CHAPTER II
BACKGROUND AND LITERATURE SURVEY

2.1 Polyamide6 (Nylon6) Fiber

Polyamides are a group of polymers characterized by a carbon chain with – CO-NH- groups interspersed at regular intervals along it (See fig.1). They are commonly referred to by the generic name "Nylon" and may be produced by the direct polymerization of amino-acids or by the reaction of a diamine with a dibasic acid. Different nylons are usually identified by a numbering system that refers to the number of carbon atoms between successive nitrogen atoms in the main chain. Polymers derived from amino-acids are referred to by a single number, for example, Nylon-6 is polycaprolactam and has the structure shown in Figure 2.1.

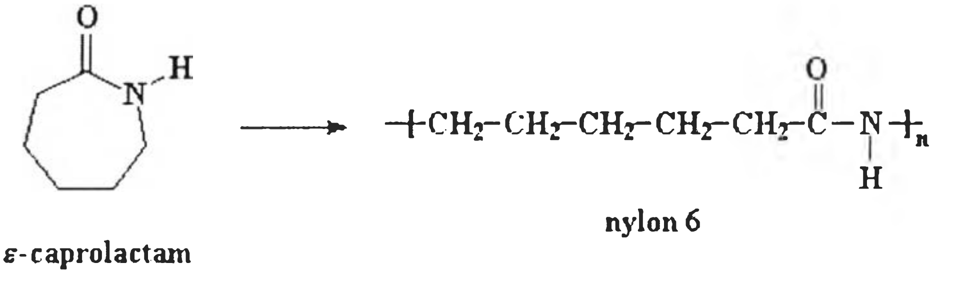

Figure 2.1 The structure of nylon6.

About two thirds of the nylon produced is used for fibers (textiles, carpets, etc.) while most of the remainder is used in injection moulded components (automotive parts, consumer goods, etc.). Other smaller uses are films and filaments.

Melt-spinning process is the process that used for polyamide fiber spinning. It is the simplest method of fiber manufacture, mainly because it does not involve problems associated with the use of solvents. It is therefore the preferred method, provided the polymer gives a stable melt. When polyamide granules or chips form the starting material for melt spinning, they are first dried and then melt in the extruder. The homogenized and filtered melt is squirted through narrow channels into a quench chamber where solidification of the fluid filament bundles is achieved (Fig.2). Finally, spin finish is applied before the filament bundles are wound on tube rolls. In large modern plants, nylon is produced in continuous polymerization units in which the melt is directly transported from the final polymerize to the melt-spinning unit.

