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A novel light, flexible and durable thermoplastic elastomer

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Based on 20 years of experience in the field of elastomeric block-co-polymers Kuraray developed a new material with remarkable characteristics [1]. The new material is available as neat polymer - Septon Q series. Moreover an alloy technology applied onto this new material generates a novel class of TPE which enters the application areas of TPAE, TPEE and TPU. The alloys show advantageous processing properties and good performance in combination with polyolefins.

1. Introduction

The new material first was presented under the name Q-Polymer. It comes now to markets under the brand name Septon Q series. It is a novel class of elastomeric polymers for common use in the field of thermoplastic elastomers. Its outstanding performance can be generated with Kuraray's own alloy technology that creates light and scratch resistant materials. These alloys work well together with various polyolefins and even polymers with some polarity.

2. General

The neat polymer of the Septon Q series is a development grade at the stage of mass production. Kuraray has a pilot plant for a few hundred tonnes per year [2]. In this paper we concentrate onto the properties of the next step closer to the end products, onto the alloys made with Septon Q series polymers. As Kuraray is a raw material supplier such application technologies are used for examination as well as customer support.

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Nevertheless, we are able to show the properties and features of the new material.

The main features of the new material are depicted in **figure 1.** An overview on the characteristics is listed in **table 1.** The table shows a comparison with competing TPU, TPAE and TPEE materials (TPAE = ThermoPlastic polyAmide Elastomer, TPEE = Thermo Plastic polyEster Elastomer). Reference is given to SEBS, TPV and PVC. The relative importance of hardness and density of these products is illustrated. These properties are the most important factors in terms of product durability. Flexibility and lightness are already intrinsic features of these elastomer products. In this examination we concentrated on the commonly used TPU grades of ester-type. Especially for comparison of the durability in warm, moist environment we also utilised a hydrolysis resistant type of TPU (described in chapter 8).

The first commercial application after setting up the new material was in specialised soccer shoes. In this shoe sole a very good abrasion resistance is combined with the advantage of a light weight material. For this application Kuraray entered into an exclusive agreement with the cus-

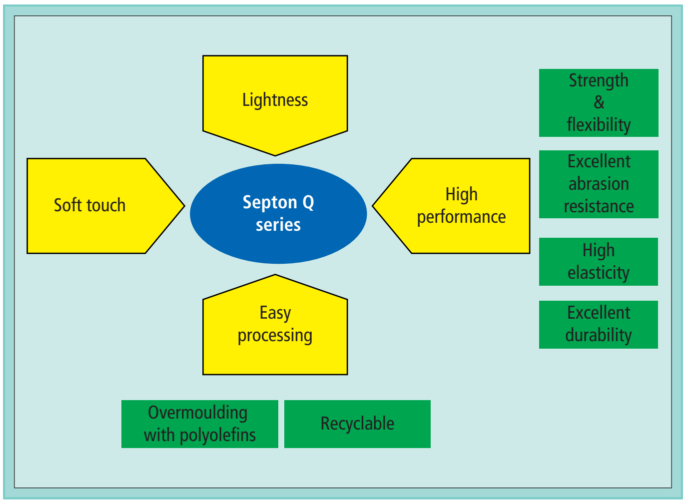


Fig. 1:
Main features of the Septon Q series

Tab. 1: Performance of Septon Q series alloys. (QA series = elastic; QB series = stiffness)

	Septon Q		Competing products			Reference		
	QA series	QB series	TPU (HR)	TPEE	TPAE	SEBS	TPV	PVC
Lightness	4	5	1	1	4	5	5	1
Elastic performance	4	5	5	5	5	4	1	4
Compression set	3	2	5	4	4	4	5	0
Low temperature properties	5	5	3	3	5	5	4	2
Hydrolysis resistance	5	5	1	0	0	5	5	2
Hot water resistance	1	5	1	0	0	5	5	2
Oil resistance	1	1	4	5	5	1	3	2
Weather resistance	4	4	2	4	4	4	4	2
Abrasion resistance	5	5	5	4	1	0	0	3
Adhesion to PO	5	5	0	0	0	5	5	0
5: excellent, 4: good, 3: fair, 2: poor, 1: bad, 0: very bad								

tomer. In **figure 2** a demonstration of this weight balance is shown. TPU shows a specific gravity level of 1.2 vs. 0.9 roughly for the Septon Q series alloy.

