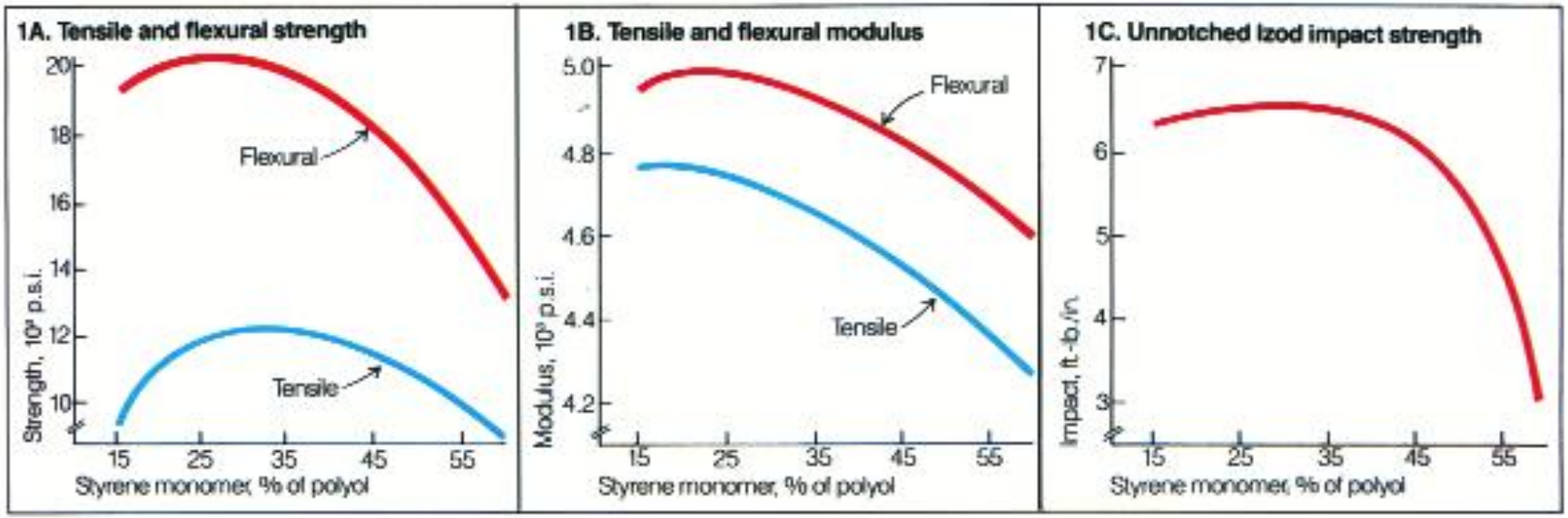
Vlakna	Natezna trdnost (MPa)	E-modul GPa	Mejni raztezek (%)	Gostota (kg/m^3)	Cena (Euro/kg)
Steklena	2500 - 3500	70 - 73	3	2560	1,5 - 2,5
Karbonska	2500 - 6000	220 - 700	0,5 - 2,0	1750 - 1900	30 - 50
Aramidna	3500 - 4000	85 - 135	3 - 5	1440	20 - 35
Lanena	500 - 900	50 - 70	1,3 - 3,3	1400 - 1500	0,5 - 1
Sisalova	80 - 840	9 - 22	3 - 14	1450	0,5
Jutina	200 - 450	20 - 55	2 - 3	1400	0,5
Konopljina	310 - 750	30 - 60	2 - 4	1480	0,5 - 1
Bombažna	300 - 600	6 - 10	6 - 8	1500	0,1 - 0,5
Platanina	530 - 750	7 - 20	1 - 4	1400	0,5

