Lo-Tech and Hi-Tech Baby Diaper Machines, Assessment of Performance and Economy

[1]Hasabo A Muhammad Ahmed[1], and R. Rajendran[2]

[1.] Africa City of Technology, Projects Manager, Khartoum, SUDAN

[2.] PSG College of Arts & Science. PG & Research Department of Microbiology, Coimbatore, INDIA. Email: hasabotek@yahoo.com

ABSTRACT

The huge consumption of baby diapers worldwide (81, 993, 30) millions has derived many investors to enter as converters. The market of baby diapers is a very competitive market. Consequently, to capture a market niche one has to decrease the diaper cost effectively. The cost variables are raw material, machine depreciation, manpower, energy, and infrastructure. To reduce the cost of any product one should look into the component that represents the highest percentage of the product cost. In that case the raw material factor should be optimized since it represents 80% of the diaper cost. The performance of machine in terms of quality and waste minimization has also been considered. The waste percentage affects the diaper cost dramatically since as the cost of wasted material is high. In this sense the machines that can save on raw material would be the one that can compete well in the baby diaper market war. The raw material cost reduction is normally on waste and carrier tissue paper which is used by Lo-tech machines in lack of vacuum pressure for holding down the diaper during processing. The engineering features of the baby diaper machines are examined in terms of performance and product quality. In this research a comparative study is conducted to find out the best alternatives to enhance the quality of the baby diaper and increase savings on raw

material cost. It is found that the Hi-Tech machine comparatively is the best in terms of performance, least cost, and quality. Consequently, it is the best investment alternative.

INTRODUCTION

Marion Donovan invented the "Boater", a waterproof covering for cloth diapers. Her first model of the disposable diaper was made of shower curtain plastic into which a conventional cloth diaper was inserted. The first "truly disposable" diapers were made using a very simple rectangular design. The absorbent core was made of several layers of tissue paper (15 to 25), the outside used a plastic film and no tapes were provided with the product. The total capacity of these diapers was estimated to be around 100 ml, so it provided a very limited service (a onetime use). Its disposability, however, added a great value for the parents; it was immediately regarded as one of the great inventions.

From the 60's onwards, the disposable diaper evolved quickly as the industry learned the requirements of the mothers. Tissue was replaced with pulp a decade after the first disposable sanitary napkins arrived in the markets. Using cellulose fibers instead of paper improved the performance of the diaper. With the Pampers, launched in the spring of 1961, the new baby diaper was a "smash hit"(internet, 2010).

WORLD CONSUMPTION OF BABY DIAPER

There are several statistical models that have been used to estimate the number of baby diapers required for the whole world. This model starts with world population projection from the U.S. Census Bureau which estimates world population at 6,431,662652 (2006). Then the total number of babies in the age group of 0-2 years can be calculated using age pyramid tables. Then total diaper consumption for each diaper stage can be calculated and estimate of a representative consumption per baby per day and finally, take into account market penetration, the most difficult part to forecast. The number of babies in the 0-2 age group in the United States is 9,612,520 each baby in the 0-2 age group requires, on an average, 4.42 disposable diapers every day 6.82 are needed for newborns (size 2) while only 3.74 are needed for two year olds (size 5 and 6 with non-linearity). This means that 40.37 million diapers are required every day in the United States alone. There are variations to consumption patterns. For example, in Japan, mothers are more concerned about hygiene and use almost two and a half more diapers per day than mothers in America do, and Americans use at least one more diaper per day than Latino Americans do. If we estimate the total world consumption on this basis, it translates into 1,375 million diapers every day – i.e. if every baby in the world uses a disposable diaper (internet, 2008).

Table 1 World Statistics on baby diaper consumption

Serial Number		2005 Total. Population 1000's	1000's 2005 Babies [0-2]	1000's Babies [0-2] 2025 (***)	2005 Max. Market Pot.	2025 Max. Market Pot.	Market penetration	1000's Current Vol.
1	China	1,313,973	47,238	40,614	76,209,065	60,185,146	6%	4,191,499
2	India	1,095,351	57,681	55,631	93,055,951	82,439,579	2%	1,861,119
3	United States	298,444	9,609	11,759	15,502,200	17,425,662	96%	14,820,103
4	Indonesia	245,452	12,003	10,931	19,363,633	16,198,649	6%	1,161,818
5	Brazil	188,078	8,299	6,858	13,387,970	10,162,129	31%	4,150,271
6	Pakistan	165,803	11,235	10,925	18,124,619	16,189,017	3%	543,739
7	Bangladesh	147,365	7,942	10,246	12,812,022	15,183,547	1%	128,120
8	Russia	142,893	3,156	2,756	5,090,768	4,083,375	21%	1,069,061
9	Nigeria	131,866	9,664	15,865	15,590,931	23,510,344	1%	155,909
10	Japan	127,463	3,018	2,290	4,868,939	3,393,551	97%	4,722,871
11	Mexico	107,449	5,638	5,124	9,095,785	7,592,515	56%	5,093,640
12	Philippines	89,468	5,273	5,499	8,506,931	8,148,968	29%	2,467,010
13	Vietnam	84,402	3,830	3,374	6,178,132	4,999,190	7%	432,469
14	Germany	82,422	1,966	1,701	3,171,748	2,519,971	96%	3,044,878
15	Egypt	78,887	4,402	4,359	7,101,747	6,459,602	31%	2,201,541
16	Ethiopia	74,777	5,656	6,785	9,124,825	10,053,951	1%	91,248
17	Turkey	70,413	3,017	2,566	4,866,519	3,802,555	44%	2,141,269
18	Iran	68,688	3,002	2,737	4,842,320	4,055,219	31%	1,501,119
19	Thailand	66,004	2,644	2,168	4,265,565	3,212,018	42%	1,791,537
20	Congo (Kinshasa)	61,895	4,990	8,389	8,050,367	12,431,659	1%	80,504
21	France	60,876	1,843	1,656	2,972,505	2,454,026	95%	2,823,880
22	United Kingdom	60,609	1,784	1,667	2,878,127	2,469,586	95%	2,734,221
23	Italy	58,133	1,319	1,048	2,127,943	1,552,290	96%	2,042,825
24	Korea, South	48,604	1,641	1,115	2,647,425	1,652,319	85%	2,250,312
25	Ukraine	47,138	1,144	1,007	1,844,809	1,492,273	24%	442,754
26	South Africa	44,187	2,311	1,541	3,727,530	2,282,867	49%	1,826,490
27	Colombia	43,593	2,226	2,230	3,591,206	3,304,637	55%	1,975,163
28	Burma	43,085	2,021	1,490	3,259,673	2,208,031	6%	195,580

