EXECUTIVE SUMMARY

INTRODUCTION

1 Both ABS (Acrylonitrile-Butadiene-Styrene) and SAN (Styrene-Acrylonitrile) are versatile engineering thermoplastics, which have replaced many traditional materials of construction like wood, glass, metal, rubber etc. in many applications. These polymers can be easily tailored for specific uses through co-polymerising, blending, alloying and changing polymer structure.

Of late, with the advent of various speciality and advanced thermoplastics such as POM, PA, PBT, PET, PPO, etc. the importance of ABS, SAN, as an indispensible engineering thermoplastic, has been slightly reduced. Today, they are used in low performance applications. Their bulk consumption in conventional applications has also reduced due to interpolymer competition from cheaper commodity plastics.

Though known to exist since 1930s, these polymers were first introduced for industrial applications in 1950s in U.S.A. Now, these polymers are consumed in significant quantities (especially ABS).

2 PROPERTIES

As ABS and SAN are composed of various building blocks (e.g. Butadiene, Acrylonitrile and Styrene in ABS and Styrene and Acrylonitrile in SAN), various combination of properties can be available by varying composition of these monomers. The properties offered by various monomers have been described here below :

Monomer	*Properties*
Butadiene	1. Impact resistance 2. Toughness 3. Low temperature property retention
Acrylonitrile	1. Chemical resistance 2. Heat stability 3. Aging resistance
Styrene	1. Rigidity 2. High gloss 3. Ease in processing

The comparative properties of ABS and SAN v/s. major themoplastics have been given in the following table.

COMPARATIVE PROPERTIES OF ABS, SAN V/S. OTHER MAJOR PLASTICS

	Specific Gravity	Vicat Softening Point °C	Tensile Strength p.s.i	Izod impact ft.lb/ inch	Compressive Strength p.s.i
ABS	1.01-1.05	100-110	310-490	10-50	490-700
SAN	1.07-1.08	70-90	700-840	12-18	-
PS	1.04	74-105	360-520	2-12	910-1100
HDPE	0.96	130-137	220-310	2	190-250
PP	0.90	160-168	310-420	2-6	240-560

3 APPLICATIONS

ABS may be processed into end products by most thermoplastic processing methods such as injection and compression moulding, extrusion, blow moulding and calendering. Other operations such as vacuum forming, vapour metallizing, plating, hot stamping and painting may also be carried out.

Different grades of ABS are available inter-nationally. Gradewise applications of ABS have been depicted in the following table.

ABS : GRADEWISE APPLICATIONS

Sr. No.	Grade	Applications
1.	High Impact Grades	Travelling bags, Helmets, Furniture, Sports Goods, Automotive Components
2.	Medium Impact Grades	Radiator and Air Conditioner grills, Heavy duty domestic appliances, Control panels
3.	Electroplating Grades	TV and Radio knobs, Bathroom fittings, Refrigerator handles, Name plates, Wheel caps, Clock rings, Canopies, Flash guns, Torch lights etc.
4.	High Flow Grades	Housing for domestic appliances and office equipments, Cabinets of TVs, Radios, Wall clocks, Tape recorders and Car stereos.
5.	High Heat Resistant Grades	Automobile components, Housing for electrictrical heaters & Dryers.
6.	Transparent Grades	Used in areas where high transparency & good impact strength is required.
7.	Impact Modifier Grades	Modifier to PVC compounding industry, covering all types of formulations-rigid, semi-flexible, clear and opaque.
8.	Glass Filled Grades	Used in applications requiring a very high flexural strength, stiffness, maintaining the impact and tensile properties.
9.	Extrusion Grades	Refrigerator linings and luggages

Note: Several ABS alloys such as ABS/PC and ABS/PVC are also being used in many areas.