Mehanske lastnosti in cene sintetičnih in naravnih vlaken

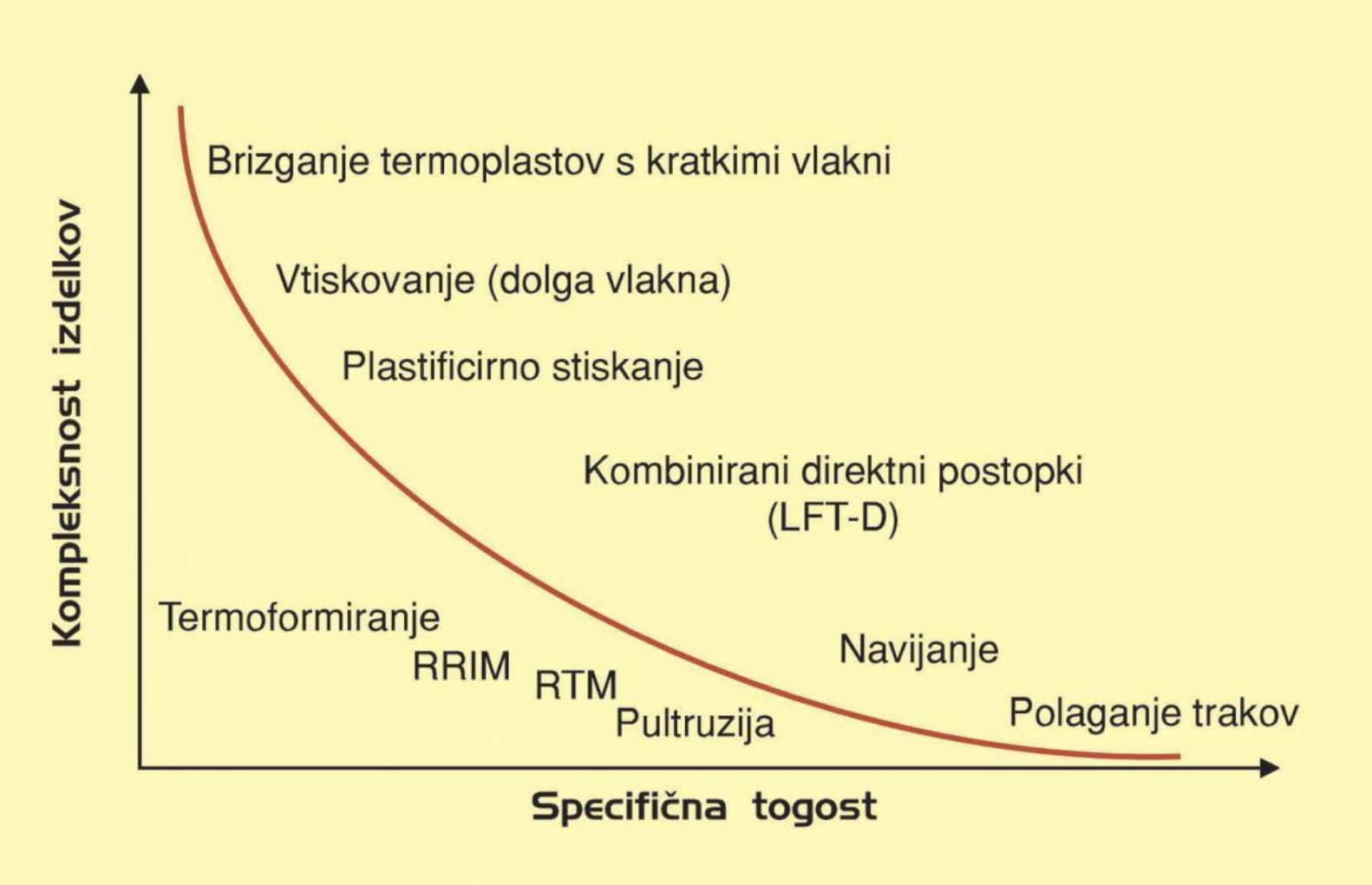




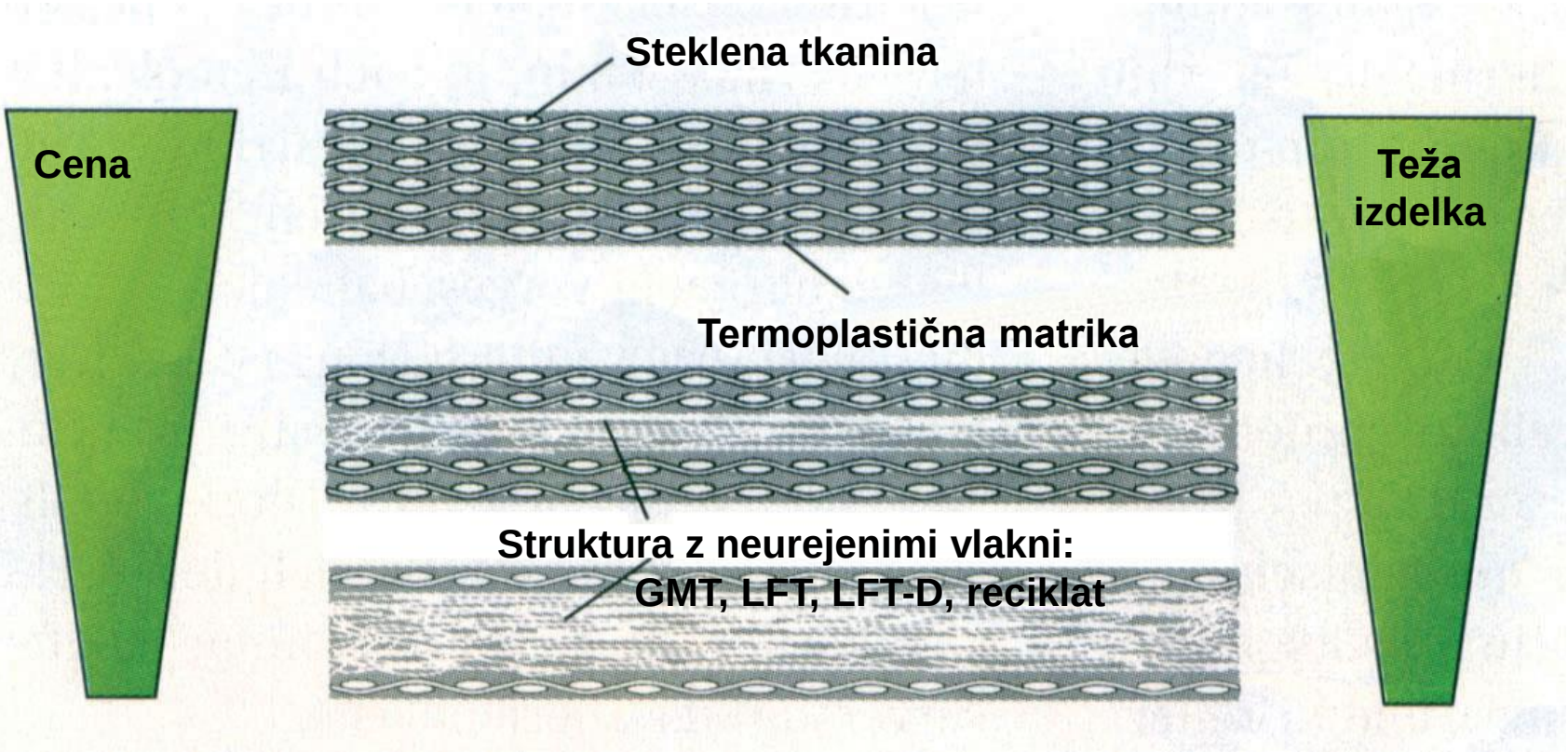
Polimerno satje za lahke in trdne sendviče



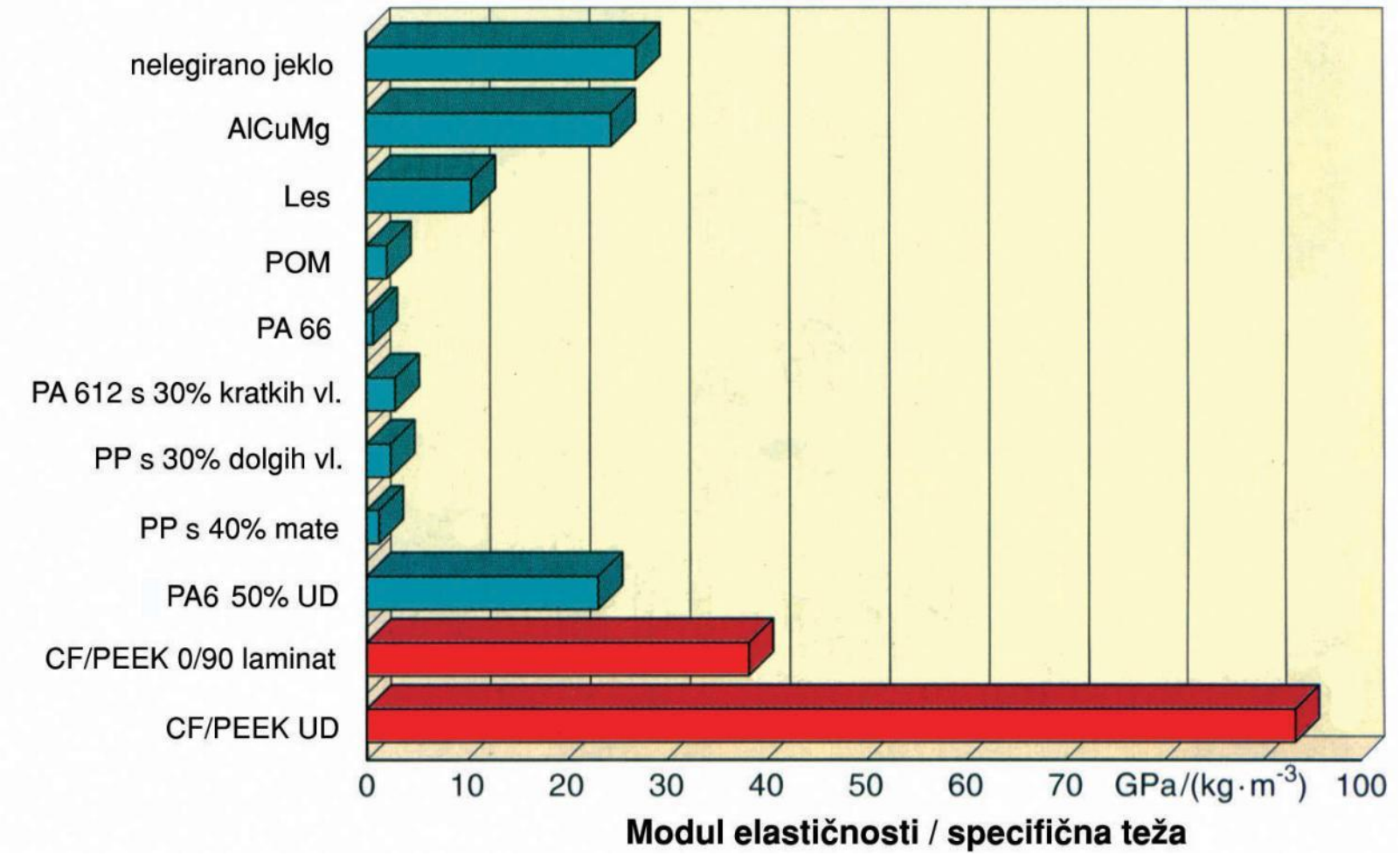
Odvisnost trdnosti, E-modula in žilavosti od deleža stirena v smoli



