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High Performance Polymers



HIGH PERFORMANCE POLYMERS

IN PLASTIC-RUBBER COMPOSITES



High Performance Polymers in Plastic-Rubber Composites

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1 Plastic-Rubber Composites

The High Performance Polymers Business Unit of Degussa AG manufactures a line of compounds specially modified for the production of adhesion promoter-free plastic-rubber composites.

This brochure describes the plastic-rubber composite process (K&K process) and the compounds available for it.

Like all high-performance plastics from the High Performance Polymers Business Unit, these compounds meet the highest quality standards. Our system of quality assurance is certified according to ISO 9001 and QS 9000. Numerous customers have tested this quality system and confirmed its superiority.

1.1 Hard-soft composites

Wherever rubber components must be fastened or fixed, composites consisting of a hard component and an elastomer perform well. They represent an important sector of the rubber industry. Such composites are found in a wide variety of applications, for example, as shock-absorbing bearings in the chassis of motor vehicles, buffers or reinforced seals in engines and machines.

Traditionally, hard components consisted of metal composites. To reduce weight, particularly in vehicles, more and more metal components are being replaced by suitable plastic parts wherever possible. This has two additional advantages: Plastics do not corrode and can be efficiently processed into very complex moldings by injection molding. However, they must be dimensionally stable at the usual vulcanization temperatures of 160-190°C. The manufacture of such complex parts from metal is very expensive. The use of plastics in the design of complex components provides the designer and component developer with much greater latitude.

For the long-term function of composites, particularly under dynamic stress, the adhesion between the hard component and the soft component of the composite is an important criterion. It is usually achieved by adhesion promoters. Combinations of all standard rubber types with most metals and simple plastics are possible. Besides additional process steps for applying the adhesion promoter, protective measures against emissions of the usual solvents and their environmentally correct disposal are required.

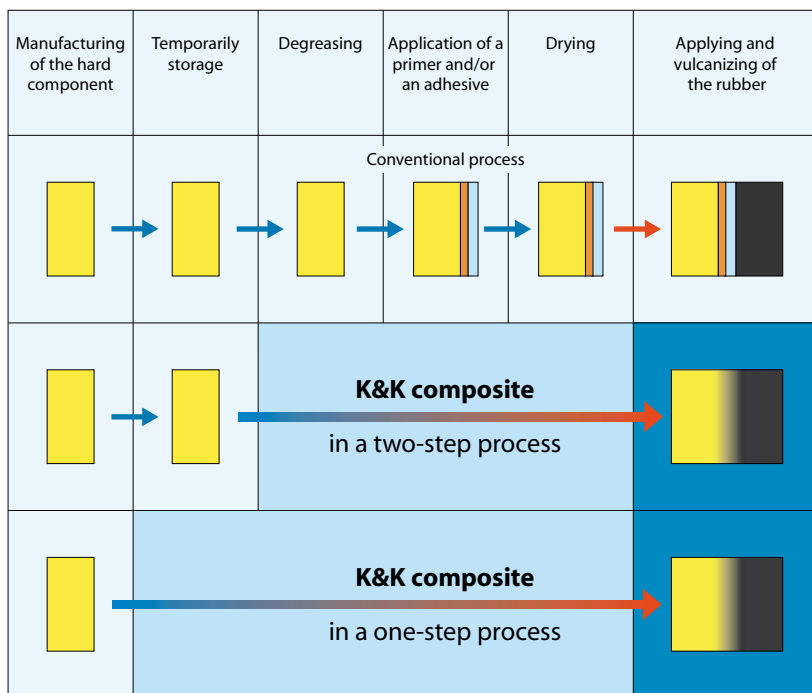


Figure 1: Process steps for composites

1.2 Adhesion without adhesion promoters

By contrast, the plastic-rubber composite patented by Degussa AG obviates adhesion promoters. Stable, permanent bonds to suitable rubber blends can be produced without special pre-treatment using special compounds of the series VESTORAN® (polyphenylene ether) and VESTAMID® (polyamide 612) and TROGAMID® blends based on polyamide 6-3-T.

The adhesion is based on several mechanisms, which are represented in Figures 2a–c. When the combination of VESTORAN and SBR or SBR-containing blends is used, (poly) styrene molecules interdiffuse in the interface. As a result, the substrates are “welded” together (Figure 2a). The composite of VESTORAN with peroxidic cross-linked EPDM consists of stable carbon-carbon bonds formed by radicals (Figure 2b). In the case of the VESTAMID types, in combination with XNBR, peroxidic crosslinking produces not only carbon-carbon bonds but also amide groups, which ensure permanent adhesion (Figure 2c). The type of the very stable bond of fluororubber to polyamides is not yet completely understood.

