

*Two-piece moulded
children's shoes by Crocs*

Polyurethane today and tomorrow

Before looking at how a material is used in an industry, it is essential to establish the background in terms of production and demand. To do this, we first need to split the global market into recognisable regions. Because of on-going geopolitical changes over the last few years, the traditional divisions may no longer be valid and a new system of 14 regions has been adopted.

Using these regional definitions it is possible to compare the levels of population, footwear production and footwear consumption for the years 1995, 2000 and 2005 (*Tables 1 and 2*).

Global population grew 13.6% between 1995 and 2005, whilst footwear production and consumption rose almost 47% during the same period, from 13.3 to 19.5 billion pairs. Living standards are also rising rapidly in many developing countries. All of which fuels the demand for more footwear and in turn soles and other component parts that can be made from polyurethane.

APPLICATIONS

There are many applications for PU in footwear manufacture encompassing the entire range of available materials, from rigid foams through flexible foams to adhesives and elastomers. The key applications are outlined below, together with the reason each is used and what the competitive materials are.

Adhesives – PU-based adhesives have been used for many years to bond uppers to soles, with polychloroprene the main competitor. Most are based on either dissolving or forming thermoplastic polyurethane in a range of solvents. The latest developments are water-based adhesives using PUDs (polyurethane dispersions), which are gaining in popularity on environmental grounds.

PU adhesives can be used on all soling materials provided that the appropriate surface treatment process is used. With the exception of all-moulded footwear such as PVC 'jellies' or ski boot shells and some direct moulding operations, the production of all footwear involves the bonding of a sole to an upper. Therefore as global demand for footwear increases, so will the demand for PU adhesives.

Coated uppers – heavier leathers are mostly split to provide a lighter grain leather and leave a 'split' which has no natural surface layer. Although leather is still widely used, synthetic upper materials—either plain or coated textiles—now dominate the overall footwear market. In order to provide a surface layer for both splits and textiles that can be coloured and embossed, a range of coating materials has been developed.

Soft plasticised PVCs have traditionally dominated because ➤

Table 1: Countries within selected regions

Region	Abbrev.	Countries
North America, Central America, Caribbean	NACAC	Canada, Mexico, USA, Central America, Caribbean
Latin America	LA	Argentina, Brazil, Chile, Colombia, Venezuela, other
North East Asia	NEA	China, S Korea, Taiwan, other
Indian Sub-Continent	ISC	Bangladesh, India, Pakistan, other
ASEAN	ASEAN	Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam, other
Other Asia	OA	Australia, New Zealand, Japan, Oceania
North Asia	NA	Russia, CIS/'Stan' Countries, other
Nordic	NORDIC	Denmark, Finland, Norway, Sweden, Nordic other
Central Europe	CE	Austria, Germany, Switzerland
Western Europe	WE	Belgium/Luxembourg, France, Ireland, Netherlands, Portugal, Spain, UK
Southern Europe	SE	Bulgaria, Greece, Italy, Slovenia, other
Eastern Europe	EE	Belarus, Czech Republic, Hungary, Poland, Romania, Slovakia, Ukraine, other
Middle East	ME	Egypt, Iran, Saudi Arabia, Syria, Turkey, other
Africa	A	Ethiopia, Maghreb, Nigeria, South Africa, other

Table 2: Population, production and consumption

Region	Population (millions)			Production (million pairs)			Consumption (million pairs)		
	1995	2000	2005	1995	2000	2005	1995	2000	2005
NACAC	455	478	515	466	440	366	2,066	2,297	2,732
LA	319	345	373	735	815	981	820	871	979
NEA	1,317	1,366	1,408	4,633	6,710	9,342	1,703	2,865	4,247
ISC	1,240	1,352	1,487	3,290	4,055	4,648	3,176	4,147	4,733
ASEAN	485	528	556	1,396	1,437	1,654	667	883	1,029
OA	153	158	161	224	153	106	636	647	712
NA	218	218	218	90	65	84	394	235	328
Nordic	32	32	32	14	17	8	106	109	113
CE	97	97	98	62	47	37	409	400	421
WE	195	199	206	550	452	274	887	890	1,129
SE	104	104	104	597	510	387	387	435	435
EE	154	151	147	204	210	214	436	502	551
ME	274	307	342	442	548	590	564	711	790
A	658	732	832	646	702	805	1,096	1,175	1,299
Total	5,701	6,065	6,477	13,349	16,161	19,496	13,347	16,167	19,498

of cost and ease of use. This is declining significantly, however, due to environmental pressures on PVC. PU coatings can be applied either from solution or as films to form a thin solid surface. Laminated PU films, on the other hand, can be either solid or microporous, with the latter having the advantage of being a breathable product that is closer to leather. The use of PU coated materials is expected to continue to grow as a result of both the increasing demand for global footwear and environmental pressures on PVC.

