OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D00409

Distribution
LIMITED

ID/WG.34/39
29 July 1969

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

[illegible]

FPT SYMP D/3

PETROCHEMISTRY AND TECHNOLOGY OF WEB FORMATION[1]

by

H. Mark
Polytechnic Institute of Brooklyn
Brooklyn
United States of America

K. Czaiga
Vienna Austria

---

[1] The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

Contents:

Tables:

[illegible]

United Nations Industrial Development Organization

[illegible]

Interregional Seminar on the Development of the Petrochemical Industry in Developing Countries

Baku, USSR, 21 - 31 October 1969

SUMMARY

PETROCHEMISTRY AND TECHNOLOGY OF WEB FORMATION[1]

by

H. [illegible]
Polytechnic Institute of Brooklyn
Brooklyn,
United States of America

[illegible]
Vienna, Austria

Webs consist of papers, felts, [illegible], leathers. They are built up from fibres and their process of formation provides an opportunity of orientating the fibres thus increasing the [illegible] and tensile strength.

A brief account is given of the art of making paper and non-woven fabrics, the former is wet forming, the latter dry forming. The structure of leather is also described.

The major part of the paper then deals with the production of [illegible] from polymers. [illegible] orient [illegible] strength [illegible] fibrillation of the filament. [illegible] in [illegible]

---

[1] The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

[illegible]

[illegible] small quantity of lower melting fibre can be included which [illegible]

[illegible] products [illegible] the products of woven [illegible] from [illegible] respectively, it follows that [illegible] will be [illegible]titive and [illegible] countries.

The formation of two-dimensional webs as papers, felts, textiles and leather out of fibres is one of the most important technological processes of mankind throughout the history. These have been manufactured since years [illegible] the use of fibres for manufacturing textiles and leather [illegible] silk [illegible] ages. [illegible] nine-teenth century [illegible] different scientific qualities [illegible] fibre [illegible] wood. This consists of fibrous materials [illegible] forming an interconnected network of [illegible].

Within the last [illegible] only less modern processes of web formation have been invented, of which we will discuss the spunbonding process and its possible applications in developing countries.

The [illegible] description of technologies of web formation in developing countries [illegible] the industrial development [illegible] their specific need for different kind of [illegible] machinery. In the following a comparison of [illegible] processes of web formation in regard to technological and economical reasons will be given.

Petrochemicals used for spinbonding and formation are facile polymers e.g. the polyolefins, polyvinyl-derivatives, [illegible], polyester, polyamides etc. [illegible] polymers involved at a later date the question, whether or not production of monomers or intermediates would be economically feasible; this can stimulate the whole petrochemical development of a country.

[illegible]mical and physical properties of fibres and their importance in web production.

[illegible] and physical properties of the fibres determine the [illegible] web [illegible] from these raw materials. [illegible] web formation was not involved [illegible] chemical bonding of fibres. However, the [illegible] composition [illegible] molecular structure of the fibres, obtained [illegible] different [illegible] chemical [illegible] processes, have determined [illegible] application. The following [illegible] characterising fibres of [illegible] chemical composition [illegible] in [illegible] their practical applica- [illegible], which can be performed during the [illegible] the improvement of the [illegible] of the fibres.

[illegible] forming and processing.

[illegible] physical [illegible] for web formation are fundamental for [illegible] following description of the classical [illegible].

[illegible] Paper

[illegible] process" paper can be produced from suspensions [illegible] content of 0,2 - 0,5%. According to their [illegible] (10-1000 g/m²) the papers produced range from "tissue papers" to [illegible] board". The [illegible] speed of the paper machinery can be high. In [illegible] thin papers speeds up to 600 m/min. have been [illegible]. In the case of [illegible] webs (100g/m²) one has not yet [illegible] in working much faster than about 90 m/min.