Applications of SAN are listed below :

Sr. No.	Applications	Articles
a)	Houseware	brush blocks and handles, broom and brush bristles, cocktail glasses, disposable dining utensils, hangers, ice buckets, jars,mugs, soap containers and tumblers.
b)	Appliances	air conditioner parts, decorated escutcheons, washer and dryer instrument panels, washing machine filter bowls, refrige-rator shelves and crisper pans, blend-ers, mixers,lenses, knobs and covers.
c)	Packaging Industrial	bottles, closures, containers, display boxes and films
d)	Automotive batteries,	business machines, apparatus and equipment, and tape reels.
e)	General (custom molding)	batteries, bezels, lenses, signals, and interior trim, aerosol nozzles, bottle sprayers, camera parts, den-tures, pen and pencil barrels, sporting goods, toys telephone parts, filter blows, tape dispensers, termi-nal boxes, etc.

Note : SAN resins are also used for making ABS resins. Grafted butadiene latex is blended in a matrix of SAN resins to produce final ABS products.

4 ABS MANUFACTURING PROCESSES

ABS is manufactured by three different polymerization processes viz., emulsion, suspension and mass process. Historically, emulsion and suspension processes have dominated the field, but recently continuous and mass process has achieved commercial importance due to its simplicity and improved rubber handling in the system.

Since bulk process does not involve process water, it consumes less energy per kg of product as dewatering and drying steps are eliminated. However, the process has greater mechanical complexity and low conversion ratio requiring devolatization step for removal of residual monomers prior to compounding of the final product.

ABS resins are manufactured using styrene acrylonitrile copolymer dispersed in rubber latex which can be either polybutadiene (PB), styrene butadiene rubber (SBR) or nitrile butadiene rubber (NBR). Other rubber systems such as ethylene propylene diene rubbers (EPDM) are also known to be used for special polymers such as AES, but are relatively uncommon. Most commercial processes use a polybutadiene rubber latex for production of ABS. Besides, several other chemicals such as emulsifiers, suspending agents, initiators, chain transfer agents, additives and stabilizers are involved depending on the process used and grade of ABS.

Originally the elastomers were mechanically blended with rigid SAN copolymers, but now grafting technique is widely used to produce ABS resins. This is done to overcome the incompatibility between the rubber particles and rigid copolymer matrix which caused the dispersion to be non-uniform and resulting in undesirable physical properties. The degree of grafting depends on the concentration of monomer, mercaptan (MW regulator), surfactant, monomer/ rubber ratio and polymerisation temperatures.

5 SAN MANUFACTURING PROCESSES

SAN copolymers are commercially produced as in the ABS process by emulsion, suspension and bulk processes. Amongst the various processes, emulsion process is quite popular but has the disadvantage of greater haze due to presence of emulsifying agents. Of late, continuous bulk polymerization has become popular and is normally used for making moulding grade SAN resin. Specifie features of various processes are described in the following table.

Sr. No.	Process	Specific Features
1.	Emulsion Process	* Uses emulsifying agents like dodecyl benzene sulfonate, polyorganosiliozanes and polyethylene oxide grafted with maleic anhydride and vinyl acetate. * This process involves considerable water pollution hazards as monomers (especially ACN) are partially soluble in water.

Sr. No.	Process	Specific Features
		* The monomer conversion in emulsion process are very high (97%) as compared to 66.5% in continuous bulk process.
2.	Continuous bulk process	* Does not involve any emulsifiers, suspending agents or water and hence no waste treatment and environmental problems
		* Consumes less energy
		* Efficient space and time utilization
		* Product has good transparency, lustre, melt flow properties

6 AES MANUFACTURING PROCESS

AES is manufactured by three polymerisation processes viz., emulsion, suspension and mass process. Amongst these processes mass polymerisation process is quite popular because its simplicity and flexibility in handling the rubber.

7 STATUS OF INDIAN INDUSTRY

ABS resins were first introduced in the country in 1978 by M/s. Synthetics and Chemicals Ltd., Bareilly, U.P. Unlike other commodity and engineering thermoplastics, the credit for introduction of this versatile family of plastics goes to scientists of Shriram Institute for Industrial Research and National Research Development Corporation. A bench scale emulsion graft ABS polymerization process was developed by them and later implemented by three Indian companies. SAN copolymers were first manufactured in the country by GSFC in early 1980s.