29	**Sudan**	**41,236**	**2,983**	**3,430**	**4,811,667**	**5,082,917**	**2%**	**96,233**
30	Spain	40,397	927	746	1,494,722	1,104,756	93%	1,390,092
31	Argentina	39,921	1,687	1,475	2,721,637	2,185,062	42%	1,143,088
32	Poland	38,646	1,009	852	1,627,013	1,261,838	21%	341,673
33	Tanzania	37,445	2,829	3,480	4,564,026	5,157,012	1%	45,640
34	Kenya	34,707	2,307	2,289	3,721,076	3,391,328	4%	148,843
35	Morocco	33,241	1,770	1,727	2,855,541	2,558,500	21%	599,664
36	Canada	33,098	924	979	1,489,883	1,450,780	96%	1,430,287
37	Algeria	32,930	1,510	1,358	2,435,276	2,012,420	20%	487,055
38	Afghanistan	31,056	2,161	3,910	3,485,535	5,793,488	1%	34,855
39	Peru	28,302	1,487	1,298	2,398,977	1,922,765	26%	623,734
40	Nepal	28,287	1,844	2,090	2,974,119	3,097,171	5%	148,706
41	Uganda	28,195	2,339	5,390	3,773,509	7,986,700	5%	188,675
42	Uzbekistan	27,307	1,458	1,734	2,352,191	2,569,615	n.a.	n.a.
43	Saudi Arabia	27,019	1,681	1,989	2,711,151	2,947,499	42%	1,138,683
44	Iraq	26,783	1,766	2,102	2,848,281	3,114,213	6%	170,897
45	Venezuela	25,730	1,255	1,205	2,023,885	1,785,690	55%	1,113,137
46	Malaysia	24,385	1,337	1,573	2,156,982	2,331,029	42%	905,932
47	Korea, North	23,113	828	803	1,335,006	1,189,225	3%	40,050
48	Taiwan	23,036	745	602	1,201,909	892,104	96%	1,153,832
49	Romania	22,303	575	458	927,648	677,969	19%	176,253
50	Yemen	21,466	1,607	3,093	2,591,766	4,582,776	2%	51,835
51	Ghana	20,727	1,568	1,535	2,529,654	2,274,717	4%	101,186
52	Australia	20,090	629	640	1,014,766	948,416	89%	903,141
53	Sri Lanka	20,064	781	689	1,259,987	1,021,029	7%	88,199
54	Mozambique	19,406	1,479	1,488	2,386,071	2,205,067	1%	23,861
55	Syiria	18,448	1,247	1,192	2,011,785	1,766,425	4%	80,471
56	Madagazcar	18,040	1,598	2,572	2,578,053	3,811,447	1.50%	38,671
57	Cote D' Ivoire	17,298	1,324	1,505	2,136,009	2,230,260	3%	64,080
58	Cameroon	16,988	1,303	1,472	2,102,130	2,181,357	4%	84,085
59	Netherlands	16,407	481	454	775,997	672,783	92%	713,918
60	Chile	15,980	628	581	1,013,152	860,984	65%	658,549

61	Kazakhstan	15,185	550	512	887,315	758,733	32%	283,941
62	Cambodia	13,636	814	1,024	1,313,226	1,517,466	2%	26,265
63	Burkina Faso	13,491	1,258	1,990	2,029,531	2,948,981	2%	40,591
64	Ecuador	13,363	752	721	1,213,202	1,068,450	38%	461,017
65	Malawi	12,707	1,151	1,600	1,856,908	2,371,040	1%	18,569
66	Niger	12,162	1,183	1,752	1,908,534	2,596,289	1%	19,085
67	Zimbabwe	12,160	799	659	1,289,027	976,572	2%	25,781
68	Guatemala	12,013	875	873	1,411,638	1,293,699	18%	254,095
69	Angola	11,827	1,017	1,320	1,640,726	1,956,108	7%	114,851
70	Senegal	11,706	889	896	1,434,224	1,327,782	5%	71,711
71	Mali	11,415	1,129	1,894	1,821,416	2,806,719	2%	36,428
72	Cuba	11,346	350	295	564,655	437,161	25%	141,164
73	Zambia	11,261	999	1,204	1,611,687	1,784,208	1%	16,117
74	Serbia and Montenegro	10,829	321	263	517,869	389,740	10%	51,787
75	Greece	10,668	256	216	413,005	320,090	74%	305,624

For the whole world, 18,238 diapers are needed every second, if we go by the theoretical calculation. Unfortunately, in reality, world consumption is less than one quarter of this because of poverty in a large part of the world where market penetration of disposable diapers is low. Many areas of the world have market penetrations of less than 2%. More than one third of the babies in this world have never used a disposable diaper!

Population of Sudan according to the 2008 census is 41,236,000, the percentage of 0-2 year babies is around 7% of total population using the population pyramid in Fig (1) estimated at 2,983,000 babies (internet, 2008). Then if consumption estimated at 4.42 diapers per baby per day. The maximum market potential is 4,811,667,000. The market penetration compared to the similar third world countries is 2%. The current market potential is 96,233,000 per year. If we can estimate the market value taking the selling price of diaper at 0.09 cent. Then the market share of diapers in Sudan is USD 8,660,970.