The fibres [illegible] relatively short (less than 5 mm), stiff [illegible] (cellulosics). The inter-connection between the fibres is brought about by the application of heat [illegible] pressure. [illegible] can be introduced by adding suspensions or [illegible] of resinous binders or by the use of additional fibrous binders ([illegible] hydrophobic fibres).

Table I: The improvement of the qualities of synthetic fibres by orientation.

	Unoriented fibres			Oriented fibres		
Materials	Modulus g/den.	Tens. Strength g/den.	Elongation to break %	Modulus g/den.	Tens. Strength g/den.	Elongation to break %
Cellulose	20	2,0	15	100	7,[illegible]	6
Cellulose-acetate	8	1,5	60	60	[illegible],2	6
Nylon 66	6	3,5	75	35	9,[illegible]	12
Polyethylene terephthalate	15	3,6	62	55	[illegible],1	10
Polyvinyl alcohol	10	2,3	71	50	[illegible],7	12
Polyvinyl-chloride	15	2,6	43	55	5,[illegible]	11
Polystyrene	30	2,2	30	35	3,[illegible]	5
Polyacrilo-nitrile	25	3,1	36	76	5,1	10
Polyethylene (low density)	5	2,2	110	35	12,[illegible]	1[illegible]
Polyethylene (high density)	10	2,3	80	4[illegible]	15,4	12
Polypropylene	12	3,4	70	67	11,[illegible]	[illegible]

The intrinsic strength of the individual fibre is actually used [illegible] building up the strength of the sheet, i.e. the stretching and, eventually, breaking [illegible] (e.g. 100 [illegible] fibre slippage [illegible] in the actual [illegible] tensile strength [illegible] 10^{-6} cm²) with [illegible] conditioned [illegible] conclusion that [illegible] theoretical strength [illegible] fibre [illegible] improvement of the fibre to fibre bonding [illegible] strength of random webs of fibres.

[illegible]

[illegible] liquid, in the case [illegible] binder can be regarded as [illegible]. The dry process for the formation of felts, [illegible] essentially of two steps namely the formation of the random web and its reinforcement to attain [illegible] several ways for the [illegible] limited length; it can be done mechanically [illegible] electrostatically or by a combination of such [illegible] the production of substantially random webs [illegible] kind of fibre (natural [illegible]) [illegible] of 20 to 60 mm with cross sections from 3 – [illegible]. Mixtures [illegible] or more fibres – both hydrophilic and hydrophobic – can be processed without difficulty in [illegible], which is in contrast favourably with the wet method. On the other hand, dry web formation with the aid of carding machines, randofeeders, randowebbers and cross-lappers is much slower than the deposition of a sheet on paper machine.

The reinforcement of the dry web can be carried out in the dry state by mechanical needling or heat sealing with the aid of binding fibres or in the wet state by mechanical felting and shrinking and by the addition of a binding resin in the form of a suspension or emulsion.

2.3. Textiles

Representative fabrics range in weights between [illegible] and 800g/m². According to the recent excellent studies of W.J. Hamburger 6) and more of the different mechanical characteristics of the individual fibres – modulus, yield point, tensile strength, elongation to break and bending modulus – are involved in building up the significant mechanical properties of woven and knitted fabrics.

2.4. Leather

Thickness of leather and leatherlike products range between 350 microns for thin glove leather to 6 mm for strong sole leather types, their weight ranges accordingly from about 200 g to about 4000g/m².

If one attempts to produce a synthetic sheet which simulates and eventually improves the properties of natural leather it is advantageous to consider the histology of the animal skin, which consists of several layers. The uppermost of them, the 'epidermis' is relatively hard and abrasion resistant, the next layer, the "corium" represents the largest part of the skin and is remarkable by its toughness, elasticity and water binding capacity. The lowest "strata" finally is a relatively thin, elastic and adhesive layer which connects the skin with the tissue underneath.

For achieving modern leather substitutes it might be best to build it up from several layers of fibrous elements and to connect them by chemical crosslinking processes.