Bonding mechanisms

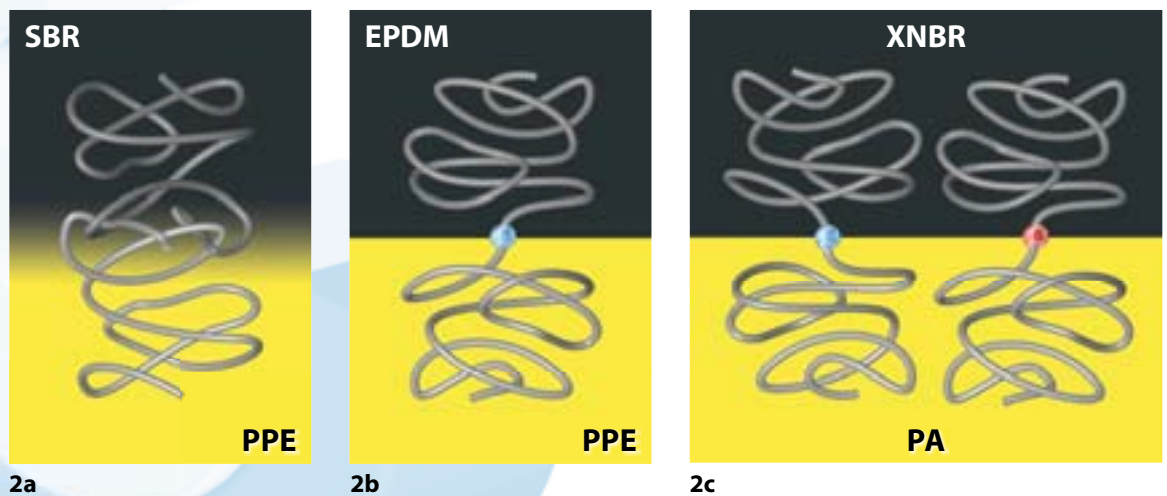


Figure 2a: Bonding of polyphenylene ether to SBR by diffusion of styrene segments

Figure 2b: Radical bonding of polyphenylene ether to EPDM by peroxides

Figure 2c: Radical bonding of polyamides to XNBR by peroxides and amide groups

Approaches

2 Two Approaches to Plastic-Rubber Composites

Depending on existing technical and plant conditions, two processes are available for manufacturing adhesion promoter-free composites.

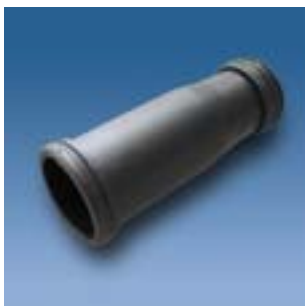
2.1 The two-stage process

The two-stage process is almost identical with the conventional production of rubber-metal and plastic-rubber components. The plastic part is manufactured separately or supplied by an injection molder. The rubber compound is applied to this insert and vulcanized. However, the intermediate step of applying the adhesion promoter is obviated.

This process is particularly useful when the vulcanization time is substantially longer than the cooling time of the associated plastic component. The two process steps can be optimally designed independently of each other. Investments in new machines are not necessary.

2.2 The one-stage process

If there is little or no difference between cooling time and vulcanization time, the one-stage process is an option. By obviating adhesion promoters, the composites can be manufactured in a common tool without intermediate steps, similarly to the two-component injection molding process. To accomplish this, the injection molding machine must be equipped with a rubber cylinder and a thermoplastic cylinder. Each cavity, that is, the thermoplastic cavity and the rubber cavity, is situated in one half of a common tool. The plastic part is manufactured in the "cold" half of the tool. It is then transferred, for example, with an index plate into the "hot" half. Here the rubber compound is applied and vulcanized. At the same time a new plastic molding is formed in the cold half. After the finished composite is dumped from the hot half, the cycle starts again. This process sequence is shown as a simplified diagram in Figure 3.



2.3 Economy

The manufacturing process can be largely automated by eliminating adhesion promoters. Repeated handling of the parts is obviated. Thus, several sources of error are eliminated and the reject rate decreases. Depending on plant-specific conditions, cost savings of up to 30 % can be achieved.

For comparing costs between the conventional process and the K&K process, we provide a cost estimate sheet upon request. Simply get in touch with the specified representative.