3. Properties

When developing the new material we looked at two different processing technologies – extrusion and injection moulding. The physical properties for extrusion grades are shown in **table 2.** We found benefits in abrasion resistance and also a wide performance range for the QA and QB series. Further development with regard to cost-efficiency was done in a second step. In the so-called economy grades of the QK series we focus on abrasion resistance only.

When looking at injection moulding performance we fabricated plaques and measured the all injection grades with TD direction of injection moulded sheet. The data are listed in **table 3.** We found good abrasion resistance and a wide performance range for the QB series and compared this with data obtained for similar products at similar hardness levels in TPAE and TPU field. For basically the same level of elongation at break we see higher flexural modulus and lower tensile strength. The best result for DIN abrasion can be observed for the QB191 grade in this series. (further explanations in chapter 7).

For the economy grades of the QK and QX series we also obtained remarkable results regarding abrasion resistance. From the data shown in **table 4** a selection based on abrasion performance points QK190 in direct focus for competitiveness.

4. Softness

In general the Septon Q series alloys are called a "soft material" which intentionally leads to a comparison in Shore hardness level. In **figure 3** an outline for Septon Q series among common TPE materials is depicted. Noting that the hardness ranges are overlapping, we achieved examples in the whole range from Shore A 60 to Shore D 60.

In using our alloy technology we were able to approach the hardness level of e.g. TPU, TPAE, and TPEE. The Septon Q series alloy material meets the demand for high quality scratch resistant surfaces in the automotive, sports goods, and other industries.

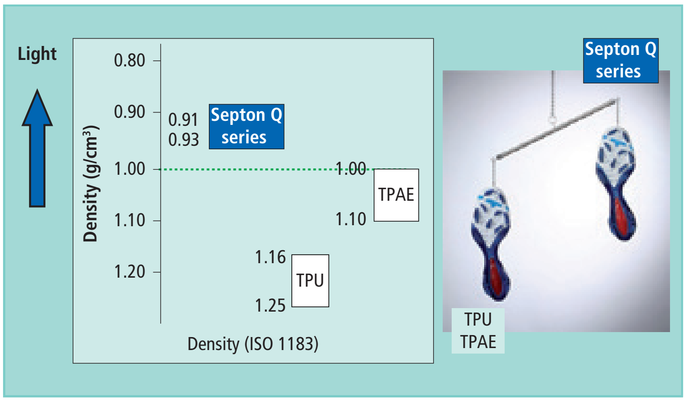


Fig. 2: Comparison of specific gravity (left). Septon Q series in the first commercial application in top level soccer shoes (right).

Tab. 2: Typical properties of Septon Q series in extrusion applications

	Septon Q series			
	QA290P-000	QA280P-000	QB190-002	QK190-005
Hardness (Shore A)	85	75	86	85
Density (g/cm³)	1.04	1.00	0.91	0.91
MFR (230 °C 2.16 kgf) (g/10min)	2.9	8.8	8.3	15
100 % modulus (MPa)	10	4	7	7
Tensile strength (MPa)	32	18	44	43
Elongation (%)	500	500	570	610
Taber abrasion (mm³)	6	3	9	10
*Samples made by press moulding				

Tab. 3: Typical properties of Septon QB series in injection moulding applications

		Septon Q series				TPAE			TPU	
		QB150-001	QB192-000	QB190-000	QB191-000	TPAE-A	TPAE-B	TPAE-C	TPU-A	TPU-B
Hardness (Shore D)	0 sec	68	61	50	46	65	54	41	62	46
	15 sec	61	52	44	41	59	52	37	–	40
Flexural modulus	MPa	778	380	275	200	260	148	68	89	36
Density	g/cm³	0.93	0.90	0.92	0.91	1.02	1.02	1.01	1.21	1.22
Tensile strength	MPa	40	41	41	46	58	59	40	56	64
Elongation at break	%	590	600	600	620	600	680	850	530	600
DIN abrasion	mm³	95	98	99	39	44	30	59	68	57
Haze (2mmt)	%	88	22	18	16	80	63	45	2	6