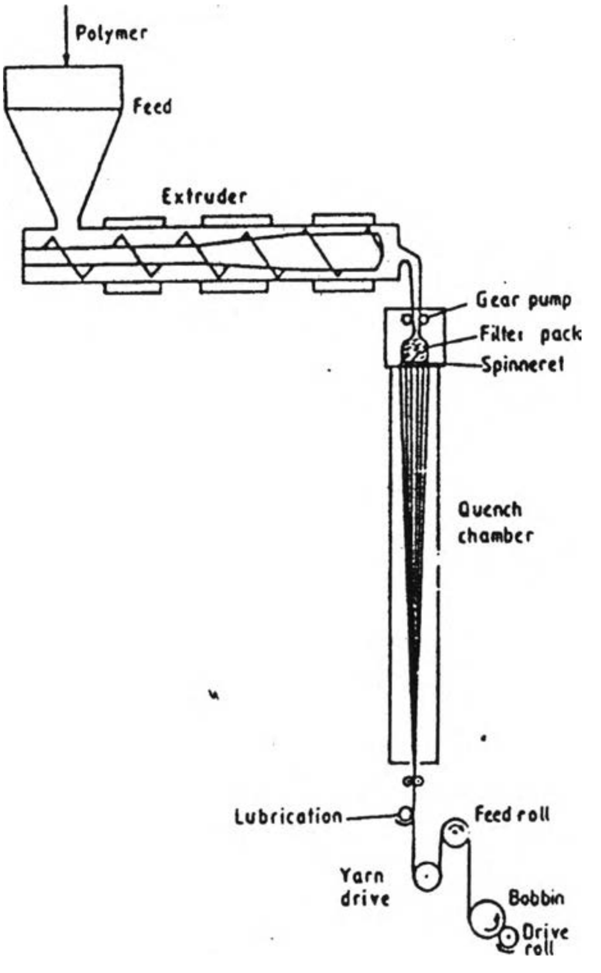

Figure 2.2 Shows a typical melt-spinning line.

A melt-spinning line is shown schematically in Figure 2.2 Strictly speaking, the line sketch is representative of melt-spinning at relatively low speeds using polyamide chips as the staring material. There are two departures from this line that need to be noted. First, in the direct spinning process, the homogeneous and spinnable melt produced by polymerization may be directly passed to the spinning machine at the gear pump stage. Second, when the winding speeds are high, the yarn may be directly dropped to the wind-up device.

When polyamide chips form the starting material, chips from several polymerization reactors are mixed to minimize batch-to-batch variation. The chips are dried (moisture content should not exceed 0.05% by weight for nylon 6) and then melted. In the majority of contemporary processes, melting is carried out continuously in screw melters as these deliver a more homogenized and uniform melt. The polyamide melt is transported under pressure to spinning blocks where an exact metering pump, e.g. a gear pump, maintains a highly even issue of the melt. The polyamide melt is then forced through a fine filter (a pack of sand particles of 20-80 μm size, a series of stainless steel wire gauzes of different mesh sizes, etc.). Filtration of the molten polyamide before it enters the spinneret further homogenizes the melt and removes solid impurities such as metal pieces and semisolid degraded polymer gel, and also eliminates gaseous bubbles.

After filtration, the melt is forced through capillaries in a plate, called the spinneret, and in this way an endless, fine stream of fluid is formed. The molten polyamide, on emerging from the spinneret, bulges slightly due to release of elastic energy stored during shear flow through the narrow channels. This is known as the die swell effect. The filaments are then quenched and solidified in the quench chamber while being drawn off from the bottom. The filament diameter reduces and a number of these filaments are then made to converge into a bundle with the help of two guides. A spin finish is applied before the bundles are wound up on the tube roll, which is often friction-driven by a roller.

2.2 Life cycle assessment (LCA)

The LCA method is an environmental assessment method, which focuses on the entire life cycle of a product from raw material acquisition to final product disposal. According to ISO 14040 an LCA study must consist of four parts (see Figure 2.3)