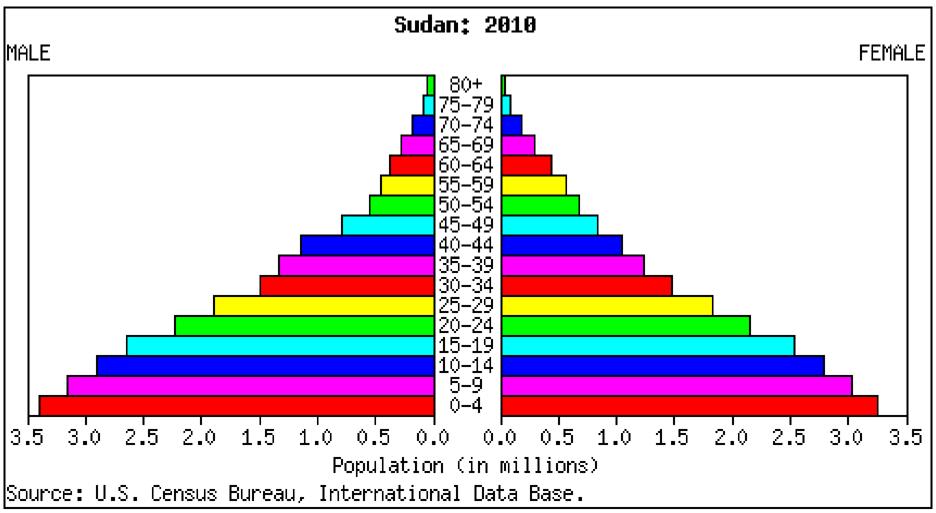


Fig. 1 Sudan population age categorization

Components of disposable diaper: The baby diaper is assembled from about ten or more components comprising the following: top sheet, acquisition layer, core fluff, back sheet, these are the main component the secondary components are the leg cuffs, the elastics gatherings, the closure tapes, and the super absorbent polymer(SAP).

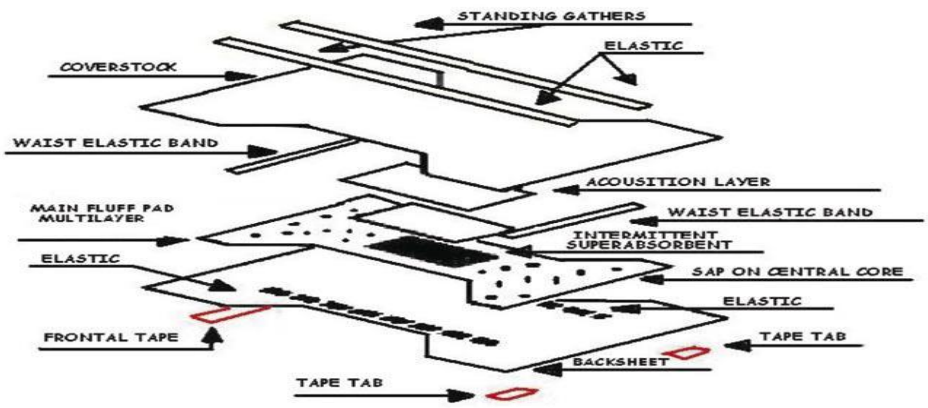


Fig. 2 baby diaper components

Back sheet: This is used as the back sheet, which prevents the liquids from leaking out of the diaper. The back-sheet can also be given a cloth-like look, by adding a thin polypropylene non-woven sheet to the film, using either the hot melt process or the heat and pressure method with direct extrusion to the nonwoven. Contrary to popular belief, the cloth-like back sheet is not cloth -it is made of plastics. Breathable cloth-like material can also be used instead of the film. Not many know that even a breathable diaper with 200 ml of urine loses less than 2.5% of its weight over a period of 24 hours and this evaporation is enough the cool the diaper, which may not be as comfortable at night.

Tissue Paper: A special tissue paper that is different from the regular bathroom tissue and has a higher elasticity and wet strength is another important component of a diaper. The tissue essentially serves as a carrier for the pad (the pad is the absorbent core of the diaper) and helps reduce the pin holes created during the compression process carried out by continuous drum forming systems. This tissue, typically at 16 grams/m.sq (also abbreviated as GSM) or more, protects the inner plastic from the superabsorbent particles. Instead of tissue, it is possible to use a low gage SMS nonwoven material as the carrier (for the pad), it can be placed right next to the back sheet or as a full wrap material around the core. In order for the SMS carrier to be cost competitive against tissue paper, it needs to be less than 12 GSM.

Hot Melts: They are used to glue the different components of the diaper, such as the pad and the elastics. They are made of a mixture of resins, oils and tackifiers. The hot melt adhesive is applied in molten form and when it cools down to provide the required bonding force to glue the materials. Most of the times two types of adhesives are used: a construction adhesive, for the back sheet and the nonwovens, and an elastomeric adhesive, for the leg and waist foam elastics. The elastomeric adhesive has higher elasticity and bonding strength and it is generally more expensive than construction adhesives. When the diaper pad is very thin, another specialty adhesive known as "pad integrity adhesive" is also used to add strength to the diaper core when it is wet. This integrity adhesive is specially useful when SAP loadings exceed 25% of the total pad weight -i.e. when the weight of the SAP is more than a quarter of the weight of the pad.

Leg cuffs: Hydrophobic Non-woven: It is used as a top sheet for the leg cuffs; it prevents water from passing through. It is made of polypropylene resin without any added surface surfactants. The hydrophobic nonwoven prevents leakage out of diaper. By applying a surfactant to a restricted area, it is possible to make a roll of hydrophobic nonwoven only partially philic. This is known as the Zebra process and it is an important feature designed to avoid leakage during leg cuff construction.