Tab. 4: Typical properties of Septon QK and QX series in injection moulding with focus on abrasion resistance

		Septon Q series			TPAE			TPU	
		QK150-000	QK190-003	QX190-000	A	B	C	A	B
Hardness (Shore D)	0 sec	57	46	46	65	54	41	6 2	46
	15 sec	54	41	41	59	52	37	–	40
Flexural modulus	MPa	631	234	288	260	148	68	89	36
Density	g/cm³	0.92	0.91	0.90	1.02	1.02	1.01	1.21	1.22
Tensile strength	MPa	34	41	21	58	59	40	56	64
Elongation at break	%	580	590	540	600	680	850	530	600
DIN abrasion	mm³	66	62	98	44	30	59	68	57
Haze (2mmt)	%	67	16	18	80	63	45	2	6

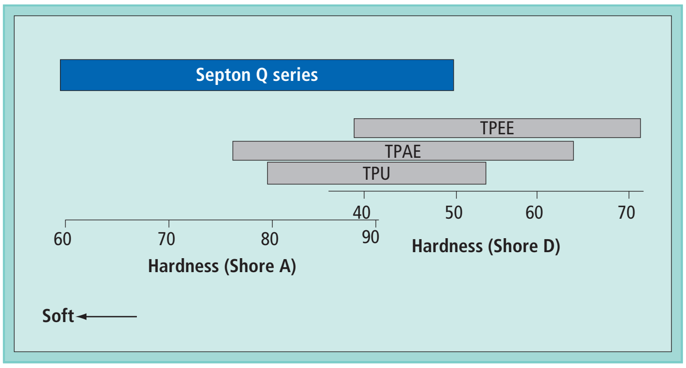


Fig. 3:
Softness/hardness ranges for Septon Q series alloy, TPEE, TPAE and TPU according to ISO 7619

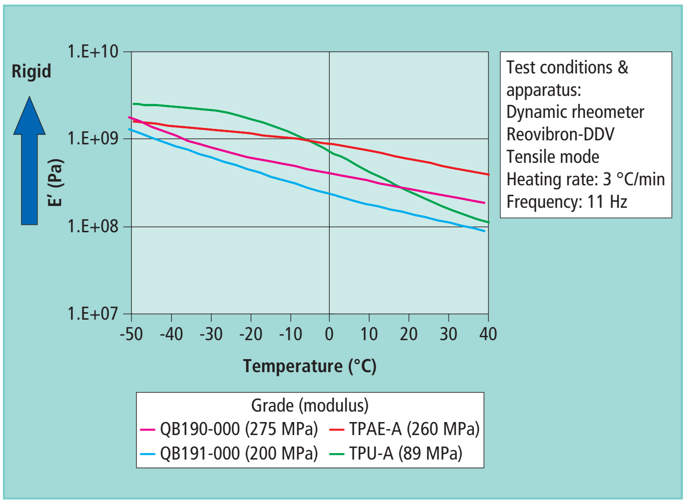


Fig. 4:
Temperature vs. elastic modulus E' (DMA) for QB190 alloy, TPU and TPAE samples