8 In the formative years of ABS and SAN industry, import of technology was not permitted. Hence only two plants came up for ABS manufacture using indigenous know-how. Presently technology import for both ABS and SAN is permitted. Details of units having ABS and SAN production capacities is as given in the following table. It may be noted that capacities for SAN production are insignificant.

Sr. No.	Company	Product	Year of Start-up	Location	Process Know-how	Capacity Mt/Yr.	Capacity Expansion Planned & Scheduled
1.	Synthetics and Chemicals Ltd.	ABS	1978	Bareilly	SRIIR/ NRDC	Pilot Scale	
2.	ABS Plastics Ltd.	ABS	1978	Baroda	SRIIR/ NRDC and Japan	10,000	20,000 TPA ABS-1992
		SAN			Synthetic Rubber		5000 TPA
3.	Polychem Ltd.	ABS	1979	Baroda	SRIIR/ NRDC Penmana, U.K.	5000	20000 TPA
		SAN	1990	-	-	3000	-
4.	Gujarat Binil Chemicals Ltd.	ABS/ SAN/HIPS	1986	Ankalesh-war	Inhouse	2200	5000 TPA
5.	Bhansali Engineering Polymers Ltd.	ABS	1990	M.P.	Sumitomo	7500	
6.	GSFC	SAN	1982	Baroda	Inhouse	300	Plant is shut down
7.	Poly Raj.	SAN	-	Vapi	-	-	-

9 Although present installed capacity is quite large, the total, estimated availability of ABS resins (including imports which are minor) is only 12,000 - 13,000 MT in 1990-91. In the year 1989-90 the total consumption of ABS in India was about 9,000 MT.

10 In order to meet the long term requirements of ABS and SAN in the country, Government has issued several Letters of Intent to Indian companies. These include projects of Indo Nippon, ABS Plastics, Hindustan Polymers, Supreme Industries, RIICO etc. Out of these only Indo Nippon and ABS Plastics projects are scheduled to be implemented within the 8th plan period. These include 5000 tpa of ABS and 5000 tpa of SAN for Indo Nippon and 5000 tpa of SAN for ABS Plastics. Polychem has commissioned a plant to manufacture 3000 TPA of SAN in March 1990.

11 CONSUMPTION PATTERN AND PROJECTED DEMAND FOR ABS RESINS

Electrical appliances and electronics sector is the largest consumer of ABS in the country. Their share in total ABS market is estimated at 40-50% and includes applications such as office automation products, home appliances, telecommunication products etc. Balance is split among applications in automotive, refrigerators and air conditioners, luggage, textile components & other miscellaneous sectors. The present (90-91) demand for ABS is around 14000 MT and by 1994-95 it is estimated to reach 28000 MT. Details of consumption in various end-use sectors are as given below:

ESTIMATED DEMAND FOR ABS BY 1994-95

(Quantity in Tonnes)

Sr. No.	End-use	Estimated Demand 1994-95
1.	Automobiles	2600
2.	Telecommunications	3500
3.	Consumer Electronics	8500
4.	Refrigerators/water coolers and deep freezers	3100
5.	Helmets	275
6.	Luggage	2000
7.	Office equipments	800
8.	Home Appliances (Excluding mixers)	1700
9.	Mixers/Juicers	2400
10.	Thermowares	1000
11.	Video Cassettes	1200
12.	Vacuum Cleaners	300
13.	Aircoolers/air conditioners	600
	Total	27975

Source: Consultants' Field Survey

12. DEMAND SUPPLY SCENARIO

Based on various projections made by different agencies regarding demand for ABS by 2000 A.D. and the estimated supply taking into consideration various expansion plans and new projects, the demand-supply is likely to be as given below :

ABS : DEMAND SUPPLY GAP

(Quantity in tonne)