Top sheet: This is hydrophilic non-woven, polypropylene, homopolymer, hydrophilic, spun or thermobonded (SMS). Grammage between 15 and 20mg per square meter. It is the main top sheet, the top surface that is in contact with the baby's skin. It allows the liquids to flow into the diaper core. The difference between the two non-woven's (philic and phobic) is the surfactant treatment used in the process. The surfactant treatment reduces the surface tension of the nonwoven, reduces the contact angle with the liquid and allows it to pass. Flow dynamics within the diaper core prevent liquids from returning to the surface. Most nonwovens used in diapers are made with the spun bonding process, though it is possible to use thermal bonded nonwovens also, which are softer but have lower resistance and strength. Trough Air Bonded nonwovens which are more lofty, can also be used.

Leg Elastics: Used to improve the fit of the diaper, usually made of polyurethane or polyester foam, synthetic rubber or Lycra (also known with the generic name Spandex). They are used in cuffs, for the waist and the legs; they can also be used as lateral side panels and in tape construction. Most gasketing cuffs use spandex to provide a seal with the baby's legs. Spandex can stretch as much as 400% of its original length before it breaks, however it is typically used at less than 300% stretch. New generations of softer and stronger elastic materials are reportedly in the pipeline.

Lateral Tapes: In premium diapers, VelcroR type materials have been used to provide mechanical grip, it is also known as the "hook tape". In lower priced diapers, adhesive tapes made of polypropylene are used. Then there are new versions of elasticized Nonwoven Velcro Tapes. In a few years baby diapers may replace training pants with the help of these new stretchable fastening systems that offer the same characteristics to the consumer but cost less. Some adult diapers use what is called the "target tape" system, where the tape has two adhesive tabs to avoid the need for a frontal tape. This is a cheaper alternative for adult diapers but not as good as the one using a frontal tape which does not require repositioning of the tape on top of the target.

Frontal Tapes: This is used to facilitate multiple repositioning of the lateral tape without tearing the back-sheet, it is made of polypropylene film and attached to the front of the diaper with adhesive. Its use has helped to reduce the thickness of the poly film without the risk of potential tears associated with the opening of the lateral tapes from the backsheet. In premium diapers, a special loop system has been developed in order to use Velcro type fasteners (also called the "hook and loop" system). This loop tape can use a "locked loop" or a "brushed loop" in order to provide a softer texture or a stronger grip. A new generation of nonwoven materials expected to be commercialized in a few years, may eliminate the need for frontal tapes - the whole backsheet will be used to reposition mechanical tapes.

Core: Cellulose is used in the construction of the pad, it gives integrity and absorbing capacity to the diaper. The capacity of normal cellulose pulp is around 10 cc of water per gram of pulp when the diaper is in "free swell" but less than 2 cc when subjected to 5 KPa of pressure; that is why a superabsorbent material is also needed to hold the liquids under pressure. Cellulose comes from pine trees, generally obtained from well managed forests. Liquids are absorbed by the capillaries in the void spaces between the fibers and the surface tension angle between the fibers and the water (Richet , 2006). Typical fiber length used in diapers is about 2.6 mm.

Acquisition and Distribution Layer: Also known with its abbreviation ADL, it is a sub layer used between the top sheet and the absorbent core. Sometimes used in full length but mostly preferred as a patch near the target zone where urine is most likely to be deposited. This sub layer is specially needed when the absorbent core is very thin - the sub layer quickly moves liquids into the absorbent core and reduces potential leakage. The ADL is very important to provide a sense of dryness to the skin, providing additional separation between the wet pad and the skin. ADL's should be used whenever the mix of SAP in the absorbent core exceeds about 15% by weight or when the liquid penetration time requires a boost in order to avoid diaper leakage due to liquid accumulation inside the diaper. ADL's are made either of through air bond (TAB) nonwovens, "curly" fibers a kind of "high loft" nonwoven (Resenbawm 1970 , Shmura 1995) .

Super Absorbent Polymer: Sodium Polyacrylate: Also known as super-absorbent or "SAP" (super absorbent polymer). It is typically used in fine granular form (like table salt). It helps improve capacity for better retention in a disposable diaper, allowing the product to be thinner with improved performance and less usage of pine fluff pulp. The molecular structure of the polyacrylate has sodium carboxylate groups hanging off the main chain. When it comes in contact with water, the sodium detaches itself, leaving only carboxyl ions. Being negatively charged, these ions repel one another so that the polymer unwinds and absorbs water, which is attracted by the sodium atoms. The polymer also has cross-links, which effectively leads to a three-dimensional structure. It has high molecular weight of more than a million; thus, instead of getting dissolved, it solidifies into a gel. The Hydrogen in the water (H-O-H) is trapped by the acrylate due to the atomic bonds associated with the polarity forces between the atoms. Electrolytes in the liquid, such as salt minerals (urine contains 0.9% of minerals), reduce polarity, thereby affecting superabsorbent properties, specially with regard to the superabsorbent capacity for liquid retention. This is the main reason why diapers containing SAP should never be tested with plain water. Linear molecular configurations have less total capacity than non-linear molecules but, on the other hand, retention of liquid in a linear molecule is higher than in a non-linear molecule, due to improved polarity (Mc Aloney, 1994 ; Majid *et al* , 1993 ; Cernakova *et al*, 2005 and Necal *et al* ; 2007) .

MATERIAL AND METHOD

The machine technology available in the market can be categorized into two types of technology according to the sophistication of the machine. In this study the two types has investigated and assessed according to the performance and cost of final product. The data for the Lo-Tech and Hi-Tech has been taken from the market in Sudan and western Europe (courtesy of GDM Italy). Two Sudanese factories one using a Lo-tech machine and another one using a hi- tech machine were studied.

1.1 Baby Diaper Machine Technology: Generally baby diaper machines are characterized by use of hi-tech due to the higher performance demanded by the convertors. As mentioned earlier competition is extremely high in baby diaper market due to the large number of investors who have been attracted to set up an enormous number of diaper lines across the globe flooding the market with large amount of inventory stock. They find themselves committed to compete and strive to survive by reducing cost of diaper in both variable and fixed cost.