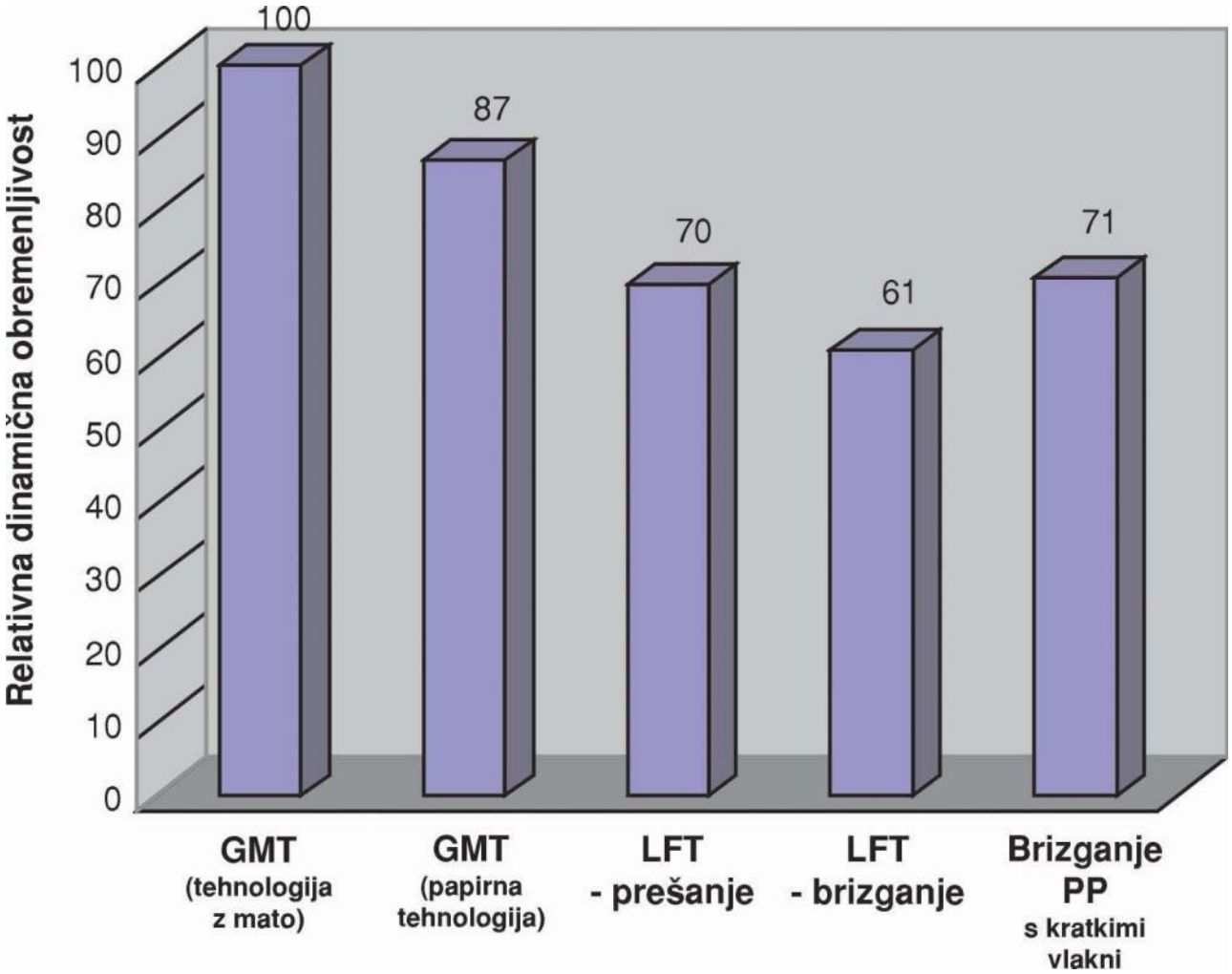
Proizvodnja termo- in duroplastičnih kompozitov



Termoplastični sendvič polizdelki



Razmerje med modulom elastičnosti in specifično težo za različne konstrukcijske materiale



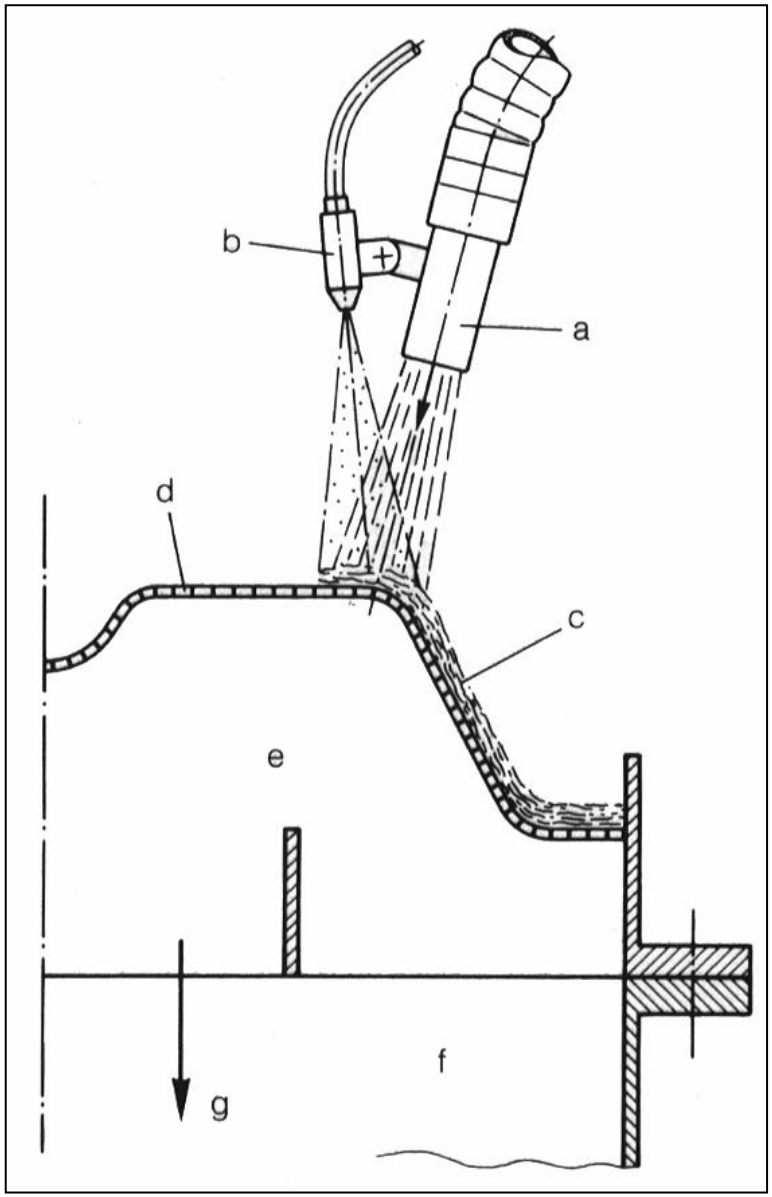
Termoplastični kompoziti - primerjava relativne dinamične obremenljivosti

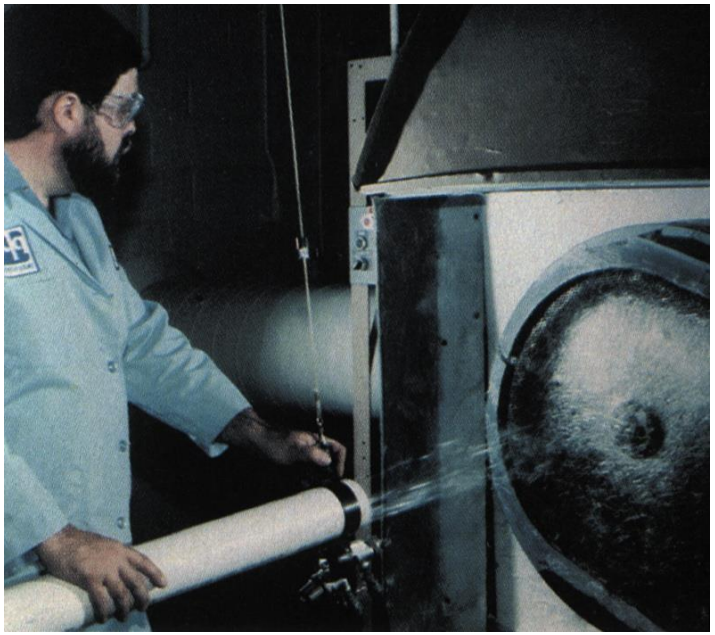
Lastnosti	PPO	PC	PBT	POM	PA	UP-navijanje	UP-pultruzija	UP-ročno
Vsebnost st. vlaken	30	30	30	30	30	75	75	40
Natezna trdnost	17,000	18,000	17,000	18,000	26,000	80,000	100,000	22,000
E-modul	12	15	14	12	13	65	65	17
Udarna žilav. FPI	1,5	3,7	1,8	1,4	2,0	60	60	14