3. Direct web-spin-process and its principles.

This process starts with an appropriate synthetic polymer in bulk (not in fibre form), as a powder or as granules converts it into filaments and directly without interruption in a twodimensional system. The operation needs no special carrier such as water or an organic liquid. Different readily fusible polymers can be applied alone or together on the same equipment.

[illegible]. 1. Fibre formation.

The sel[illegible] [illegible] consisting of one or more suitable polymers is fed to an extruder. [illegible] extruder the polymer melts and then the [illegible] the spinneret [illegible] temperature range between 160 [illegible] 300 [illegible] for polyester and poly- [illegible] (low shear rate) [illegible] of the orifices are [illegible] capillaries are two to three times their diameter [illegible] from the orifice [illegible] viscosity which [illegible]. At this point, however, [illegible] spinneret the temperature is only [illegible] filaments are sticky so that [illegible] allowed to touch any solid material. In order to bring stretching forces [illegible] on the filament in this condition a rapid [illegible] is used which gradually reduces [illegible] and [illegible] considerable degree of [illegible] crystallinity (between 30 and 60%). [illegible] this aerodynamic drawing are described in the [illegible] with [illegible] temperatures between 250 and [illegible], which [illegible] pipes and funnels and accelerate the filaments [illegible] m/min

[illegible]

As the filaments [illegible] with the accelerating gas from a tube or slit [illegible] and [illegible] deposited in a random manner on a belt, which move[illegible] their impingement. The randomisation can be effected [illegible] means, mechanically or by an electrostatic charge which is put on the filaments either by contact with a conductor or simply by friction. [illegible] the filaments of 3 denier are deposited on the belt with [illegible] m/min., which apparently is a very smooth working speed, then [illegible] gram of material is delivered by every spinneret hole per minute or [illegible] per hour. The literature indicates that several thousand holes can be combined to deposit [illegible] on the moving screen.

Assuming for the purpose of illustration 2000 holes, then 2000 grams of web will be deposited on the screen per minute. If the belt has a width of 2 m and if a 100 g/m^2 web is desired, one lineal meter of the web weighs 200 g and the belt has to be moved at the speed of 10 m/min. This is small as compared with the web velocities obtained by the "classical" methods and shows, that the new method can only be competitive in productivity if an assembly of 10,000 spinneret holes can be made to deliver filaments for the formation of one web. This leads to a delivery speed of 50 m/min. of a web with 100 g/m^2 and 2 m width, which compares favourably with the classical processes.

3.3. Reinforcements.

In contrast to this processes the filaments of the present web are endless and need much less reinforcement than the relatively short fibres of the classical sheets. Heat sealing or pressure at elevated temperatures already leads to remarkable mechanical properties in the case of polyethylene and polypropylene sheets and webs. If higher melting polyamides or polyesters are used the addition of a small percentage of a lower melting binder filament provides for the necessary heat sealing and leads to superior mechanical properties. Table 2 presents [illegible] on the mechanical and thermal properties of several webs, as paper, textile and random sheets produced by direct web spin process; Table 2 shows that the new materials are very clearly superior in quality to paper, are at the same level with textiles and leather and, very probably, have a substantial economic advantage over the products of these two industries.

3.4. Finishing.

All kind of finishing operations are possible on random webs. Special procedures exist for printing for using it as wallpaper.

Table 2:

A few important mechanical properties of cellulosic paper products, selected fabrics and some random webs :

Material	ST	E	M	A	T	MP °C
a) Papers:						
Tissue paper	0.4 - 0.6	5 - 8	-	-	0.01 - 0.02	-
New print	3 - 4	2 - 3	14 - 16	-	0.03 - 0.06	-
Wrapping paper	8 - 10	3 - 4	25 - 30	-	0.3 - 0.4	-
Heavy duty bag paper	10 - 15	3 - 4	30 - 35	-	0.5 - 0.6	-
b) Selected fabrics:						
Cotton	13	12	94	20	3.0	-
Wool	8	13	77	23	2.4	-
Nylon	26	15	89	38	4.5	-
Polyester	25	14	91	36	4.2	-
Acrylics	17	14	86	28	3.6	-
c) Random webs:						132
Polyethylene	56	33	120	60	-	175
Polypropylene	67	36	132	64	-	260
Polyester	22	78	75	15	2.3	225
Nylon 6	19	83	66	20	2.2	260
Nylon 66	24	22	68	24	2.4	