	1990-91	1994-95	1999-2000
Estimated Supply	13300	31350	43300
Estimated Demand			
- C.P.P	-	24000	35000
- C.E.W	-	27000	49000
- Consultants	14000	29000	46000
Demand Supply Gap			
- C.P.P demand	-	(7350)	(8300)
- C.E.W demand	-	(4350)	5700
- Consultants	700	(2350)	(2700)

C.P.P.- Committee for Perspective Planning on Petrochemicals

C.E.W.- Chemical Engineering World, Issue

* *Based on 10% CARG over 1994-95 demand estimates by Consultants*

No separate demand projections for SAN copolymers are available as the industry is still in infant stage. Not much production of commercial significance is there and demand is likely to build up only when raw materials are available indigenously. It is estimated that a demand of around 4000-5000 MT would be there by 1994-95, for merchant sale. This can be adequately met by Polychem, ABS Plastics and Indo Nippon SAN project.

ABS Plastics Ltd., Baroda : ABS Plastics is a leading producer of ABS in the country. It has recently expanded its capacity from 5000 tons to 10,000 tons based on imported know-how from Japan Synthetic Rubber (JSR), Japan. Earlier its 2000 tpa capacity plant was based on modified NRDC process of emulsion graft polymerization of ABS. Even the new JSR process is batch emulsion process but is highly efficient due to low consumption of raw materials and utilities and has versatile ABS product range. ABS grade available from ABS Plastics include high impact, high melt flow and high heat resistant grades. ABS Plastics is also expanding its ABS capacity to 20,000 tons and another project is under implementation to set up 5000 tpa SAN capacity using continuous bulk polymerization technology of JSR, Japan.

Polychem Ltd., Baroda: Several problems were encountered by Polychem in scaling up bench scale process of NRDC to a 2000 tpa commercial size plants. Operations were not very profitable and capacity utilization was low in the initial years (as was the case with ABS Plastics). With the import of technology for its expanded 5000 tpa ABS plant, various operational parameters have been considerably improved and product range has also been expanded to meet the requirements of Indian markets. Raw material consumption per ton of ABS product has been reduced by 7-8% and energy requirements have been more than halved. Polychem also employs a batch emulsion graft polymerization process. Polychem has also set up a plant to manufacture 3000 TPA of SAN. This plant was commissioned in March 1990.

Bhansali Engineering Polymers Ltd., M.P. : This project is based on the Sumitomo process which again utilizes emulsion process but has an impressive range of ABS products. The plant has only recently been commissioned and actual performance of this plant will become evident in coming years. However, technology employed is claimed to be highly efficient (96% polymer yields are claimed).

Gujarat Binil Chemicals Ltd., Ankleshwar : In the initial years, this company had teething troubles establishing quality of its end-products viz. ABS, SAN and HIPS. But operations are now stable in its continuous bulk process plant. Gujarat Binil is the only producer using this process in India. Their current focus in the combined ABS/SAN/HIPS plant is on ABS and SAN products. This process involves 3-4 reactors and 70% conversion per pass is achieved.

Gujarat State Fertilizer Co. Ltd., Baroda : GSFC's SAN plant was set up based on in-house R&D effort. It is a small plant using suspension batch process set up mainly for scale up study and to produce material for market study. Operations have been discontinued since last 3-4 years as the plant operations were uneconomical. Basically GSFC were unable to scale up the bench scale process and faced severe operational and quality problems in the actual plant.

Recently Polyraj has set up a plant near Vapi to manufacture SAN.

14 INTERNATIONAL SCENARIO

ABS is the sixth largest consumed thermoplastic material in the world. 1990 consumption of ABS resins was estimated to be between 2-2.5 million tons. SAN copolymers are relatively consumed in small amounts and 1990 consumption worldwide is estimated to be 0.2 million tons. Major producers in this industry sector are Dow Chemicals, Monsanto, GE Plastics, JSR, BASF, Mitsubishi etc. The consumption of ABS and SAN of late, has stagnated and not many plants are coming up as is observed in other commodity and high performance engineering plastics.