Primerjava kompaundov in poliestrskih kompozitov

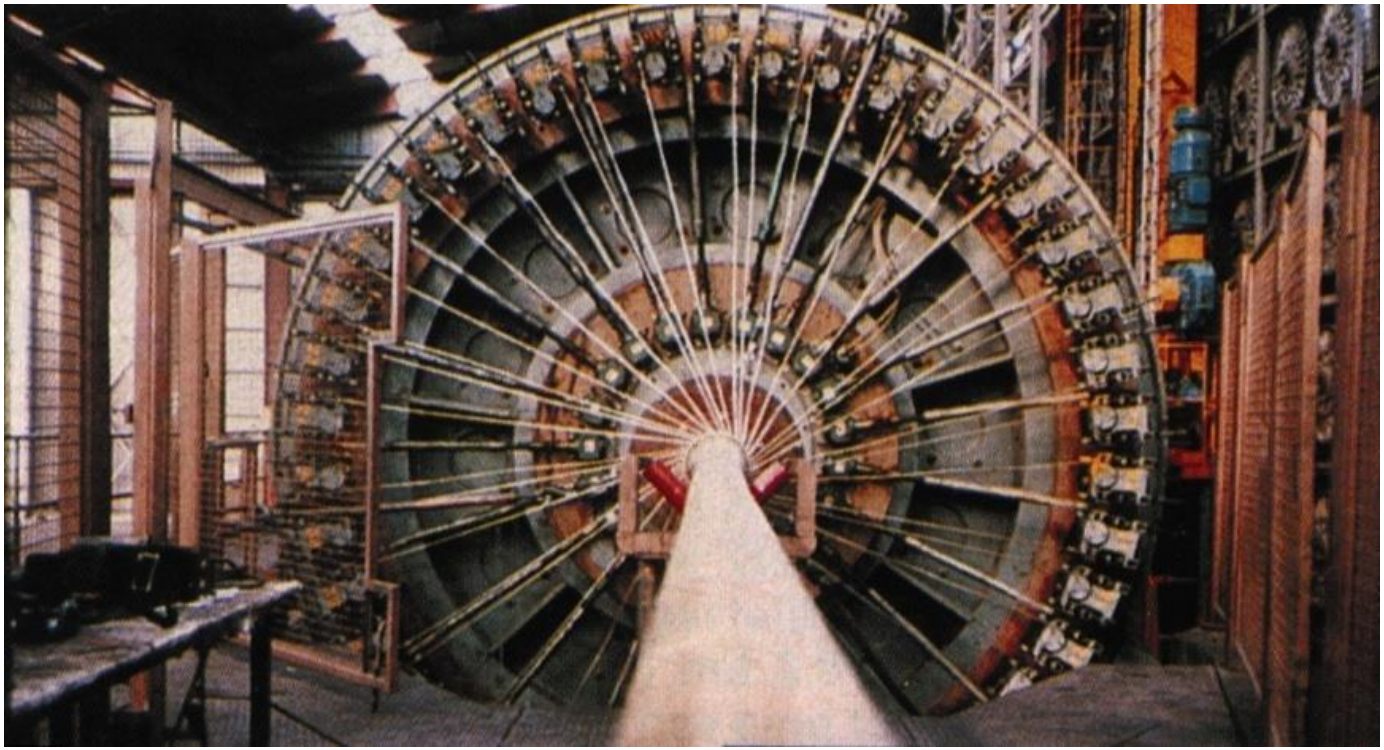
	RTM	Ročno	SMC
Površina	Zelo dobra	Zadovoljiva	Odlična
Trdnost	Odlična	Dobra	Zadovoljiva
Enosmerno ojačenje	Da	Da	Ne
Izdelki/uro	1,3-2,0	0,2	4-6
Cena kalupa v $	100 000	20 000	500 000+
Tip kalupa	Elektroform.	Poliester	Jeklo
Cena orodja na izdelek	$ 5	$ 10	$ 5