ST - Strip tensile in lbs per lineal inch
E - Elongation in %
M - Mullen burst in psi
T - Tongue tear in lbs
A - Abrasion resistance in cycles of the CSIA machine
MP - Melting point.

Table 3:

Direct web - spin process

Raw material	Fusible synthetic polymers in bulk
Fibre formation	Extrusion of the melt [illegible] by [illegible] Substantial molecular orientation and crystallization Reduction of fibre [illegible] by a factor of 10 – 20 Speed of [illegible] of filaments up to [illegible]
Randomization	through mechanical [illegible] or electrostatic action
Reinforcement	directly [illegible] or by heat sealing
Further optional treatment	Printing, [illegible], coating, [illegible] calendering

4. Applications in developing countries and future outlook.

The chances for the future applications of the web-spin process in developing countries depend on economic advantages compared to the classical methods of web formation. For this some cost evaluations will be given.

To give an idea of the cost of producing an air dry sheet of paper (5-7% moisture) from the fibre suspension (between 0.2 and 0.5% solid content) the machine direct costs for a bond paper (bleached Kraft or Sulphite), which weighs 70 g/m² amount to about 0.8 - 1.2 cts/m². This figure depends on many factors, such as mode and condition of the machine, cost of steam, water, power and labour but should give the correct order of magnitude. It is indicated that the cost increment from one lb. of cellulosic fibre suspended in water to the same quantity of the same fibre in the form of a paper is between 7.8 and 9.6 cts in the case of a bond paper sheet. This figure has to be changed if a much thinner (tissue) or a much thicker (heavy duty bag) sheet is considered.

Considering the cost of the conversion of a given unidimensional yarn into a two dimensional woven, it is difficult to present any meaningful average. It can be estimated, that the "weaving costs" of one m² of a cotton [illegible] amount to about 10-15 cts depending on the design of the weave and of such other factors as origin and functioning of the loom, labour, steam and power.

There exist more or less reliable and realistic cost estimates for the conversion of a fibre-forming polymer into a staple fibre by the process of melt spinning and cold drawing. If the melting point of the polymer is within the range between 130 and 270 °C, if the drawing takes place between room temperature and 230 °C and if a heavy denier staple tow with filaments [illegible] an amount of about <u>25 cts/lb</u> has to be added to the cost of the original polymer. It seems that this figure can be reduced to 22 and even 20 cts/lb if very large units are operated and if the process is under excellent control, works at high speed, produces few threadbreaks and a high percentage of first quality product.

Thus e.g. an approximate estimate of the cost of a specified nylon fabric can be made up as follows:

Cost of polymer in the form of granules	35 cts/lb
Production of a staple fibre from this polymer	25 cts/lb
Spinning and weaving of these fibres into a fabric weighing 70 g/m²	25 cts/lb
Total	85 cts/lb
This amounts to about [illegible] c/m²	

Similarly the cost of a corresponding cotton fabric could be estimated as:

Cost of the needed staple fibres of cotton fibres	26 cts/lb
Spinning and weaving of these fibres into a fabric weighing 70 g/m²	25 cts/lb
Total	51 cts/lb
or about [illegible]	

The economic advantages of the direct melt-spin process are indicating the future position considering the actual market situation of the classical processes for web formation.

The applications of nonwovens made out of synthetic polymers depend on the input materials and the manipulation of the process-variables during production. The products are versatile and could include practically all kinds of known textiles in their competition between tissue paper and also leather. Actual applications are for wallpapers, clothing and different technical equipment for industry. Special applications will be developed and established for the future.

16. 3. 72