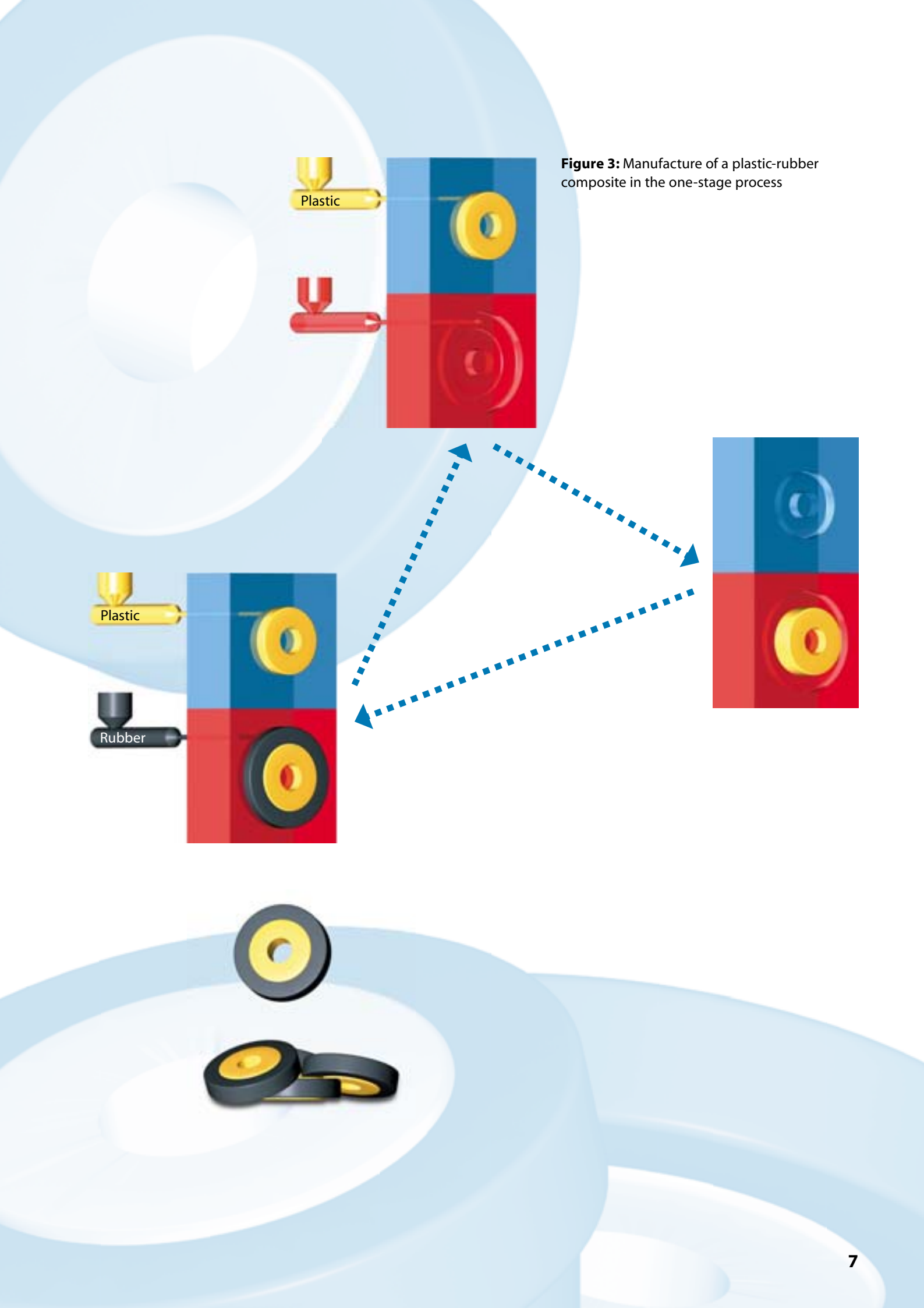


Figure 3: Manufacture of a plastic-rubber composite in the one-stage process

3 List of Compounds

Table 1: List of compounds available for adhesion promoter-free plastic-rubber composites

Compound	Filler	Combined with	Cross-linking system	Applications
VESTORAN 1900		SBR, NR/SBR, NBR/SBR EPDM	◀ Sulfur ◀ Peroxide	Vibration absorbers, shock absorbing bushings, reinforced profiles, seals
VESTORAN 1900GF20	20 % glass fibers			
VESTAMID X7094		XNBR, HNBR, AEM, FPM	Peroxide, bisphenol, amine	Oil resistant seals, moldings
VESTAMID X7099	20 % glass fibers			
VESTAMID DX9301	4 % graphite			
VESTAMID DX9320	10 % glass fibers, impact modified			
VESTAMID DX9321	20 % glass fibers, impact modified			
VESTAMID DX9322	15 % milled glass fibers			
VESTAMID DX9323	35 % glass fibers, impact modified			
TROGAMID BX9727	40 % glass fibers, 20 % mineral	HNBR, AEM, FPM	Peroxide, bisphenol, amine	Oil resistant seals, moldings
TROGAMID BX9728	30 % glass fibers			

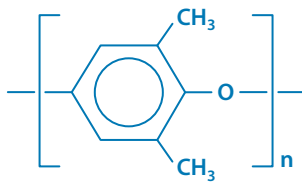


VESTORAN

4 Polyphenylene Ether VESTORAN

VESTORAN® is the registered trademark of Degussa AG for compounds based on poly-2,6-dimethyl-1,4-phenylene ether (PPE). The amorphous material has high heat deflection temperature. Moldings of VESTORAN have very low mold shrinkage and warpage. VESTORAN is hot water-resistant. The water absorption is very low. It is resistant to alkalis and acids but less resistant to fats, oils and fuels. Section 4.2 provides details on chemical resistance.

Figure 4:
Molecular structure of polyphenylene ether



Four VESTORAN grades are available for adhesion promoter-free plastic-rubber composites:
VESTORAN 1900 natural and 1900 black
VESTORAN 1900GF20 light ivory and 1900GF20 black

These grades can be combined with SBR and SBR blends, such as NR/SBR; the SBR portion should be at least 15 wt%. These rubbers are to be crosslinked with sulfur. Applications of such combinations include vibration bushings and shock absorbers in the chassis of motor vehicles.

Combinations with EPDM compounds that are peroxidically crosslinked perform well. Examples of application are reinforced profiles and seals.

Examples of SBR, NR/SBR and EPDM formulations are shown in Chapter 7.