Counters – toe puffs and heel counters are largely made by coating fabrics with an adhesive that can be heat and pressure bonded to the upper, and subsequently moulded to shape. High molecular weight caprolactone polyols are not pure polyurethanes as no isocyanate is present, however, they are tough polymers with a low melting point and excellent adhesive properties. Now being used in this reinforcement application, they still form part of the polyurethane family.

Foam Linings – shoe linings normally consist of a single textile or leather layer. For extra comfort, an inter-layer of flexible foam can be added between the upper and lining. In sports shoes, the extensive use of flexible foam is often used to provide special protection and support padding, with most walking boots and

many casual shoes now also incorporating foam padding in the ankle area. The use of PU in this way is increasing rapidly.

Sockliners – these can vary from a simple foam sock covering the insole to a complete pre-shaped orthotic footbed. They are made from a wide range of materials including blown PVC, foamed vulcanised rubber, closed cell PE, EVA and polyurethane, and are increasingly found in all but the cheapest footwear.

The use of PU is again increasing, driven by the better physical properties obtained, and as the systems are normally based on polyether polyols, very good hydrolytic and microbial resistance can be built in without the use of expensive additives. Complex designs can consist of a blown TPU shell with microcellular PU filler, plus incorporation of a soft elastomeric PU gel shock-resistant component. It is estimated that about five billion pairs of foam sockliners were produced in 2005, and this is set to grow in line with the overall increase in demand for footwear.

Sole Inserts – multi-component sole units are now very popular. One effective way to produce these is by adding coloured inserts into the mould prior to moulding the main soling material, which then bonds the insert into the unit. This method has been used for many years in order to add logos to the waist of vulcanised rubber sole units. While the concept has been greatly extended and materials such as TPR, PVC and vulcanised rubber are used for inserts, TPU is gaining ground thanks to its toughness, ease of use and compatibility with a wide range of soling materials.

Another application is the visible air-bag in sports shoes, where a pressurised multi-celled thermoplastic PU bag is moulded into a PU midsole that is then bonded between a rubber sole and the upper. So what began mainly as a decorative function has now acquired a technical one. This is another strong growth area that appears to be limited only by imagination and the ability to develop novel concepts.

Soling – PU soling is normally associated with microcellular compounds that have now been available for over 30 years. ➤





Multi-coloured PU sole.
Courtesy Klöckner Desma GmbH

Their main application is for producing single or dual density soles, either as unit soles or by direct moulding. The compounds used can be based on either polyether or polyester polyols, with the latter being dominant. They are also used to produce midsoles, which can be made as a separate unit for subsequent bonding to sole and upper, or direct moulding on to a vulcanised rubber or TPU outsole.

TPU also has a long history as a specialist soling material. It has been widely used for the production of ski boot shells and skating boots. It also has a major share of the market for the thin

soles known as 'plates' found on soccer, rugby and hockey boots and golf shoes, due to its ability to hold studs or cleats in place and provide good lateral stability to the foot. It is increasingly being used as a mainstream material following the

development of softer grades and the ability to blow them to densities close to traditional microcellular materials.

Rigid PU foams have also been used when fashion demands thick platform soles and high wedge heels, usually in conjunction with a separate sole in a more flexible material. PU therefore has a wide range of applications as a soling material and further development of TPU could seriously impact sales of PVC and TPR.

Upper components – manufacturers are constantly building new features into sports shoe uppers in order to enhance performance. This is another area where TPU has established a strong niche market due to its physical properties. Typical applications are lacing strips, motion control devices, anti-pronation fittings, external heel stiffeners and logos.

Upper materials – a relatively new application, this involves bonding a lightweight woven fabric containing 3-5% of elastomeric fibres to thin upper materials in order to improve the stretch and fit of the shoe. The initial focus was on women's dress shoes but the technology has now been extended to a whole range of other styles.

Waterproof barriers - there is an increasing demand for totally waterproof footwear that is also breathable. Several inter-lining materials have been developed to provide this function, with most incorporating a thin polyurethane film. Gore-Tex, for example, uses an expanded PTFE coated with a film of PU, while Sympatex is a fully microporous PU film. Although these materials are mainly used in garments, they are increasingly finding a use in footwear designed for outdoor and sporting activities.

Table 3: Consumption (Ktonnes)

Applications	1995	2000	2005
Adhesives	65	79	80
Coated uppers	155	170	190
Counters	0	1	1
Foam linings	12	14	16
Sockliners	20	23	28
Sole inserts	11	13	16
Soling (microcellular)	257	440	546
Soling (TPU)	45	55	65
Upper components	4	5	6
Upper materials	0	4	10
Waterproof barriers	11	14	17
Total	580	809	975