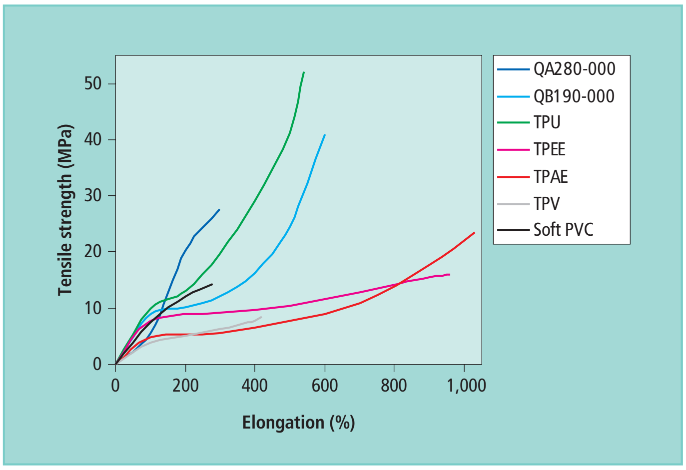


Fig. 5:
The tensile testing was done on ISO 37. The specimen were originated by 2 mm thick press moulding sheets and cut with shaped dumbbell no. 5.

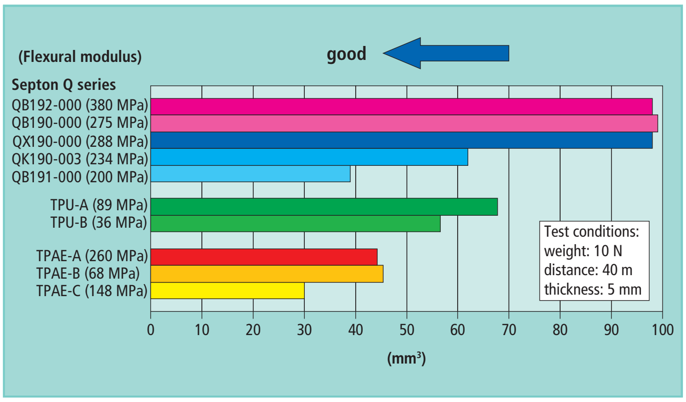


Fig. 6:
DIN abrasion test [5] for five alloys compared to TPU, TPAE and TPEE

Initial tests show the combination of soft touch with mechanical stability against i. e. Erichsen 318 test.

5. Elasticity at low temperatures

The comparison data for an alloy, namely QB190 versus TPU and TPAE are depicted in **figure 4.** The smooth stiffening behaviour of the material in focus along with temperature shows similarities between QB190 and TPAE and significant differences compared to TPU. Above room temperature the QB190 alloy behaves more stiff or rigid whereas TPU becomes soft. In contrast to this the QB190 alloy shows flexibility at low temperatures where TPU is limited in bendability. This alloy QB190 may be best ascribed as a soft TPAE.

6. Tensile strength

The tensile strength vs. elongation is shown in **figure 5.** Elastic properties are basic information for the end user. In most cases an elongation of up to 500 or 600 % is sufficient. Therefore the comparison of QB190 closed up to TPU performance. The application purpose of TPAE and TPEE usually does not require higher tensile strength.

7. DIN and Taber resistance

A crucial factor of any new material is the question if it will withstand the constant use and handling in an industrial or consumer application, which is commonly known as mar resistance. Out of various methods we exemplary selected the DIN abrasion [5] and Taber abrasion as a useful examination of the performance. The results are shown in figures **6** and **7.**

In our experience, conventional Septon compounds perform around 150 mm^3 and up at the DIN abrasion test. The range for DIN abrasion of Septon Q series alloys is prominent between 100 mm^3 and down lower than 40 mm^3. The selected TPU is in a range around 60 mm^3, the TPAE examples in the range of 45 mm^3 to 30 mm^3.

For the Taber abrasion we found that both alloys, the elastic (QA280) and the stiffness grades (QB190), perform at the same level as TPU, but the rigid samples of TPAE and TPEE rub off at least three times more.

8. Hydrolysis resistance

A test condition for hydrolysis resistance, known from leather and other industries, is the so-called "Jungle Test", that signifies severe wet weathering. For a period of at least 3 weeks a sample is being exposed to elevated temperatures (75-85 °C) and high humidity with not less than 90 % RH [3].

However, the conditions may vary according to the focus of the application. **Figure 8** shows the results of a test according to a Kuraray method (conditioning at 80 °C at 95 % relative humidity).