Table 2: Properties of polyphenylene ether compounds for plastic-rubber composites

Properties		Test method	Unit	VESTORAN 1900	VESTORAN 1900GF20
Physical, thermal and mechanical properties					
Density	23 °C	ISO 1183	g/cm ³	1.04	1.19
Melt volume-flow rate (MVR)	300 °C/21.6 kg	ISO 1133	cm ³ /10 min	> 20	15
Tensile test		ISO 527-1/-2			
Stress at yield			MPa	60	
Strain at yield			%	6	
Tensile strength			MPa		110
Strain at break			%	> 50	3
Tensile modulus		ISO 527-1/-2	MPa	2000	5600
Flexural modulus		ISO 178	MPa	2400	5700
CHARPY impact strength*	23 °C	ISO 179/1eU	kJ/m ²	250 P	26 C
CHARPY notched impact strength*	23 °C	ISO 179/1eA	kJ/m ²	25 C	8 C
Heat deflection temperature under load		ISO 75-1/-2			
Method A	1.8 MPa		°C	> 170	185
Method B	0.45 MPa		°C	> 190	190
Vicat softening temperature		ISO 306			
Method A	10 N		°C	> 190	200
Method B	50 N		°C	> 185	190
Flammability acc. UL94	0.8 mm 1.6 mm	ISO 60695		HB HB	HB HB
Water absorption	Saturation	ISO 62	%	0.4	0.4
Mold shrinkage		Determined on 2 mm sheets with film gate at rim, mold temperature 80 °C			
in flow direction			%	approx. 0.9	approx. 0.5
in transverse direction			%	approx. 0.8	approx. 0.6
Electrical Properties					
Relative permittivity	100 Hz 1 MHz	IEC 60250		2.6 2.9	2.9 2.7
Dissipation factor	100 Hz 1 MHz	IEC 60250		$8 \cdot 10^{-4}$ $16 \cdot 10^{-4}$	$8 \cdot 10^{-4}$ $18 \cdot 10^{-4}$
Dielectric strength	K20/P50	IEC 60243-1	kV/mm	40	33
Comparative tracking index		IEC 60112			
Test solution A	CTI			225	200
	100-drop-value			200	175
Volume resistivity		IEC 60093	Ohm · m	> $1 \cdot 10^{13}$	> $1 \cdot 10^{13}$
Surface resistance R _{OA}		IEC 60093	Ohm	$2 \cdot 10^{14}$	$1 \cdot 10^{13}$
Electrolytic corrosion		IEC 60426	Stage	A1	A1

* C = complete break, P = partial break



4.1 Processing VESTORAN

Pre-drying

Although VESTORAN absorbs very little moisture, pre-drying in a circulating or vacuum dryer is extremely important. To prevent damage to the material, drying conditions should not exceed 110-120 °C for 2 hr. The pre-dried granulate must be introduced hot into the machine hopper. The dwell time of the melt in the cylinder should be less than 5 min.

Machine parameters

Screw:	L/D-ratio min. 20:1, compression ratio 2:1 to 3:1
Nozzle:	Diameter greater than 3 mm
Injection pressure:	800 - 1600 bar
Holding pressure:	50 - 80 % of injection pressure
Specific back pressure:	5 - 10 bar
Temperature settings:	
Cylinder	280 / 300 / 320 / 320 °C
Nozzle	310 °C
Melt	300 - 330 °C

The melt temperature should not exceed 340 °C to prevent thermal damage to the PPE.

Mold

Externally heated hot runner systems must be used. Approximately 0.05 mm deep venting channels should be placed near the welding lines.

Temperature settings for separate manufacture of the moldings (two-stage process):

VESTORAN 1900	80 - 90 °C
VESTORAN 1900GF20	130 - 140 °C

Temperature settings for the one-stage process:

VESTORAN 1900	180 °C
VESTORAN 1900GF20	180 °C

The higher mold temperature in the one-stage process enables the molding heat to be utilized for a shorter vulcanization time of the rubber component.

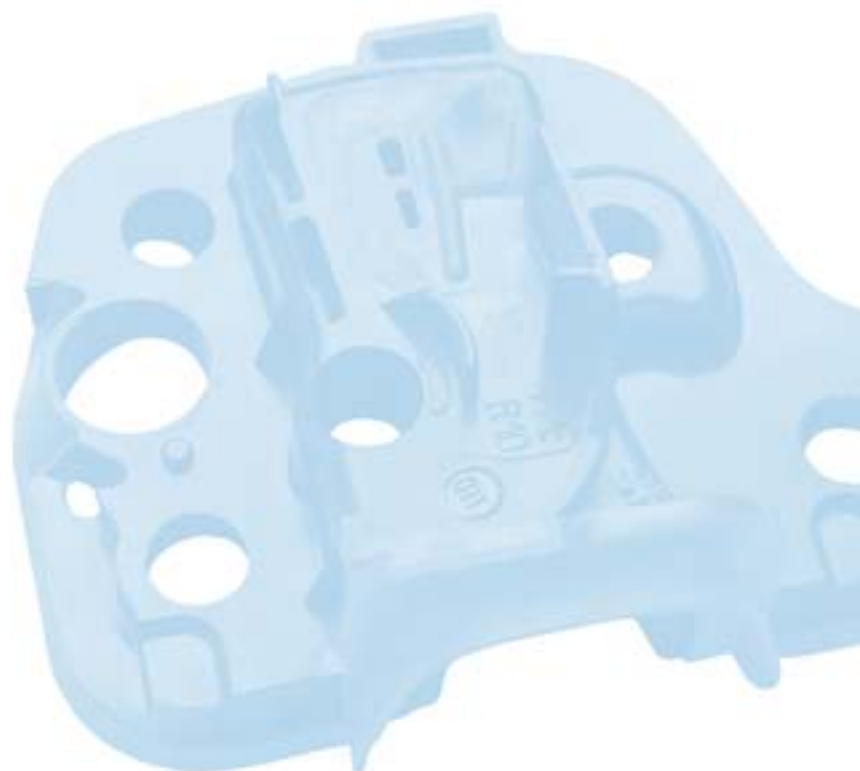
An exhausting device above the injection molding machine is strongly recommended.