Table 4: Population, production and consumption

Region	Population (millions)			Production (million pairs)			Consumption (million pairs)		
	2005	2010	2015	2005	2010	2015	2005	2010	2015
NACAC	515	541	570	366	401	422	2,732	2,987	3,278
LA	373	401	430	981	1,041	1,105	979	1,050	1,128
NEA	1,408	1,450	1,488	9,342	10,474	12,103	4,247	4,872	5,746
ISC	1,487	1,625	1,776	4,648	5,121	5,651	4,733	5,187	5,709
ASEAN	556	601	650	1,654	1,882	2,142	1,029	1,160	1,462
OA	161	163	165	106	89	76	712	758	815
NA	218	219	222	84	112	153	328	397	483
Nordic	32	32	32	8	6	6	113	119	125
CE	98	98	98	37	35	28	421	434	447
WE	206	209	212	274	218	190	1,129	1,173	1,276
SE	104	104	104	389	230	205	435	387	419
EE	147	144	142	214	244	279	551	580	624
ME	342	374	411	590	680	789	790	913	1,057
A	832	926	1,031	805	958	1,145	1,299	1,469	1,713
Total	6,477	6,887	7,330	19,498	21,491	24,294	19,498	21,486	24,282

Table 5: Consumption (Ktonnes)

Application	2005	2010	2015
Adhesives	80	90	95
Coated uppers	190	240	320
Counters	1	2	3
Foam linings	16	20	26
Sockliners	28	36	46
Sole inserts	16	22	30
Soling (microcellular)	546	650	820
Soling (TPU)	65	95	140
Upper components	6	8	10
Upper materials	10	15	25
Waterproof barriers	17	22	28
Total	975	1,200	1,543

MARKET FOR PU IN 2005

Table 3 shows data for these eleven applications of PU in footwear, clearly indicating a dramatic increase in its use over the past ten years.

The greatest use is in four of the key areas discussed, with combined soling way out in front at 63%. If we add adhesives and coated uppers, it rises to 90% of the total.

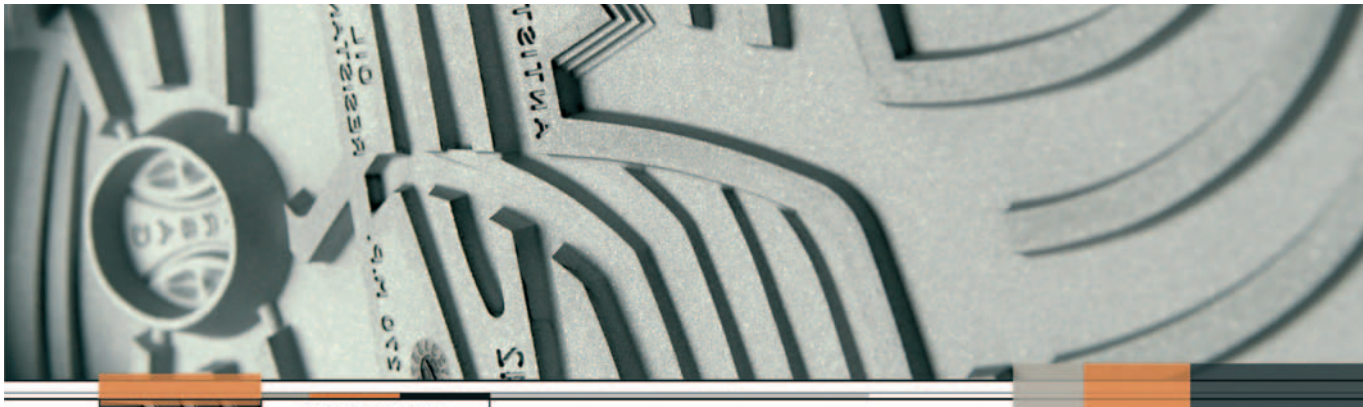
THE FUTURE

These figures clearly show that the past ten years have seen significant growth in the demand for PU-based materials, but what might happen in the next ten years? Table 4 once more compares levels of population, production and consumption, but this time looks forward to 2015. Again there is a continuing growth in population, with a predicted increase of 13.2%.

This table also shows that the dramatic increase in footwear production and consumption is predicted to continue, reaching 21.5 billion pairs in 2010 and around 24.5 billion in 2015. Over the next 20 years both will have almost doubled, with forecasts supporting this view of further dramatic growth in demand (Table 5).

The same major areas of use as before again represent around 90% of total demand. The key point to note, however, is how the increase in demand for PU is expected to have almost trebled over 20 years. This is a much higher rate of growth than seen in the overall footwear production and consumption market during the same period, which is expected to have increased by around 80%. The penetration of polyurethane into the footwear market is therefore showing higher levels of growth than might have been anticipated, with the only possible limiting factors expected to be the availability and price of basic raw materials.

This article is based on two papers presented by Steve Lee of Steve Lee Associates at the 2006 API Technical Conference.



TPU - PU

U-POWER SAFETY SHOE



Lo stampista ha lavorato bene!
The mould-maker did a good job!

9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

ZAGO'S FOOTWEAR DIRECT INJECTION MOULDS RANGE:

PU	RUBBER - PU
PU - PU	RUBBER - PU2
TPU - PU	RUBBER - PUR
PU - PU / TPU	RUBBER - RUBBER
TPU - TPU / PU	RUBBER - RUBBER / PU

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