Consumption of ABS resins in advanced countries such as USA, Japan, Canada and those of Western Europe is as shown below :

SALES OF ABS V/S OTHER POLYMERS - 1990

('000 tonne)

	ABS	LDPE	HDPE	PP	PVC	PS
USA	551	4941	3870	3700	4230	2337
W. Europe	501	5245	2937	3685	5158	1792
Japan	607	1672	1113	2080	2003	1183
Canada	63	1254	394	263	457	184

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15 Study of consumption pattern in the West European countries indicates that ABS is most widely used in automotive component sector. The share of various sectors is as follows :

Automotive	26%
Appliances	18%
Electrical and Electronic Sector	18%
Recreational items	7%
Furniture	2%
Pipes and Fittings	2%
Others	27%

SAN finds applications in appliances, automotive components, batteries, compounding, housewares, molded packaging good etc. One major application for SAN is for blending it with grafted ABS resins.

16 The large producers of ABS and SAN resins normally use continuous mass polymerisation process. In case of ABS variations of mass process are also used. These include mass-suspension and mass-emulsion process. Solution process is used only for special grades and is getting outdated. For small size ABS plant, emulsion batch process is ideally suited and is adopted by leading Japanese producers like JSR, Sumitomo etc. For SAN batch suspension and continuous bulk processes are normally used.

17 Amongst various ABS processes, emulsion and continuous bulk polymerization are quite popular. Emulsion process offers wide variety of products, high rubber content grades and superior conversion efficiency. Continuous bulk is popular because of its low cost of production and low investment costs. Normally this process is favoured for large size plants. Since water is not used, pollution hazards in this process are minimal. However, this process takes longer time in achieving steady state and considerable off-grade material is produced during grade change over, or plant shut downs. Relatively, the other ABS processes viz. solution and suspension processes are less popular.

18 In SAN processes, again emulsion and bulk processes predominate. Emulsion and suspension SAN processes have very high conversion rate of 99.5% as compared to 60-70% in bulk process. However, due to presence

of emulsifiers and suspending agents, the final product is of poor optical clarity. Continuous bulk processes offer water-clear SAN products at an economical price. A brief comparison of SAN processes is shown below:

COMPARISON OF TYPICAL SAN PROCESSES

	Emulsion Process (Batch)	Suspension Process	Continuous Mass Process
Reaction Temp °C	68	95-120	160
Reaction Time Hr.	4-5	7.5	-
Overall Conversion %	97	99	66
Styrene wt %	70	75	75
ACN wt%	30	25	25
Water wt %	120	130	-
Steam Kg/Kg	3	0.1	N.A.
Cooling Water Lit/Kg.	48	48	20
Power KWH/Kg.	0.19	0.16	0.10

19 STATUS OF R&D AND TECHNOLOGY ABSORPTION IN INDIA

Through indigenous R & D efforts two processes for manufacture of ABS and SAN have evolved. These are NRDC/SRHR process for ABS resins and IIP process for SAN copolymers. While the former has been actually implemented, the latter has not been commercially exploited. NRDC process was licensed to three Indian companies and later Polychem and ABS Plastics have implemented this process after conducting pilot study in their plants to make it suitable for commercialisation, while GSFC did not pursue the same. Both these processes were essentially bench scale and scaling up to commercial size plant required considerable technical inputs.

20 The NRDC process was actually developed by Shriram Institute for Industrial Research at Delhi in late 1960s. The process was developed for general purpose moulding grade, extrusion grade, electroplating grade and grade for impact modifier for PVC. This process is based on batch emulsion polymerization process in which ABS is produced by grafting acrylonitrile and styrene onto PB or SBR latex. Conversions are usually around 90% and reaction batch cycle between 15-18 hrs.

21 IIP process for SAN copolymers is based on suspension batch process. Since this process has not been commercially adopted, its performance cannot be ascertained. This process also is a bench scale process and is tried only in a small 30 litre capacity glass lined reactor. Batches of 10 kgs. have been obtained and samples were distributed for market assessment. But still, this process was not adopted and continues to remain largely untried.