Handling of VESTORAN moldings in the two-stage process

When pre-molded components are used for the plastic-rubber composites, no mold release agents may be used. The VESTORAN surfaces must be free of grease and dust. Intermediate storage of the moldings is done in the dark, for example, in black polyethylene bags. Further processing within two weeks is recommended. Contaminated surfaces can be cleaned by wiping them off with toluene.

4.2 Chemical resistance of VESTORAN

The stress cracking susceptibility test according to ISO 4599 under the influence of different media is a criterion for chemical resistance (bent strip test, 3.5 % outer fiber strain with basic grades; 2.7 % outer fiber strain in the case of glass fiber-reinforced grades). The resistance is dependent on temperature but also on the stress state of the test specimen. Therefore, we recommend using a test under field conditions to determine whether the requirements are met.



VESTORAN

Chemical resistance

Medium		Test temperature [°C]	VESTORAN	
			Basic grades	Glass fiber reinforced grades
Acetic acid	50 %	80	+	+
	100 %	20	-	-
Acetone		20	-	-
Ammonia	25 %	20	+	+
Antifreeze	50 %	100	+	+
	100 %	100	+	+
Brake fluid (ATE DOT 4)		20	-	-
Cyclohexane		20	-	-
Diethylene glycol	50 %	20	+	+
	99 %	20	+	+
1,4-Dioxane		20	-	-
Ethanol		20	+/-	+/-
Ethyl acetate		20	-	-
Ethylene glycol		20	+	+
Formic acid	80 %	20	+	+
	100 %	20	+	+
Glycerin		20	+	+
Hydraulic fluid (Shell Tegula 32)		20	-	-
Hydrochloric acid	10 %	20	+	+
	35 %	20	+	+
Isobutanol		20	+/-	+/-
Isopropanol		20	+/-	+/-
Lubrication oil (BP Energrease)		80	-	-
Methanol		20	+/-	+/-
Methyl ethyl ketone		20	-	-
Methyl-tert.-butyl ether (MTB)		20	-	-
Motor oil SAE 15-W40		80	-	-
N,N-Dimethylformamide		20	-	-
Nitric acid	65 %	20	-	-
Oxalic acid	5 %	80	+	+
Paraffin oil		20	+	+
Phosphoric acid	10 %	20	+	+
	85 %	20	+	+
Potassium hydroxide solution	10 %	20	+	+
	60 %	20	+	+
Silicone oil 740		20	+	+
		80	+	+
Sodium hydroxide solution	10 %	80	+	+
	50 %	20	+	+
Sulfuric acid	10 %	80	+	+
	25 %	20	+	+
	98 %	20	-	-
Toluene		20	-	-
Water		100	+	+

+ resistant

+/- somewhat resistant

- not resistant

VESTAMID

5 Polyamide 612 VESTAMID

Degussa manufactures and sells its Polyamide 612 products under the trade name VESTAMID®. Compounds are available in the D series specifically for adhesion promoter-free manufacture of plastic-rubber composites. As partially crystalline materials, they feature excellent chemical resistance, particularly toward greases, oils and fuels. Besides very good sliding friction properties, polyamide 612 shows appreciably less water absorption than polyamide 6 or polyamide 66.

Further properties and data on chemical resistance are available in the brochure "VESTAMID—Polyamide 612". Recommendations for processing are found in the brochure "VESTAMID—Handling and Processing".

The properties of the VESTAMID grades suitable for plastic-rubber composites are listed in Table 3. Compounds with different glass fiber contents and, in some cases, with impact modification are available. For manufacture of oil-resistant and fuel-resistant seals and moldings, they can be combined with appropriate rubber compounds, for example, based on XNBR rubber, partially saturated HNBR rubber and FPM rubber. Moldings for the two-stage plastic-rubber process should be stored in a dust-free atmosphere and processed within 3 months.

Examples for known rubber formulations are found in Chapter 7.