The machines technologies play an important role in saving and cost reduction. The main features of the hi-tech machines are mainly the servo motors, the electronic sensors, the Programmable Logic Control (PLC) and automatic loading and doffing of inputs and products. These may be a common feature for all modern state of the art and edge cut Hi-Tech machines. These features in general save cost on product by reducing down time, reducing waste, reducing manpower required.

Low and Hi-Tech diaper lines:

In this study the difference in cost saving by using lo-Tech low cost machines and a Hi-Tech high cost machines is investigated. The main features being in the use of vacuum and perforated rotary conveyor that carries the assembled components of the diaper holding down the chassis of the diaper instead of a top and bottom carrier. This reflects on the use of the carrier tissue paper instead of the vacuum. The holding down vacuum is an added cost to the capital investment, but excludes the use of tissue paper. This will be investigated whether it is worth considering or not. The amount of waste is also a cost factor that of importance to competition. Any reduction in the amount of waste reduces the product cost. The manpower is also becoming an essential component of the variable costs, any saving in such a high competition industry makes sense. The use of sensor for detection of faults reduces the man supervision and waste encountered.

One extra important feature of typical diaper produced by lo-tech machines is the simple rectangular core made with cheap technology. Simple rectangular core consists of a straight core without any profile. On the other hand the hi-tech machine uses tri-dimensional (3-D) pockets formed by a rotary vacuum drum. This control to a large extent the distribution of the fluff and sap where needed see Fig [3] below.

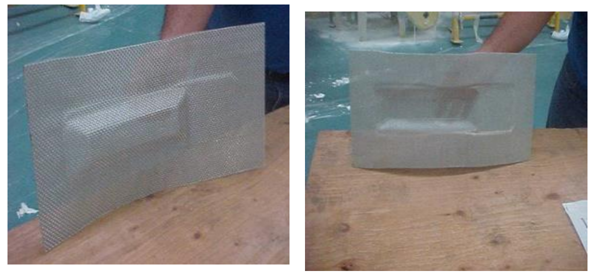


Fig. (3) 3-D pocket core design

RESULTS AND DISCUSSION

Product cost analysis:

Raw material cost: To investigate the variable costs the cost of each input material item that goes into the produced diaper has been estimated as provided by the suppliers of the raw material. The cost taken as factory delivered in US cent in US and western Europe for size Max (7/8 kg). For the lo-Tech machine that does not have the rotary drum core forming 13 items are included as on Table (2) featuring the tissue paper and its glue. For the Hi-Tech machines 12 item were displayed excluding the wrapping tissue paper and its glue as on Table (3).

Table 2 * Lo-Tech- Machine Product analysis Size 7/8 Kg Max

	Description	Type	Length Mm	Width Mm	Area m2	Q (No)	BW (g/M2)	Weight (g)	UM	Unit price USD	Product cost US/100
1	Fluff	Untreated	370	100	0.037			22	Kg	0.75	1.65
2	SAP							6	Kg	2400	1.44
3	BS Ploy	Cast poly	490	320	0.1568		22	3.45	Kg	2200	0.7589
4	Top sheet	Spunbonded NW	490	170	0.0833		15	1.25	m2	0.038	0.3165
5	Acquisition layer	Thermobonded NW	220	80	0.0176		30	0.53	m2	0.09	0.1584
6	Frontal Tape	Cast	35	240	0.0084		90	0.76	m2	0.27	0.2268
7	NW Cuffs	SMS	490	270	0.1323		15	1.98	m2	0.037	0.4895

*

8	leg elastic	Spandex	120			6	0.24	0.17	Kg	10	0.1728
9	Cuffs Elastic	Spandex	120			2	0.24	0.06	Kg	10	0.0576
10	Tapes	Fast+Rel	20	67	0.0027	2	120	0.64	M	0.08	0.32
11	waist band	Fluted	25	96	0.0024	1	45	0.11	m2	0.5	0.12
12	Tissue	Porous	370	230	0.0851		15	1.28	Kg	1.5	0.1915
13	Glue										0.7214
13.1	TS glue	Central for structure	490	5	0.0025	17	5	0.21	Kg	3.4	0.0708
13.2	TS glue	side stripes for structure	490	10	0.0049	4	5	0.1	Kg	3.4	0.0333
13.3	AQL glue	Spray for strucure	210	80	0.0168	1	5	0.08	Kg	3.4	0.0286
13.4	BS glue	Spiro for structure	490	315	0.1544	1	5	0.77	Kg	3.4	0.2624
13.5	Leg cuffs glue	Slot continuous	490	5	0.0025	2	10	0.05	Kg	3.4	
13.6	Leg cuffs glue	Slot intermittent	120	5	0.0006	2	10	0.01	Kg	3.4	0.0167
13.7	Leg cuffs elastic glue	Spiro for elastic	490	20	0.0098	2	10	0.2	Kg	3.7	0.0041
13.8	Leg elastic glue	Spiro for elastic	320	20	0.0064	2	20	0.26	Kg	3.7	0.0725
13.9	Tissue glue	Spiro for structure	370	220	0.0814	1	5	0.41	Kg	3.4	0.1384
					Total weight			**39.9**	**Total (US cents)**		**6.6235**

Courtesy of GDM Italy

Table 3 * Hi-tech machine product analysis Size 7/8 Max

	Description	**Type**	Length mm	Width mm	Area m2	Q (No)	BW (g/M2)	Weight (g)	UM	Unit price USD	Product cost US/100
1	Fluff	Untreated	370	100	0.037			22	Kg	0.75	1.5
2	SAP							6	Kg	2400	1.2
3	BS Ploy	Cast poly	490	320	0.1568		22	3.45	Kg	2200	0.7589