Primerjava med ročnim armiranjem, RTM in SMC postopkom

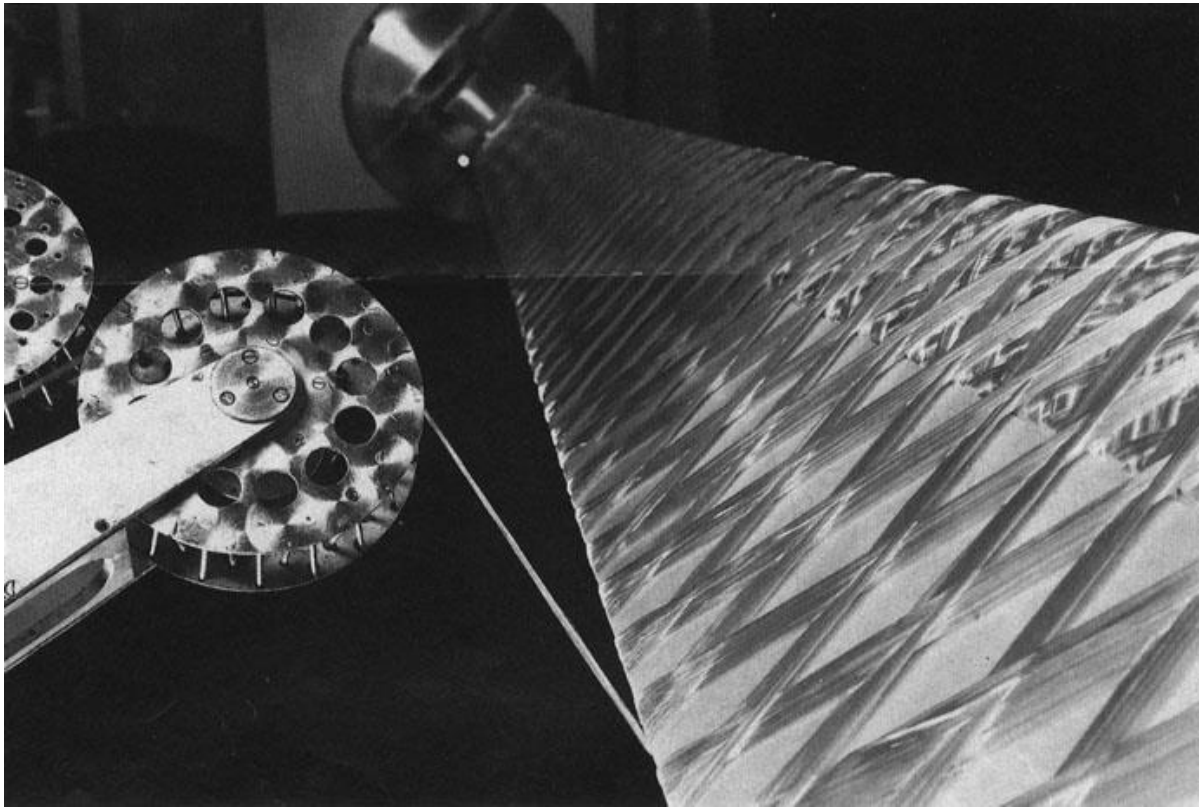




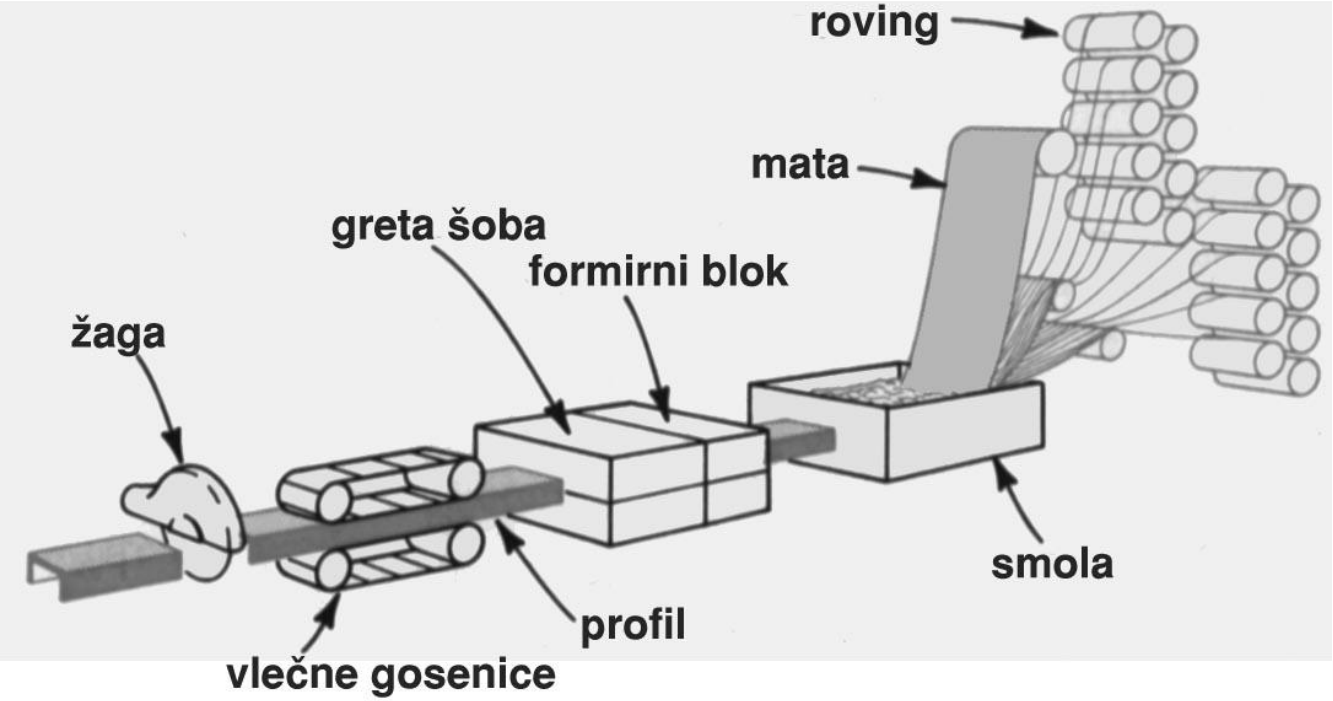
Proizvodnja preform iz nasekanih vlaken po postopku nabrizgavanja vlaken



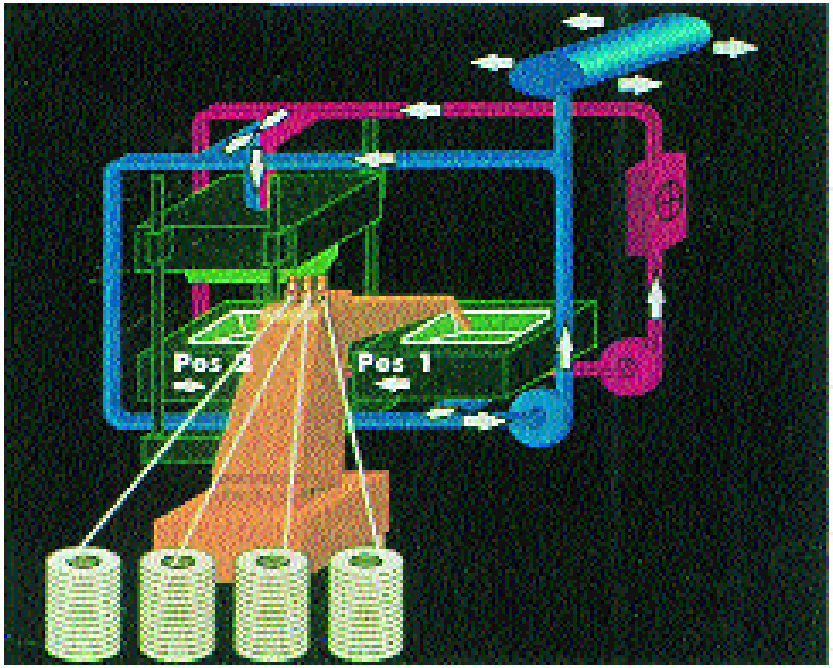
Novost navijalnega postopka so velika vretena