Figure 5:
Molecular structure of polyamide 612

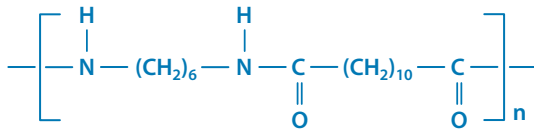


Table 3: Properties of polyamide 612 compounds for plastic-rubber composites

Properties		Test method	Unit	X7094 black
Physical, thermal and mechanical properties				
Density	23 °C	ISO 1183	g/cm ³	1.06
Melting temperature	peak temperature 2. heating	ISO 11357	°C	215
Heat deflection temperature under load		ISO 75-1/ -2		
Method A	1.8 MPa		°C	60
Method B	0.45 MPa		°C	150
Vicat softening temperature		ISO 306		
Method B	50 N		°C	185
Coefficient of linear thermal expansion	23 °C - 55 °C longitudinal transverse	ISO 11359	10 ⁻⁴ K ⁻¹	
Flammability acc. UL94	1.6 mm 3.2 mm	IEC 60695		HB HB
Water absorption	23 °C, saturation	ISO 62	%	2.8
Moisture absorption	23 °C, 50 % r.F.	ISO 62	%	1.0
Mold shrinkage	in flow direction in transverse direction	Specimen 127 · 12.7 · 3.2 mm ³ ; Processing acc. ISO 1874-2	% %	1.3 1.1
Tensile test		ISO 527-2/1 A		
Stress at yield			MPa	60
Strain at yield			%	5
Tensile strength			MPa	
Strain at break			%	> 50
Tensile modulus		ISO 527-2/1 A	MPa	2100
CHARPY impact strength*	23 °C -30 °C	ISO 179/1eU	kJ/m ² kJ/m ²	N N
CHARPY notched impact strength*	23 °C -30 °C	ISO 179/1eA	kJ/m ² kJ/m ²	8 C 7 C
Electrical properties				
Relative permittivity	100 Hz 1 MHz	IEC 60250		4.4 3.9
Dissipation factor	100 Hz 1 MHz	IEC 60250	KV/mm	590 390
Dielectric strength	K20/P50	IEC 60243-1		30
Comparative tracking index	CTI	IEC 60112		
Test solution A	50-drop-value 100-drop-value			> 600
Volume resistivity		IEC 60093	Ohm · cm	10 ¹⁴

* N = no break, P = partial break, C = complete break

DX9301 black 4 % graphite	DX9320 black 10 % glass fibers	DX9322 black 15 % milled glass fibers	X7099 black 20 % glass fibers	DX9321 black 20 % glass fibers	DX9323 black 35 % glass fibers
1.09	1.12	1.17	1.23	1.19	1.31
215	215	215	215	215	215
85	183	114	190	189	196
185	201	186	210	208	213
187	199	193	205	207	209
1.3	0.7	1.0	0.5	0.5	
1.1	0.8	0.6	0.7	0.7	
	HB	HB	HB HB	HB	HB HB
2.7	2.6	2.4	2.0	2.0	1.9
1.0	1.0	0.9	0.8	0.8	0.8
1.2	1.29	1.92	0.55	0.66	0.35
1.4	0.97	0.93	1.05	0.88	0.8
65	82	63 8	120	109	140
7	10	59 18	5	6	5
2650	3700	3050	5500	5450	8340
115 C	81 C	46 C	80 C	93 C	104 C
110 C	96 C	43 C	20 C	106 C	110 C
4 C	11 C	4 C	8 C	18 C	20 C
3 C	5 C	3 C	7 C	11 C	15 C
	4.3	4.3	4.4	4.4	
	3.1	3.1	3.9	3.1	
	470	430	650	500	
	466	493	430	470	
			38		
	> 600	> 600		> 600	
	600	575		600	
	10 ¹⁴	10 ¹⁴	10 ¹⁴	10 ¹⁴	

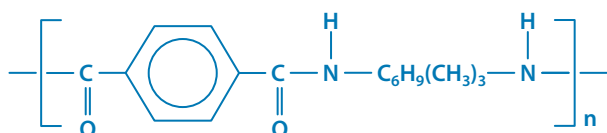


TROGAMID

6 Polyamide 6-3-T Blend TROGAMID

In addition to polyamide 612, blends of amorphous and crystalline polyamides are also available for plastic-rubber composites. They are based on polyamide 6-3-T and bear the trademark TROGAMID® BX.

Figure 6:
Molecular structure of polyamide 6-3-T



TROGAMID BX compounds are oil- and fuel-resistant. They are suitable for manufacturing moldings with high strength and hardness that are subjected to high thermal stress. The mold shrinkage, warpage and moisture absorption are low.

Other data, including chemical resistance, can be obtained from the brochure "TROGAMID T Series". The processing is described in the brochure "TROGAMID—Handling and Processing". Intermediate storage for two-stage manufacture of the plastic-rubber composites must be dust-free like in the case of polyamide 612; further processing must be done within three months.

TROGAMID BX compounds can be combined with the same rubber compounds as polyamide 612 except XNBR to manufacture oil- and fuel-resistant composites.