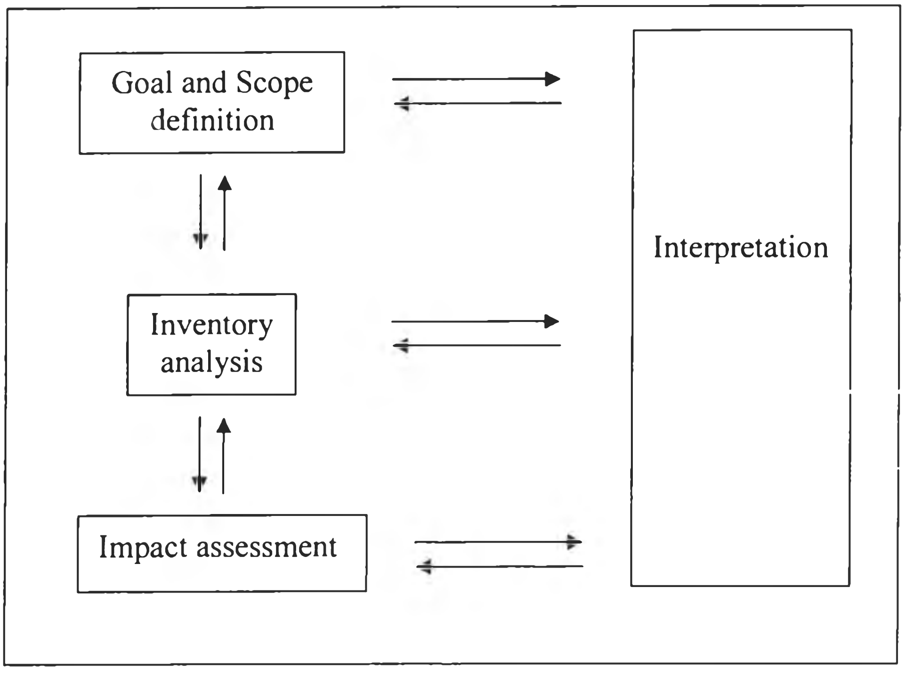

Figure 2.3 Shows phases of an LCA.

2.2.1 Goal and Scope Definition

The goal shall state the intended application, the reason for carrying out the study and the target audience. The scope describes the breadth, the depth and the detail of the study. It is important to define a functional unit and the system boundaries. The data quality requirements should be carefully specified.

-Function, functional unit and reference flow

A particularly important issue in product is comparison in the functional unit or comparison basis. In many cases, one cannot simply compare product A and B, as they may have different performance characteristics. For example, a milk carton can be used only once, while a returnable milk bottle can be used ten or more times. If the purpose of the LCA is to compare milk-packaging systems, one cannot compare one milk carton with one bottle. A much better approach is to compare two ways of packaging and delivering 1000 litres of milk.

-Initial System Boundaries

It is clear that one cannot trace all inputs and outputs to a product systems, and that one has to define boundaries around the system. It is so clear that by excluding certain parts as they are outside the system boundaries, the results can be distorted.

-Data Quality Requirement

It is important to determine in advance what type of data we are looking for. In some studies we would like to get an average of all steel producers in the whole world. In other studies we would like to have only data from a single steel producer or from a group of Electro steel producers in Germany. Likewise, we should determine if we want data on average, modern, or worst case technology.

2.2.2 Inventory Analysis (ISO 14041)

Inventory analysis aims at determining flows of material and energy between the technical product system and the environmental. It involves data collection and calculation procedures for the technical process. Input data could be resources such as raw materials, energy or land and output data could be emissions to air, water or land.