22 **TECHNOLOGY ABSORPTION EFFORTS IN INDIA**

Several efforts have been put in by Indian manufacturers in absorbing indigenous as well as imported knowhow :

- Two of the Indian ABS manufacturers (Polychem and ABS Plastics) have been involved in scaling up a bench scale process into commercial size plant. This involved tremendous efforts on their part both for process development and design of equipments.
- Capacity expansion by existing producers based on imported knowhow has been smooth because of producers' past expertise built up in ABS industry. By import of know-how they have been able to get State-of-the-Art technology.
- These two producers have been able to considerably reduce cost of expansion of their ABS plants. Foreign exchange outgo also was minimal as they were able to indigenously procure most of the capital goods.
- Through indigenous R & D efforts, producers have been able to successfully absorb imported know-how for manufacturing new grades of ABS. These include heat resistant, high flow, high impact and electroplating grades. Using special additive packages, grades having UV resistance and antistatic properties are also produced.

  Indigenous vendor development activity has been prominent with some manufacturers. Number of equipments are obtained from within the country.

23 TECHNOLOGY GAPS

Although the ABS industry is now more than a decade old, significant technology gaps still exist. These are :

- The process used domestically are comparable with the processes available abroad, but the indigenous process has poor yield and the product has low surface gloss and poor impact strength.

- Only emulsion batch polymerization process has been adopted in India. One plant using continuous bulk process is there, but it is of very low capacity.

- Technology import dependence is likely to continue as development efforts in this area are lacking after having been initially started by SRIIR.

- Scale of operations are very small as compared to plant sizes abroad.

- New polymer materials such as ABS polymers using different rubber latexes such as SBR, NBR and EPDM rubbers are not made in India. Overall grade availability is largely restricted to commodity grades. New grades for speciality applications are being introduced.

- ABS blends and alloy industry is not developed. ABS manufacturers themselves have not put in required efforts for this development, though there exists a good potential for this.

- Manufacturers of ABS should try to tap overseas market.

- Import dependence on capital goods and automation systems remain to some extent.

- Cost of ABS products in India is almost twice the international prices, mainly due to lack of economy of scale of production and high cost of raw materials. Capacity utilisation is also low, as raw materials are not readily available from indigenous sources.

24 In case of SAN, there is not even a single plant of commercial significance. Operations in two small scale plants are discontinued. Initial product trials in these plants were not well received in the market due to poor optical clarity. Again in this industry too, only suspension batch process

has been used and no efforts have been made to bring in new technology from abroad. In coming 2-3 years, two plants are likely to be commissioned based on imported continuous bulk process know-how. Situation is likely to change only then.

25. RECOMMENDATIONS

- Speeding up of SAN and ABS projects under implementation and capacity expansion of existing ABS plants in order to meet long term requirement of Indian industry. For SAN, atleast one plant of 5000 TPA should be commissioned by 94-95.
- Utilizing earlier technological base, co-ordinated and concentrated efforts of manufacturers, research institutes and engineering consultants is recommended to continue efforts for development of State-of-the-Art process.
- Technology import from internationally reputed companies may be considered for continuous bulk technology for making general purpose grades of ABS resins, as this will have sufficient demand to go in for world size plants.
- Raw materials availability needs to be improved and speedier implementation of new petrochemical projects is recommended.
- Market exploitation by introducing new alloys and blends of ABS is desirable. Tailor made blends of ABS especially for automotive applications need to be introduced.
- Possibility of introducing high ACN content ANS copolymers and ABS speciality resins needs to be assessed.
- Special consideration should be given for making AES resins, as it would reduce the over dependence on butadiene rubber. Moreover, butadiene import and transport poses difficulties as it is a hazardous chemical.
- Product Application Centers need to be set up for overall developments of engineering plastics in India.
- The availability of raw materials such Butadiene, Acrylonitrile and some speciality additives and chemicals should be ensured for the healthy growth of this industry.