Table 4: Properties of polyamide 6-3-T compounds for plastic-rubber composites

Properties		Test method	Unit	TROGAMID BX9727	TROGAMID BX9728
Density	23 °C	ISO 1183	g/cm ³	1.65	1.41
Tensile test		ISO 527-1/-2			
Tensile strength			MPa	210	185
Strain at break			%	2.0	3.2
Tensile modulus		ISO 527-1/-2	MPa	14500	9000
CHARPY impact strength*	23 °C	ISO 179/1eU	kJ/m ²	70 C	60 C
	0 °C		kJ/m ²	60 C	
	-30 °C		kJ/m ²	55 C	50 C
CHARPY notched impact strength*	23 °C	ISO 179/1eA	kJ/m ²	10 C	9.5 C
	0 °C		kJ/m ²	9.5 C	
	-30 °C		kJ/m ²	9 C	9.0 C
Shore hardness D		ISO 868		> 90	89
Ball indentation hardness H30		ISO 2039-1	N/mm ²	310	250
Heat deflection temperature		ISO 75-1/-2			
Method A	1.8 MPa		°C	> 230	> 230
Method B	0.45 MPa		°C	> 230	> 230
Vicat softening temperature		ISO 306			
Method A	10 N		°C	> 230	> 230
Method B	50 N		°C	> 230	> 230
Linear thermal expansion	23 °C - 55 °C	ISO 11359			
	longitudinal		10 ⁻⁴ K ⁻¹	0.3	
	transverse		10 ⁻⁴ K ⁻¹	0.3	0.2
Mold shrinkage		ISO 294-4			
	in flow direction		%	0.3	0.1
	in traverse direction		%	0.6	0.7

*C = complete break

Formulations

7 Examples of Rubber Formulations

7.1 SBR formulation for K&K composites with VESTORAN

Formulation-No.:		RD 3530		
SBR 1500		100		
Carbon black N 550		50		
Paraffin oil		5		
ZnO		3.0		
Stearic acid		1.0		
Sulfur		1.75		
Vulkacit® NZ (TBBS)		1.0		
ML (1+4)	100 °C			85
Rheometer	180 °C	t ₁₀	min	2.8
		t ₉₀	min	5.9
Vulcanization 180 °C; 10 min				
Hardness 23 °C		Shore A		68
Hardness 75 °C		Shore A		46
Tensile strength		MPa		18.6
Elongation at break		%		378
Modulus 100 % elongation		MPa		3.0
Modulus 200 % elongation		MPa		8.5
Modulus 300 % elongation		MPa		15.5
Rebound resilience 23 °C		%		46

7.2 NR/SBR formulation for K&K composites with VESTORAN

Formulation-No.:		RD 5010		
NR		80		
SBR 1500		20		
Carbon black N 772		59		
ZnO		4		
Stearic acid		1.0		
Vulkanox® HS (TMQ)		1.2		
Vulkanox® 4020 (IPPD)		2.0		
Antilux® 600		2		
Sulfur		4.0		
Vulkacit® CZ (CBS)		0.65		
Vulkalet® E		0.2		
ML (1+4)	100 °C			38
Rheometer	180 °C	t ₁₀	min	1.5
		t ₉₀	min	3.0
Vulcanization 180 °C; 4 min				
Hardness 23 °C		Shore A		58
Hardness 75 °C		Shore A		56
Tensile strength		MPa		14.2
Elongation at break		%		374
Modulus 100 % elongation		MPa		2.3
Modulus 200 % elongation		MPa		6.2
Modulus 300 % elongation		MPa		11.6
Rebound resilience 23 °C		%		58
Rebound resilience 75 °C		%		75
Tear propagation resistance (ring)		N/mm		43