Both the elastic (QA280) and the stiff alloy (QB190) have been examined. The behaviour of the alloys QA280 and QB190 shows stable tensile strength along the 4 weeks. A reasonable drop of tensile strength was observed for TPAE material. TPEE is slightly more stable but cannot withstand in the long term. The more stable hydrolysis resistant TPU type undergoes a limited weakening on the level of relative 80 %. The data clearly show that the two alloy examples are well qualified even for tropical weather requirements.

9. Adhesion to polyolefines

In many applications of these materials the adhesion to polyolefines like PP is requested to refine the standard part by adding a "soft touch" or "grip", e. g. in automotive or consumer applications. Adhering to polyolefines is often used to create higher processabilities in functional devices like air flaps. The key factor is always the adhesion strength to PO, but no standardised measurement is defined so far.

For the preparation of the samples we used injection moulded sheets at 230 °C. The two layers were joined by press moulding at 220 °C. Then the peel strength was examined in 180° geometry – similar to tensile testing **(fig. 9)**. The data obtained show that Septon Q alloys have excellent adhesion to PO.

10. Flowability

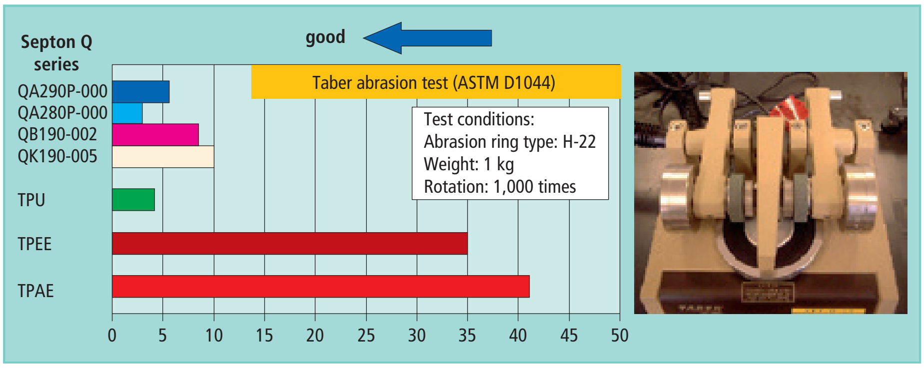
The examination of the flowability for Septon Q series shows good properties for injection moulding processing. Septon Q alloys can get wide processing temperature range for film moulding. The relevant temperature window was found to be around 205 ~ 230 °C for QB190 and 225 ~ 245 °C for QA290P for example.

11. Possible applications

When looking at possible applications we have to separate between extrusion and injection moulding applications. The materials are well suited for the production of industrial goods like tubes, hoses, belts, sheets, films as well as wire and cable applications. Applications in this area basically aim at the substitution of TPU, TPEE and TPAE for the reason of weight reduction.

Looking at injection moulding applications we are mainly considering sports and leisure goods (shoe soles, golf ball covers, cleats, ski boots, caster outsides, watchstraps, goggle

Fig. 7: Taber abrasion test. ASTM D1044 (test conditions: truck wheel H-22, weight 1.0 kg, at 1,000 rotations and 2 mm thickness of the sample)



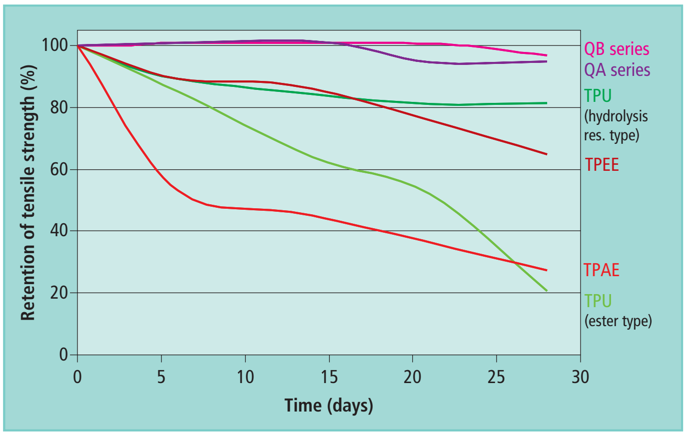


Fig. 8: Hydrolysis resistance vs. time, so-called "Jungle Test" (conditions: temperature 80 °C, humidity 95 % RH). Significant parameter is the retention of tensile strength.