4	Top sheet	Spunbonded NW	490	170	0.0833		15	1.25	m2	0.038	0.3165
5	Acquisition layer	Thermobonded NW	220	80	0.0176		30	0.53	m2	0.09	0.1584
6	Frontal Tape	Cast	35	240	0.0084		90	0.76	m2	0.27	0.2268
7	NW Cuffs	SMS	490	270	0.1323		15	1.98	m2	0.037	0.4895
8	leg elastic	Spandex	120			6	0.24	0.17	Kg	10	0.1728
9	Cuffs Elastic	Spandex	120			2	0.24	0.06	Kg	10	0.0576
10	Tapes	Fast+Rel	20	67	0.0027	2	120	0.64	M	0.08	0.32
11	waist band	Fluted	25	96	0.0024	1	45	0.11	m2	0.5	0.12
12											0.5831
13											
Glue											

12.1	TS glue	Central for structure	490	5	]	17	5	0.21	Kg	3.4	0.0708
12.2	TS glue	side stripes for structure	490	10	0.0049	4	5	0.1	Kg	3.4	0.0333
12.3	AQL glue	Spray for strucure	210	80	0.0168	1	5	0.08	Kg	3.4	0.0286
12.4	BS glue	Spiro for structure	490	315	0.1544	1	5	0.77	Kg	3.4	0.2624
12.5	Leg cuffs glue	Slot continuous	490	5	0.0025	2	10	0.05	Kg	3.4	0.0167
12.6	Leg cuffs glue	Slot intermittent	120	5	0.0006	2	10	0.01	Kg	3.4	0.0041
12.7	Leg cuffs elastic glue	Spiro for elastic	490	20	0.0098	2	10	0.2	Kg	3.7	0.0725
12.8	Leg elastic glue	Spiro for elastic	320	20	0.0064	2	20	0.26	Kg	3.7	0.0947
					Total weight			35.62	**Total (US cents)**		**5.9036**

***Courtesy of GDM Italy**

The tables also include the type of material, description, length and width, weight, unit price, and cost price of item per 100 pieces and the total cost of 100 diapers

Lo-Tech machine production data:

Component cost LCc_n= component $LCc_w X C_{up}$

Where, LCc_n is component cost

LC_w is component weight, C_{up} is component unit price

For the lo-tech m/c the total cost of component LCt_c (for 100 diapers) = 6.6235

For the high-m/c the total cost of component HC_{ct}(for 100 diapers) =5.59036

The difference in material cost between the Lo-tech and hi-tech m/c for 100 pieces of diapers is calculated as follows:

$Diff_{RM} = LCct - HCct =$ 6.6235-5.59036 =0.7199

Where, $Diff_{RM}$ is the difference in raw material between the lo-tech and hi-tech m/cs. For 100 diapers.

Table 4 Total cost per year for lo-Tech m/c

	Lo-Tech m/c

Line saturation	75%
Speed (PPM)	350
Efficiency rate per minitue	70%
Waste rate percent	6%
Change over time per hour	4
Change over per week	1
Manpower	4
Man-hour cost ($)	5
Maintenance times (hours/week)	4
MUT%	92%
Production shifts per day	2
Net raw material ($/p)	0.0662
Power consumption (KW)	200
KWH cost ($)	0.05
Yearly land & building cost (1000$)	42.5
Line cost (1000$)	700
Machine life time	5
Product selling price ($/P)	0.09

Yearly data (lo-Tech m/c):

Net production ($Lp_{net/yr}$) 40,000,000 (Calculated using data in Table 4)

Rejected ($Lp_{rej/yr}$) 3,390,000

Total Production time LT_{yr} =3,000 h/yr

Total raw material cost per year *($LM_{c/yr}$)* *0.0662* X43,390,000=2,872,418 -----------

(1/1)

Gross raw material cost per piece ($LM_{gc/p}$)

$$\frac{\frac{LMc}{yr}}{\frac{LPnet}{\square r}}$$

$= \frac{2872418}{40000} = 0.0718$

Total waste cost per year 3,390,000X0.072= 243,708 -------- (1/2)

Total energy cost per year 200X0.05X3000 = 30,000 -------- (1/3)

Total labor cost per year 6X5X3,000= 90,000 ---------------- (1/4)

Total building and land depreciation 42,500 ------------------ (1/5)

Line depreciation per year 700,000/5= 140,000 -------------- (1/6)

Maintenance and update 100,000 ------------------------------ (1/7)

Total of items 1/3 to 1/7 = 402,500

Total cost of production per year = 2,872,418+402,500=3,274,918

The gross revenue for the lo-tech m/c 40,000,000X0.09= 3,600,000

Net profit per year ($)= 3,600,000-3,274,918= 325,082

Table 5 Hi-Tech machines production data

	Hi-tech m/c
Line saturation	90%
Speed (PPM)	270
Efficiency rate per minute	80%
Waste rate percent	5%
Change over time per hour	4
Change over per week	1
Manpower	4
Man-hour cost ($)	5
Maintenance times (hours/week)	4
MUT%	96%
Production shifts per day	2
Net raw material ($/p)	0.059
Power consumption (KW)	200
KWH cost ($)	0.05

Yearly land & building cost (1000$)	42.5
Line cost (1000$)	1,300
Machine life time	5
Product selling price ($/P)	0.09

Quality and performance of Hi-tech machines:

The Hi-tech machine data for the cost of material and other variables of diaper is has been taken in the same way as for the Lo-tech, from the material suppliers delivered to the factory store see table (3) the cost of total component in this case is less that the case of the Lo-Tech, due to the absence of the tissue paper required by the lo-Tech. As mentioned this is compensated for by the addition of the vacuum system. This will add a cost to the total line initial cost and will increase the line depreciation, but at the same time save on the material used for the diaper and cost of waste.

It is also observed that the cost of manpower is reduced by reducing the number of man operating the machine. The sophisticated technology of PLC and photo-sensor and in some cases the use of servo-motors also add cost to the initial capital investment but on the other hand will reduce the down time for break down and.