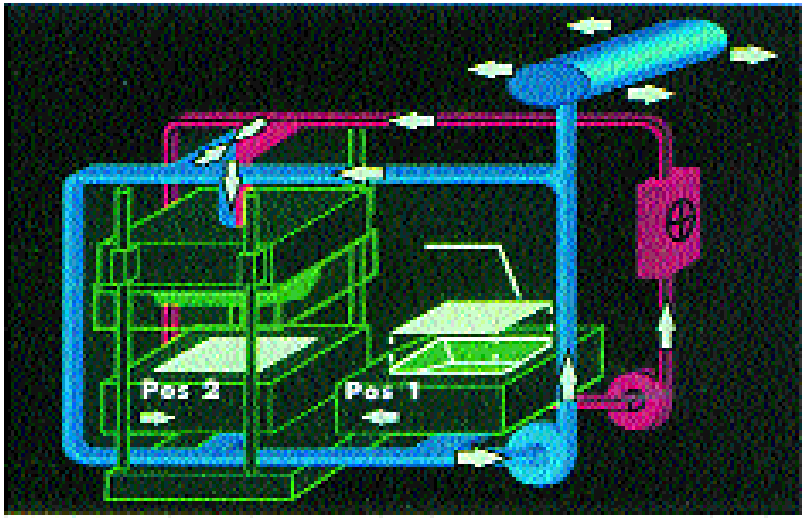


Moderni CNC navijalni stroji za vetrnice

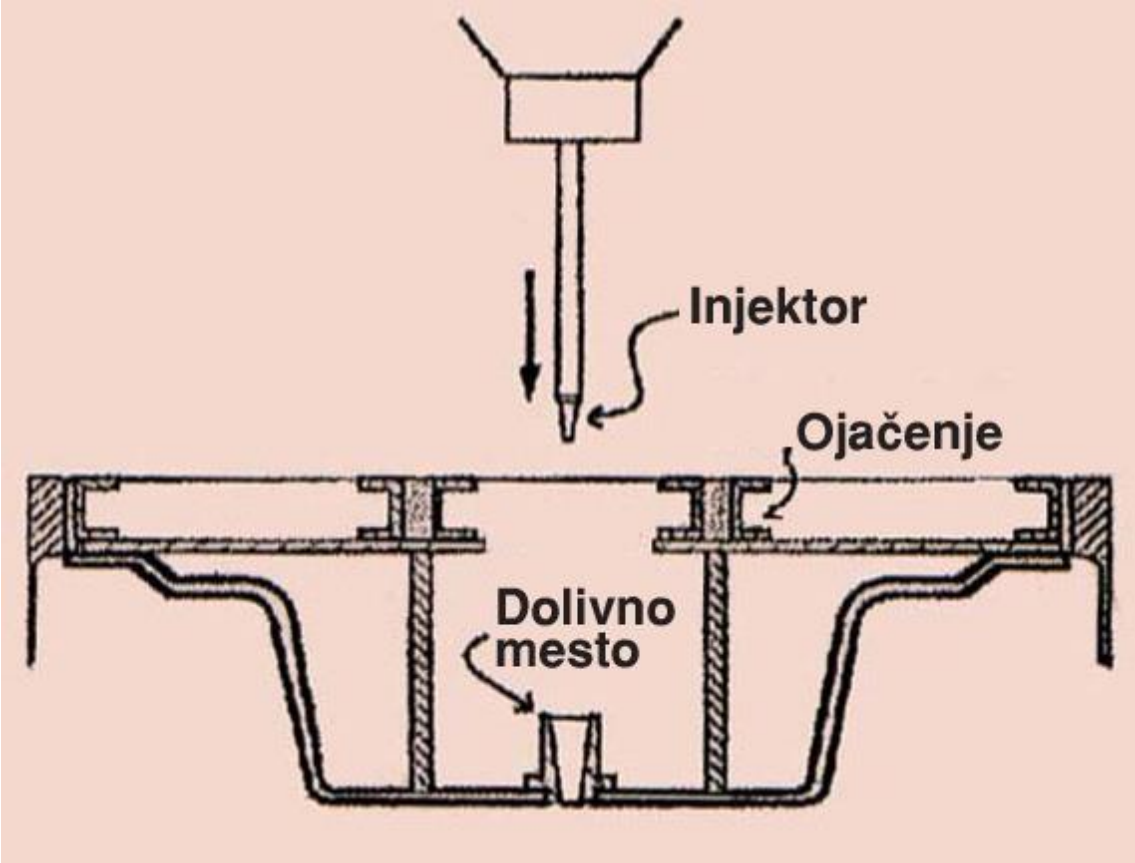


Pultruzijski profili iz rovinga in mate





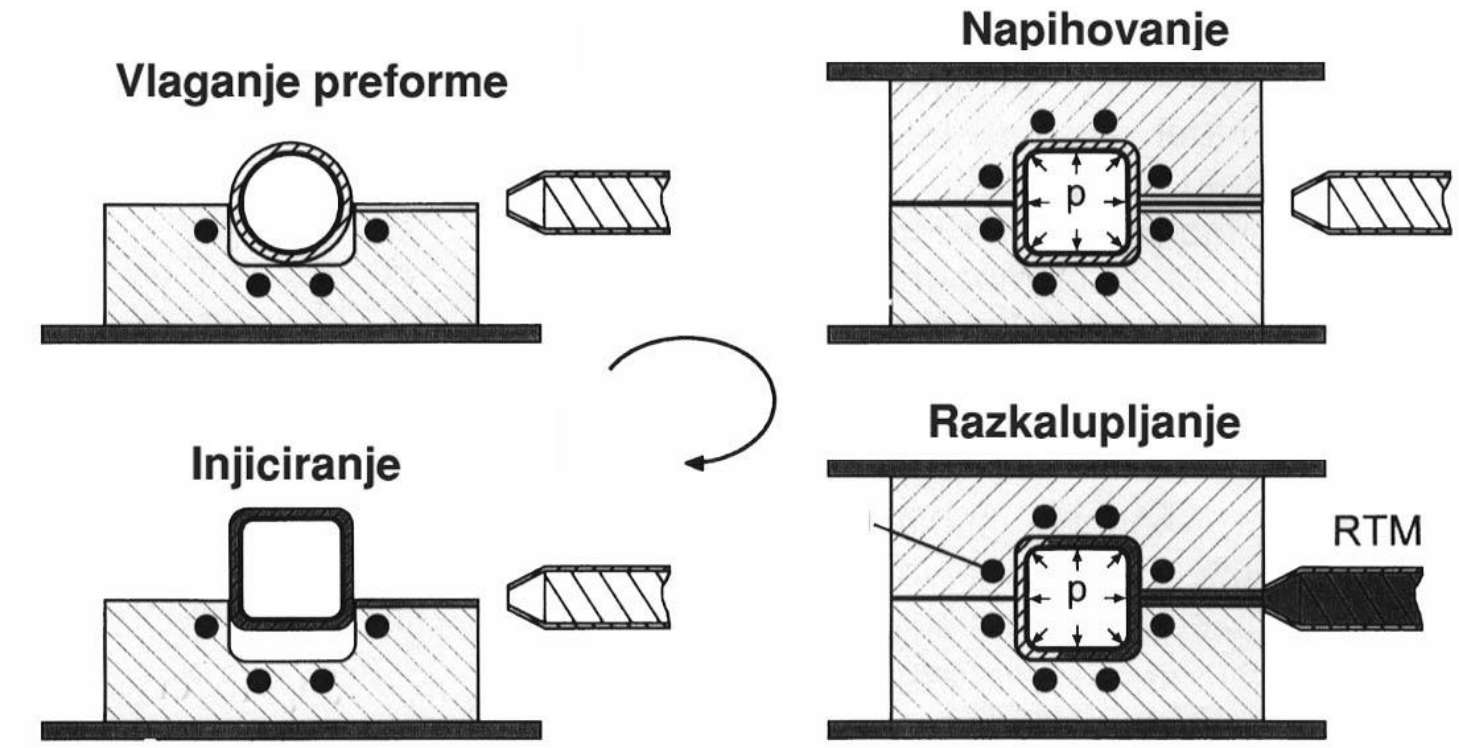
RTM: Sistem z izdelavo predform uporablja avtomatski način dovajanja vlaken skozi šobo na določeno pozicijo v določeni debelini



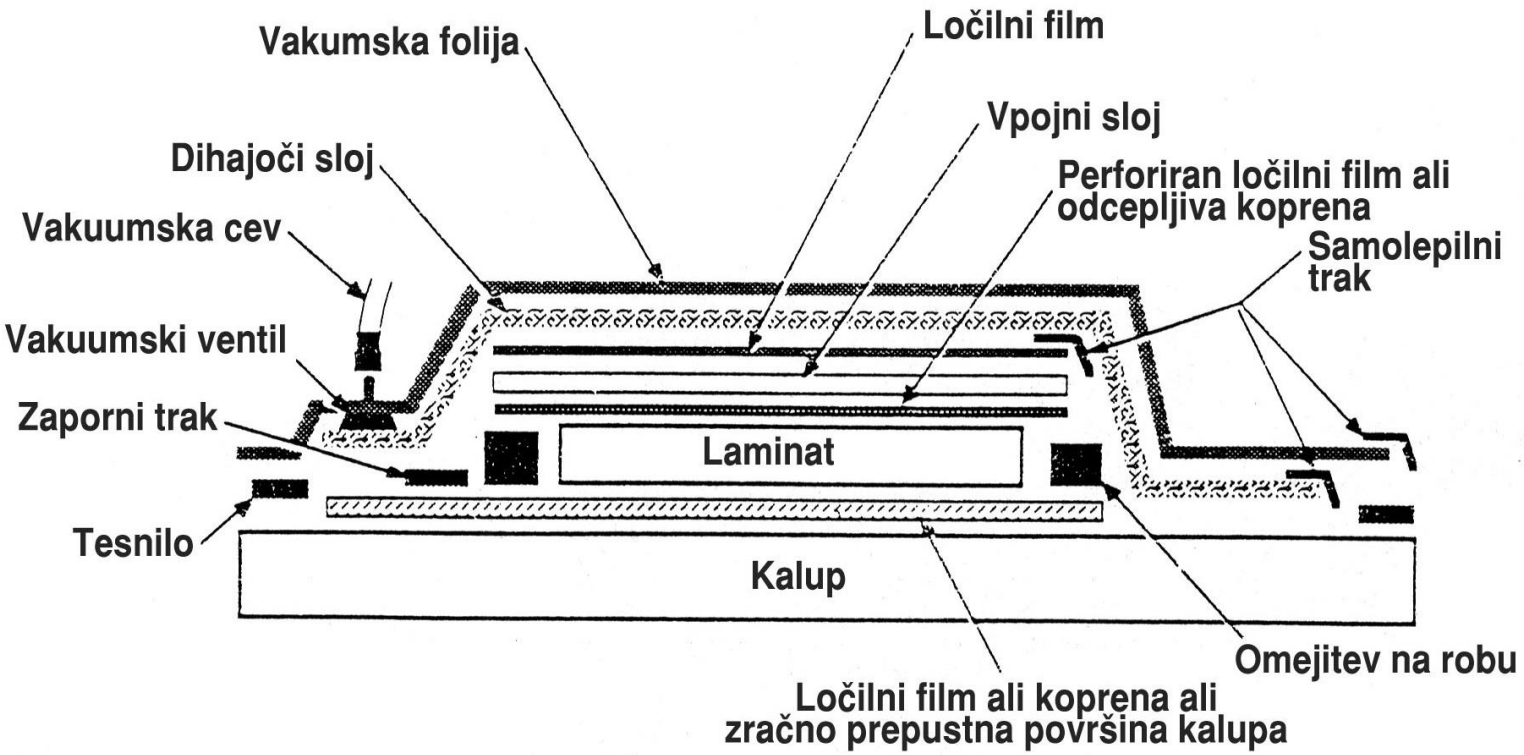
RTM postopek

Kalup z VE gelcoatom in epoksidom,

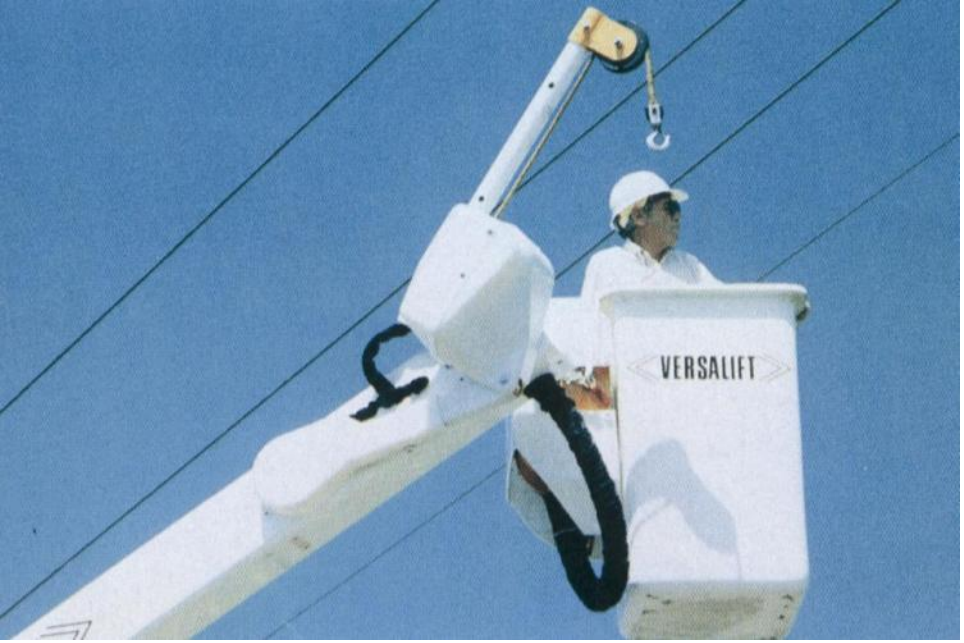
RTM z robotom



Pihanje (BBM postopek)