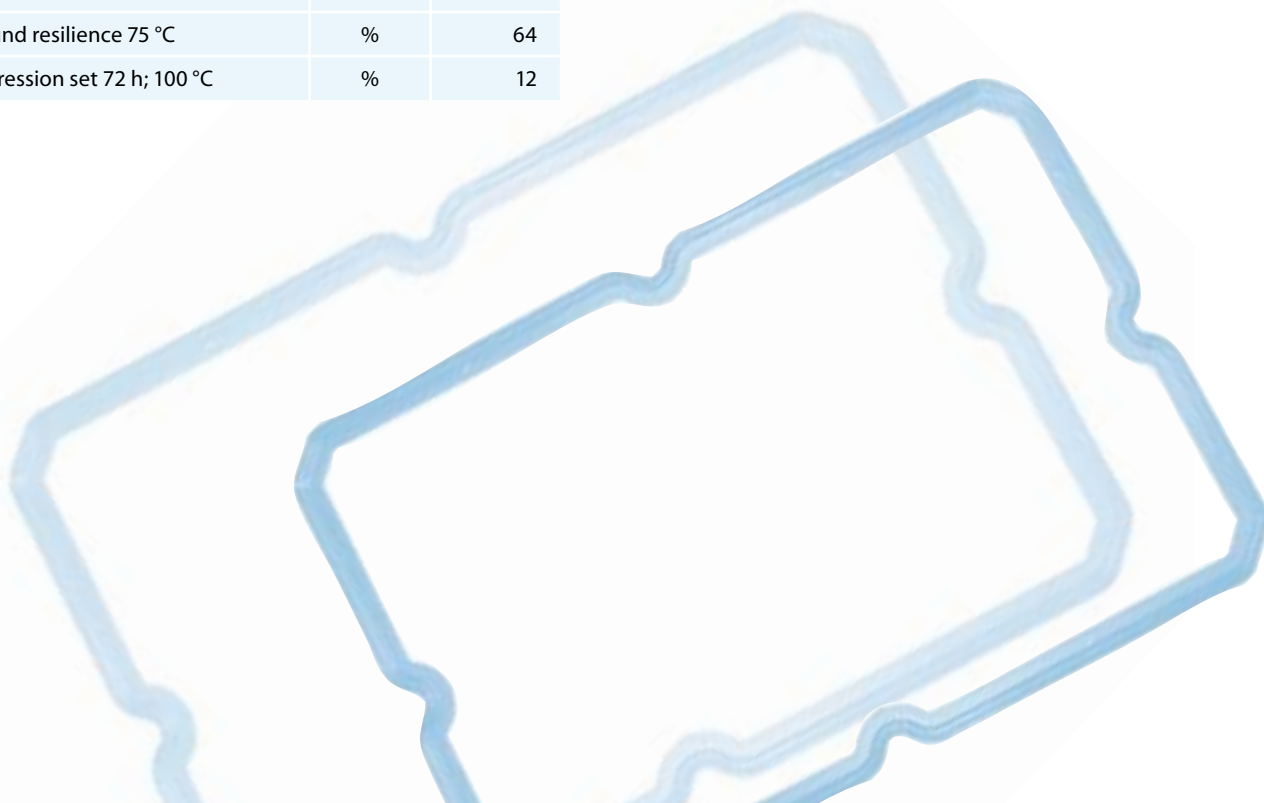
Formulations

7.3 EPDM formulation for K&K composites with VESTORAN

Formulation-No.:		RD 5114		
BUNA® EP G 6470		90		
VESTENAMER® 8012		10		
Carbon black N 539		72		
Paraffin oil		51		
ZnO		5.0		
Vulkanox® HS (TMQ)		1.0		
TRIM		1.25		
Perkadox® 14/40		5.5		
ML (1+4)	100 °C			50
Rheometer	180 °C	t ₁₀	min	1.8
		t ₉₀	min	7.2
Density			g/cm ³	0.96
Vulcanization 180 °C; 20 min				
Hardness 23 °C		Shore A		67
Hardness 75 °C		Shore A		52
Tensile strength		MPa		16.8
Elongation at break		%		450
Modulus 100 % elongation		MPa		2.5
Modulus 300 % elongation		MPa		10.5
Residual elongation		%		18
Tear propagation strength (DIN 53507)		N/mm		9
Rebound resilience 23 °C		%		54
Rebound resilience 75 °C		%		64
Compression set 72 h; 100 °C		%		12

7.4 XNBR formulation for K&K composites with VESTAMID

Formulation-No.:		RD 3731		
Nipol® 1472 (or Chemigum® NX 775)		100		
Sillitin® Z 86		60		
Polestar® 200 (Calc. Clay)		20		
Carbon black N 660		3		
Vulkanol® 88		10		
Stearic acid		1.0		
BDMA		1.5		
Perkadox® 14 / 40		6.0		
ML (1+4)	100 °C			56
Rheometer	180 °C	t ₁₀	min	1.4
		t ₉₀	min	3.8
Vulcanization 180 °C; 10 min				
Hardness 23 °C		Shore A		75
Hardness 75 °C		Shore A		70
Tensile strength		MPa		11.7
Elongation at break		%		314
Modulus 100 % elongation		MPa		6.4
Modulus 200 % elongation		MPa		9.9
Rebound resilience 23 °C		%		27
Compression set 22 h; 70 °C		%		8
Tear propagation resistance (ring)		N/mm		28



7.5 HNBR formulation for K&K composites with VESTAMID and TROGAMID

Formulation-No.:				RD 5080
Zetpol® 3110				100
Carbon black N 550				65
Rhenosin® W-759				10
ZnO				2
HVA 2				4
Perkadox® 14 / 40				7
Vulcanization 180 °C; 5 min				
Rheometer	170 °C	t ₁₀	min	0.32
		t ₉₀	min	2.0
Hardness 23 °C		Shore A	79	
Tensile strength		MPa	21.2	
Elongation at break		%	154	
Modulus 100 % elongation		MPa	12.8	
Rebound resilience 23 °C		%	32	
Adhesion to VESTAMID X7099		%	100	

7.6 FKM formulation for K&K composites with VESTAMID and TROGAMID

Formulation-No.:				RD 3367
DAI-EL™ G 763				100
Carbon black N 990				15
Rhenofit® D/A				3
Fluorel® E				6
Rheometer	180 °C	t ₁₀	min	1.5
		t ₉₀	min	2.8
Density			g/cm ³	1.83
Vulcanization 170 °C; 10 min				
Post cure 175 °C; 24 h				
Hardness 23 °C		Shore A	61	
Tensile strength		MPa	10.1	
Elongation at break		%	240	
Modulus 100 % elongation		MPa	6.1	





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For more information, please contact:

Frank Lorenz
Phone +49 2365 49-7579
Fax +49 2365 49-5992
E-mail: frank.lorenz@degussa.com

Degussa AG
High Performance Polymers
45764 MARL
GERMANY
Phone +49 2365 49-9878
Fax +49 2365 49-5992
www.degussa-hpp.com