The robust structure and precision engineering, with cutting edge technology increase efficiency and maximum utilization time (MUT) leading to a quality diaper that appeals to the customer in highly competitive market flooded with brands.

Yearly data Hi-tech m/c

Net production ($HP_{net/yr}$) =42,000,000 (calculated using the data in Table 5)

Rejected production per year ($HP_{rej/yr}$) =2,610,000

Total production per year ($HP_{t/yr}$)= 42,000,000+2,610,00=44,610,000

Total Production time per year (T_{yr})= 3,600 h/yr

Total raw material cost per year $HM_{c/yr}$ 0.059 X44,610,000= 2,631,990 ----------- (2/1)

Total cost of material per piece ($M_{t/p}$)=

$$\frac{\frac{HMc}{yr}}{\frac{HPnet}{\square r}}$$

$$= \frac{2631990}{42000} = 0.63$$

It is clearly evident that cost optimization should on raw material

Total waste cost per year= 2,610,000X0.063= 164,430-------- (2/2)

Total labor cost per year 4X5X3,000 = 72,000 ------ (2/3)

Total energy cost per year 200X0.05X3000 = 30,000 ------- (2/4)

Total building and land depreciation = 42,500 ------ (2/5)

Line depreciation per year 1300,000/5= 260,000 ------ (2/6)

Maintenance and update = 50,000 -------- (2/7)

Total cost of items 2/3 to 2/7 =454,500

Total cost of production per year ($HC_{p/yr}$)= 2,631,990+454,500= 3,186,490

The gross revenue for the lo-tech m/c (R_g)= 42,000,000X0.09= 3,780,000

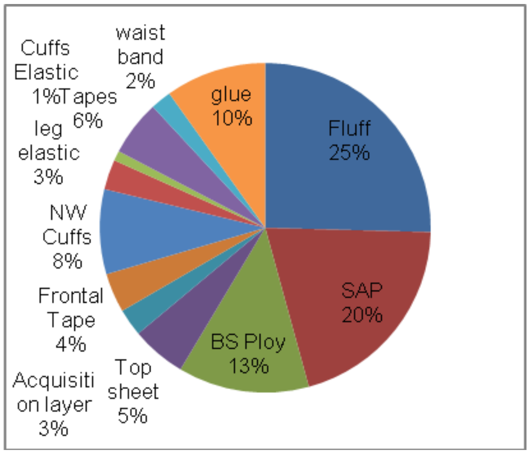
Net profit per year ($F_{net/yr}$) 3,780,000-3,186,490= 593,510

Table 6 Comparison one year production Between Lo-Tech and Hi-Tech M/Cs

item	Lo-Tech m/c	Hi-Tech m/c
Raw material cost ($)	2,872,418	2,631,990
Gross raw material cost per piece	0.072	0.063
Waste cost ($)	243,708	164,430
Cost of production ($)	3,194,918	3,186,490

Cost of production per piece ($)	0.08	0.076
Gross revenue ($)	3,600,000	3,780,000
Net profit ($)	325082	593,510
Profit%	9.93	18.6
Payback period (yr)	1.7	2.2

A comparison between the two technologies has been made as in Table (6), the cost of raw material per piece is clearly higher for the lo-Tech m/c, caused by the use of the tissue paper and waste and lower efficiency and higher labor cost. On the other hand the Hi-Tech machine is advantageously utilizes the technology to lower the cost per piece. This of course is reflected on the total cost of production per year. The net profit per year of 325,082 of lo-tech is less compared to the profit of 593,510 of the Hi-Tech. The profit percent 0f 9.93 for the Lo-Tech is clearly far less than that of the Hi-Tech amounting to 18.6%. The only advantage of the Lo-Tech over the Hi-Tech is the shorter payback period of 1.7 year compared to 2.2 year for Hi-Tech. This is merely due to the low cost of the lo-Tech line. But on the other hand one expects more machine life time for the Hi-Tech due to the robust construction of the Hi-Tech.The cost of each component in the diaper is shown for both technologies on Figures 4 and 5. The material cost to other costs is shown on figure 6 where clearly proved that the material cost is extremely high for the raw material compared to other costs. However, it is logical to optimize cost of material in order to keep the diaper price competent.



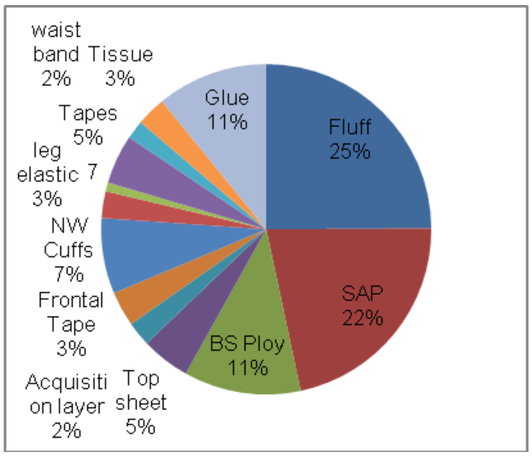


Figure 4 Product cost analysis(Hi-tech) Figure 5 Product analysis (Lo-tech)