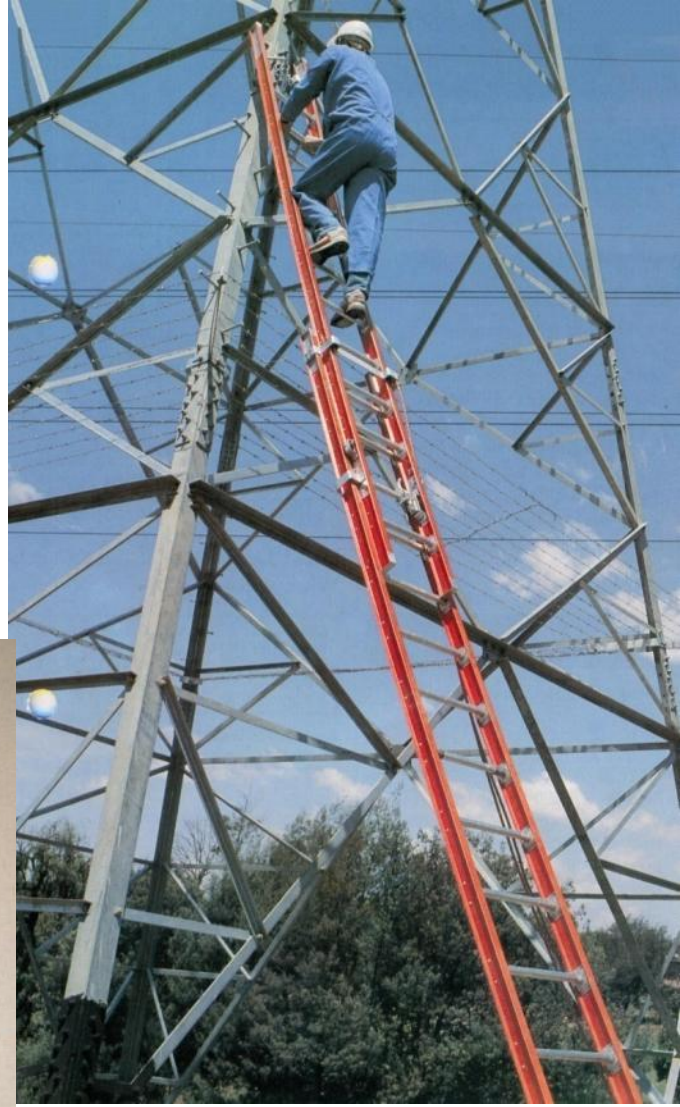
Shema kalupov za VI ali avtoklav postopek



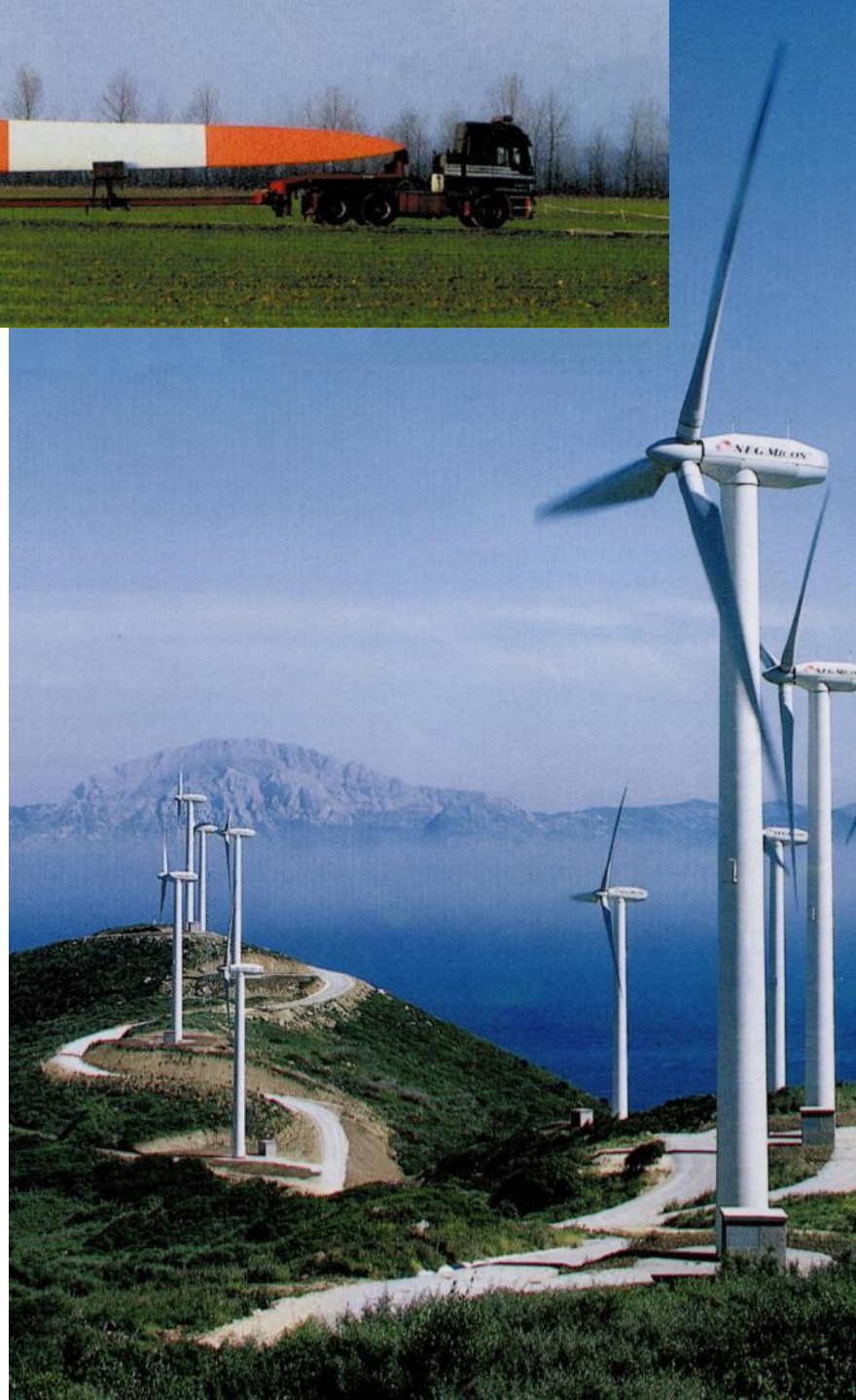
Izdelki - gradbeništvo


GELCLAD
GELCLAD
Highly efficient cladding
eco-panels with improved
nano-insulation properties