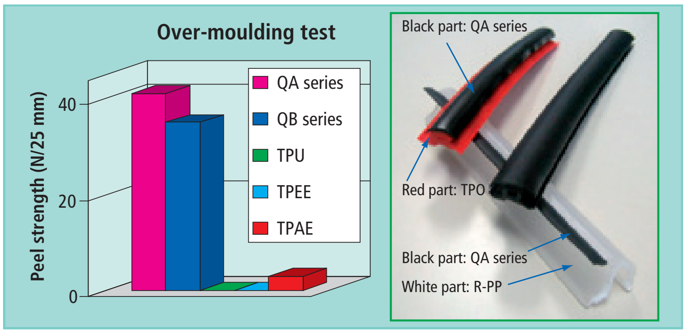


Fig. 9: Adhesion of Septon Q series alloys and engineering thermoplastic elastomers. (Adherend: random-PP resin plate; moulding method: heat press, machine, 220 °C, 1MPa, adhesion measurement method: ISO 36)

frames, grips, etc.) In these applications the new materials can contribute significantly to a performance increase in processing compared to conventional TPU, TPEE and TPAE.

12. Conclusion

In this paper the new material Septon Q series has been presented with alloys. It was shown that the mechanical properties of the materials combined with their hydrolysis stability, their lightness and good adhesion to polyolefines make them ideally suited for high class applications. In addition some outline for application of this new material shall be given. The resistivity against mechanical impact and chemicals combined with overmouldability may dedicate these alloys to wheel and roll applications. The elastic behaviour at lower temperatures combined with weather resistance and light weight points towards water- and wintersports goods and skiboots. In general all sports goods applications can benefit from this material. But also more demanding requirements in surface skins for automotive or flooring applications are possible and already tested.

On the other hand the new materials can improve properties within existing fields of applications, e. g. wire and cable, which need mechanically stable surfaces. In industrial applications tubes, hoses, belts, sheets and films can be mentioned.

To sum up we can state that in comparison to TPU, TPEE, TPAE we achieved advantageous properties like lightness, soft touch, easy processing combined with high performance. In detail we showed the strength and flexibility at high elasticity, excellent abrasion resistance and excellent durability.

Looking at overmoulding applications we were able show that Septon Q series materials have good adhesion to PO based substrates with material performance like TPU, TPEE, TPAE which offers new opportunities.

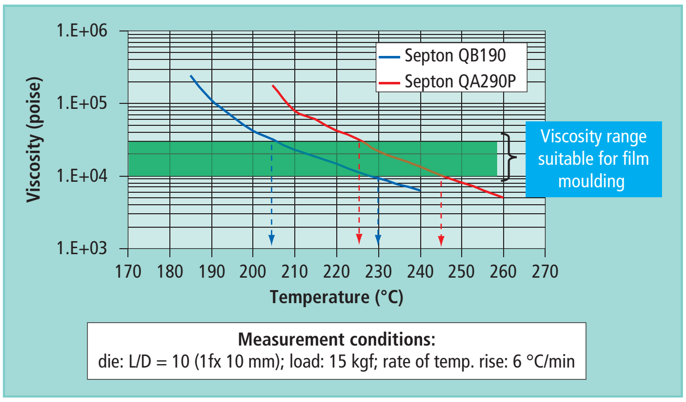


Fig. 10: Flowability measured with capillary flowmeter

13. References

[1] Septon brochure

[2] "The Chemical Daily", 16 October 2008, http://www.thechemicaldaily.co.jp

[3] Standard literature

[4] e. g. EP1776892 (3w, 6w,10w, 70 °C, 95 % RH), US Patent 7144535 (5w, 7w, 10w, 75 °C, 90 % RH), WO/2004/092240

[5] "DIN abrasion test" is in accordance with ASTM D5963/ISO 4649 (formerly DIN 53516) standards