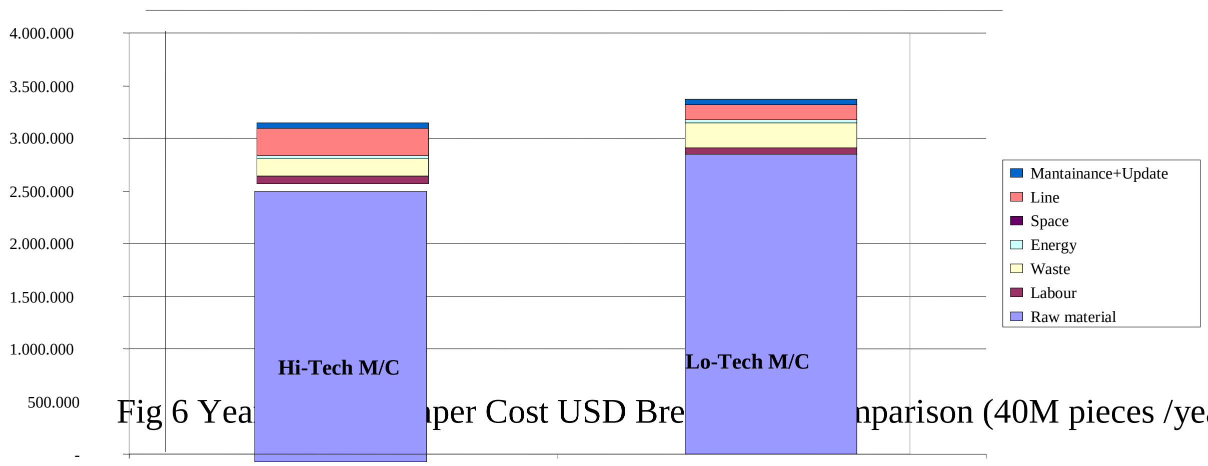


Fig 6 Yea… per Cost USD Bre… nparison (40M pieces /year)

CONCLUSION

The study of the technology of baby diaper machines has clearly revealed some important findings and ascertained the utilization of Hi-Tech and state of the art engineering design.

The fact that baby diaper composed of several components made the assembly of the diaper needs high precision processing in order to avoid rejects and seconds, adding to this the high speed production, demanded by the market for price competition.

The diaper in general is under continuous innovation, making the diaper machine also under continuous innovation and improvement, putting a burden on the convertors to add attachments or use innovated production lines frequently to cope with the market trends.

The raw material of the diaper represents about 80% of the total cost of the piece, this means cost has to be optimized on the material cost i.e. any unnecessary item such as the wrapping tissue paper should be avoided, leaving only component which are real functioning parts of the diaper. This is compensated for by the vacuum system that holds down the diaper chassis during assembly. The waste and rejects has to be minimized since their cost represents a high portion of the total cost of the diaper.

REFRENCES

Cernakova L., D. Dovacik. A. Zahoranova, M. Cernak, and M. Mazur (2005). Surface modification of polypropylene Non-woven Fabrics by Atmospheric pressure Plasma Activation Followed by Acrylic Acid Crafting, Plasma Chemistry and plasma processing, Vol., 25 No. 4, August.

Internet (2008). Sudan population, census, Sudan National Statistic Council, Ministry of Cabinet Affairs, browse, website, http//www.mca.gov.sd.

Internet (2010). How Disposable Diaper are made, Mary Bellis, Inventors Guide, WWW.about.com

Majid, A.Sarmad, Young A. H. Kwon, and Raymond A. Young (1993). Wettability of Nonwoven Fabrics, Effect, Flourochemical Repellency, Finishes on Water**,** Ind. Ing. Chemistry Res., 32, 279-287.

McAloney Regina (1994). Thin is in, Nonwoven Industry,, November, P. 52.

Necal Yaman, M. F. Senol, A.Ebru Tayar (2007). Alternative Methods for Assessing Mechanical Properties of Disposable Diapers., Fibers and Textiles in Eastern Europe., April/June Vol. 15 No. 2.

Ohmura Kin (1995). Super Absorbent Polymers in Japan, nonwovens Industry, January, p. 32.

Richet C. (2006). Absorbency: Does anybody really know what it is?", S.A. CV ,-Diaper Consulting Services, Insight 2 Nov, Memphis TN,

Rosenbaum F. Charles (1970). Absorbent Fibrous Product, Patent, August.

World Statistics, American Census Bureau, Federal Government of the United States of America Washington, DC,(2010).

تقييم أداء وأقتصاديات ماكينات انتاج حافظات الاطفال ذات التقانات البسيطة والعالية

حسب الرسول عبد الباقي محمد 1- آر. جندرات 2

مدير مشروعات مدينة افريقيا التكنولوجية - شعبة الاحياء الدقيقية – كلية كويمبا تدر الهند

الملخص

إن الاستهلاك الهائل لحافظات الاطفال على مستوى العالم (83,933,30) مليون دفعت بالعديد من المستثمرين للدخول كمحولين. إن سوق حافظات الأطفال سوق ذو منافسة عالية و بالتالى التمكن من وجود فرصة فى السوق يتطلب تخفيض تكلفة حافظات الأطفال بدرجه كبيرة تشمل متغيرات تكلفة المواد الخام، إهلاك الماكينه، القوى العاملة، الطاقة، والبنيات التحتيه. لخفض تكلفه اي منتج يجب النظر إلى المتغير الذي يمثل اكبر نسبة في تكلفة المنتج. في هذا الصدد يجب خفض تكلفة المواد الخام وذلك لانها تمثل فى حدود 80% من تكلفة المنتج لقد تم وضع أداء الماكينة و نسبة العوادم فى الإعتبا. أن تشبه العوادم تؤثر بدرجه كبيرة فى تكلفة المنتج. مادامت تكلفة المواد الخام عالية. وبناءاً على ذلك فأن الماكينه التى تخفض نسبة العوادم هى الماكينه التى تتمكن من المنافسة فى حرب أسعار حافظات الأطفال. من المعتاد أن يكون خفض تكلفة المنتج فى نسبة العوادم وورقة الأنسجة الحامله. والتى تستخدم فى حمل المواد فى حالة عدم وجود مفرغ فى الماكينات ذات التقانة البسيطة.تمت دراسة ماكينه حافظات الأطفال من ناحية خصائص واداء وجودة المنتج لقد تمت دراسه مقارنه بين الماكينات ذات التقانة البسيطة والعالية للوصول وإلى أحسن البدائل لرفع جودة حافظات الأطفال وزيادة التوفير فى المواد الخام وقد وجد أن الماكينات ذات التقانه العاليه هى الأفضل من ناحيه الجودة والاداء و بالتالي هي الافضل من الناحية الاستثمارية .