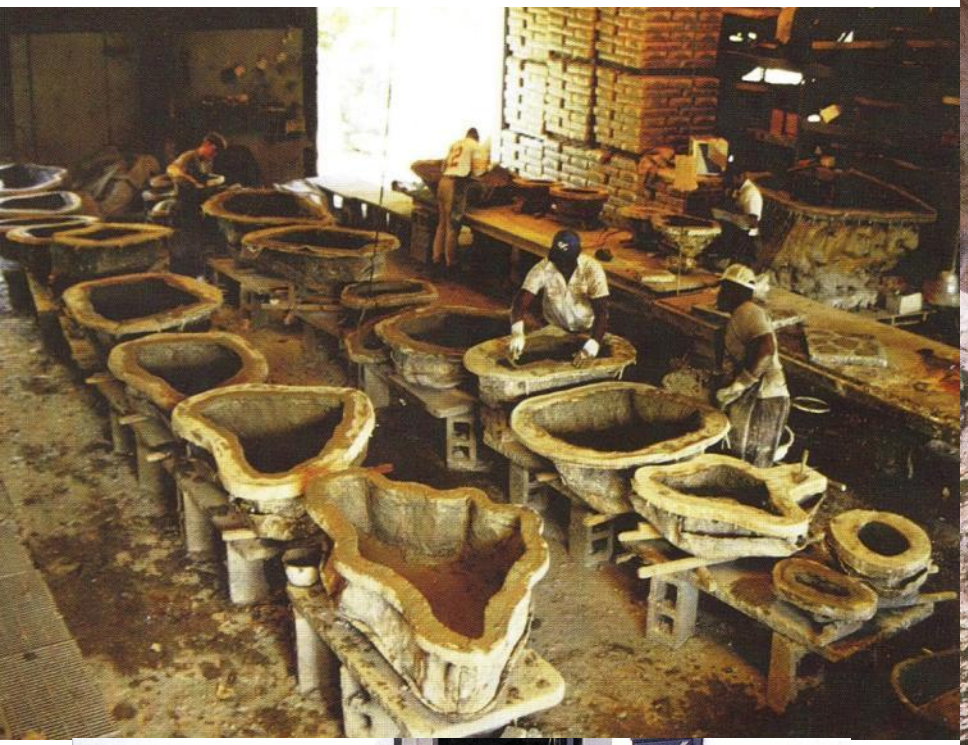

GELCLAD
GELCLAD

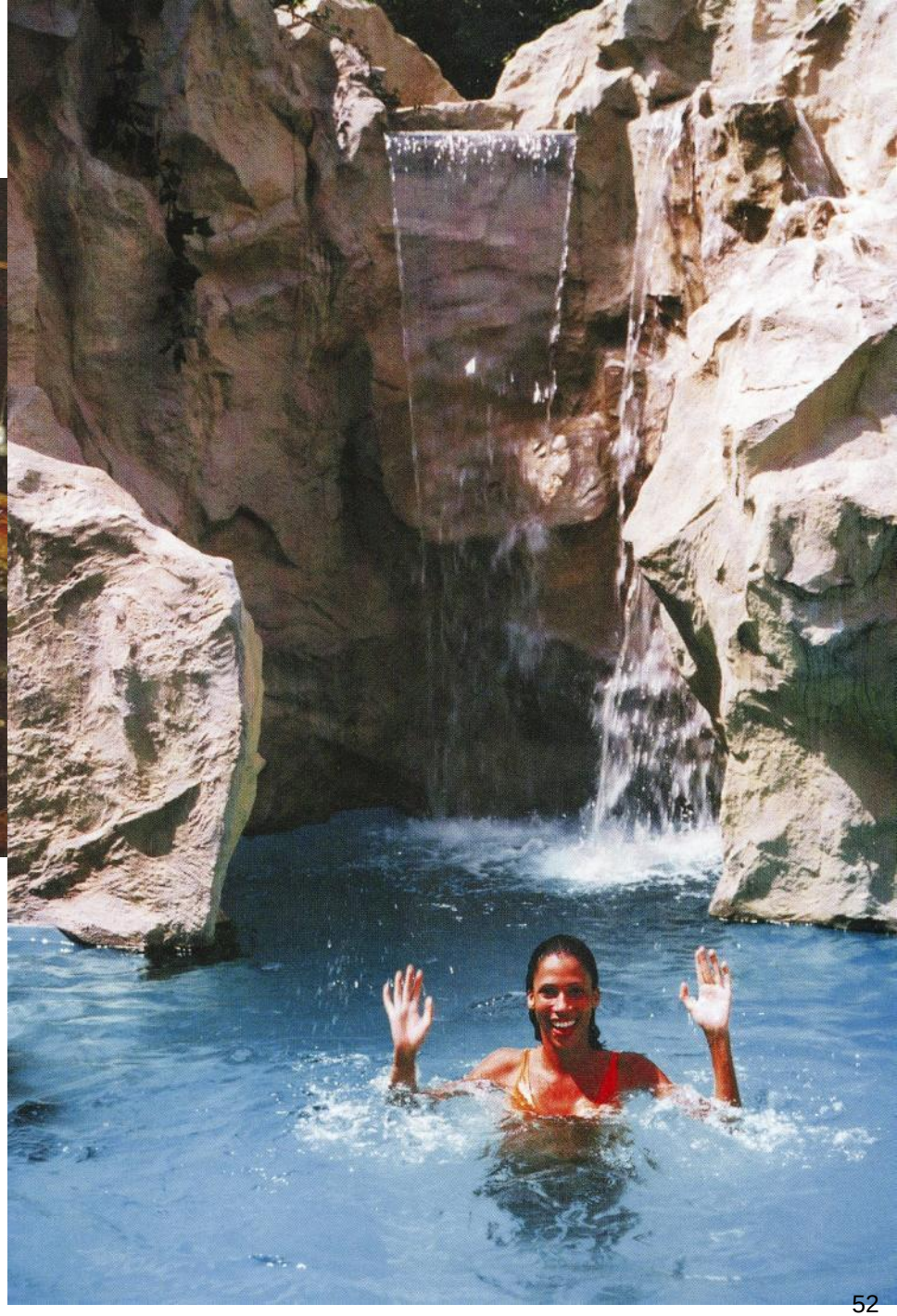


Elektro izdelki



Izdelki - kamen

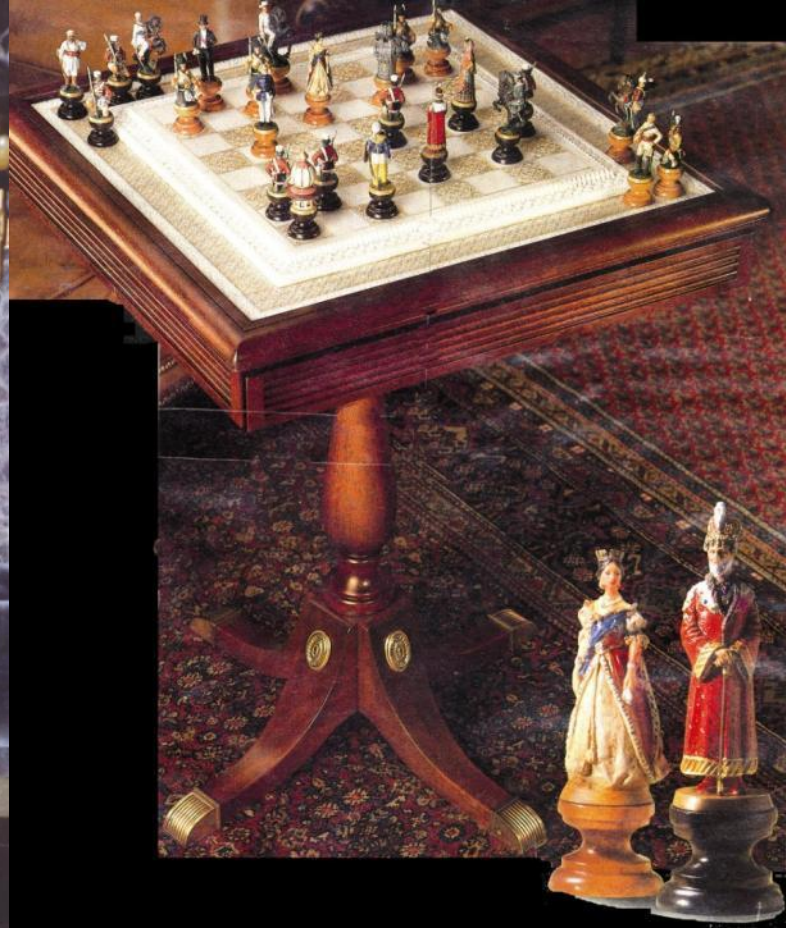




Komunalna oprema

Notranja oprema


TELEFON




Hvala za vašo
pozornost!