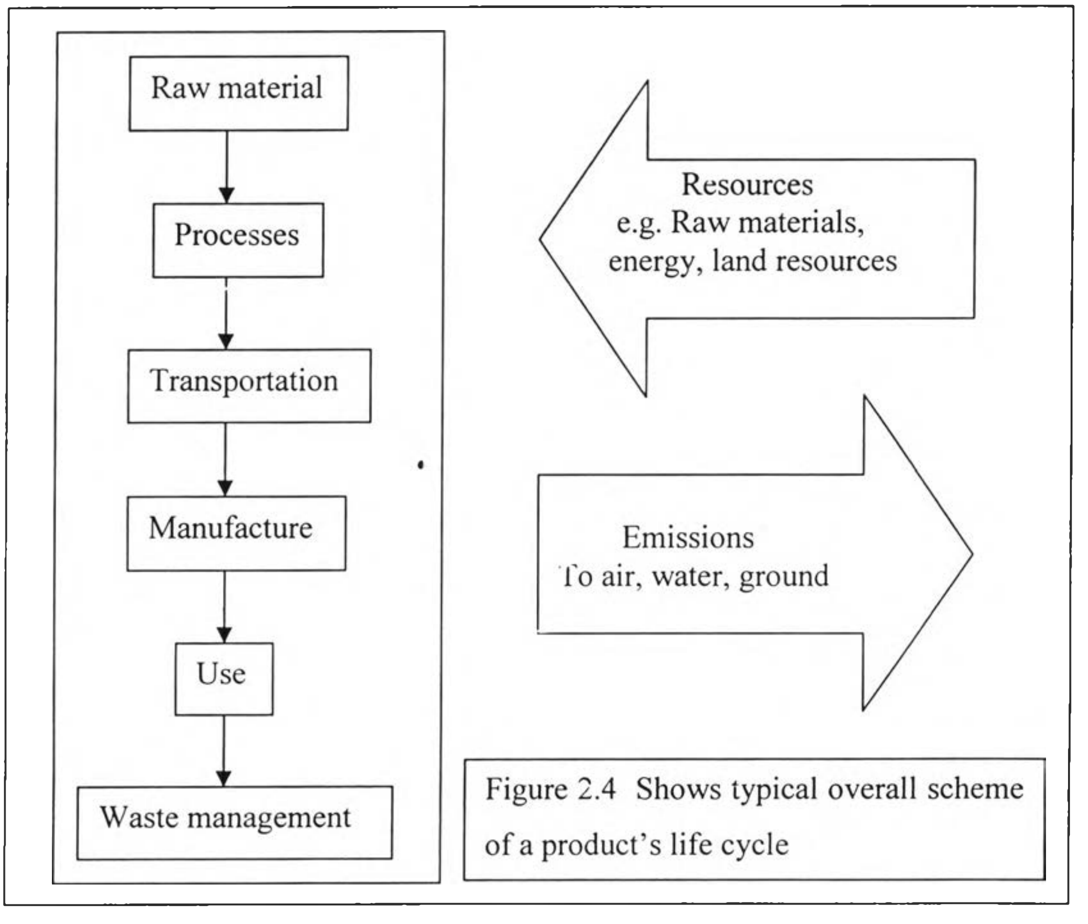

Figure 2.4 Shows typical overall scheme of a product's life cycle

2.2.3 Impact Assessment (Life Cycle Impact Assessment, LCIA), (ISO 14042)

Impact assessment aims at evaluating the significance of potential environmental impact based on the result of the life cycle inventory analysis (LCA result). Impact assessment includes:

-Definition of impact categories and category indicators.

An important step is the selection of the appropriate impact categories. The choice is guided by the goal of the study.

Common impact categories (and indicators) are:

- Climate change (CO_2 equivalents)
- Acidification (SO_2 equivalents)
- Eutrophication of waters (PO_4 equivalents)
- Photo-oxidant creation potential (Ethylene equivalents)
- Stratospheric ozone depletion (CFC-11 equivalents)

- Classification

The inventory result of an LCA usually contains hundreds of different emissions and resource extraction parameters. Once the relevant impact categories and determined, these LCI results must be assigned to these impact categories. For example CO_2 and CH_4 are both assigned to the impact category "Global warming", while SO_2 and NH_3 are both assigned to an impact category acidification. It is possible to assign emission to move than one impact category at the same time; for example SO_2, may also be assigned to an impact category like Human health, or Respiratory diseases.

-Characterization

Once the impact categories are defined and the LCI results are assigned to these impact categories, it is necessary to define characterization factors. These factors should reflect the relative contribution of an LCI result to the impact category indicator result. For example, on a time scale of 100 years the contribution of 1 Kg. CH_4 to global warming is 42 times as high as the emission of 1 Kg. CO_2. This means that if the characterization factor of CO_2 is 1, the characterization factor of CH_4 is 42.

Thus, the impact category indicator result for global warming can be calculated by multiplying the LCI result with the characterization factor.

After characterization comes an optional step called normalization and weighting (ready-made LCIAs)(ISO 14042). It is used when there is a need to compare the relative important of various impact categories. If the environmental burdens are summarized, a single value is obtained that can be used for comparing different products, process or services.

- *Normalization*

Normalization has two purposes:

- To provide an impression of the relative magnitudes of the potential impacts and resource consumption.
- To present the results in a form suitable for the final weighting and decision-making

In normalization, the impact potentials and resource consumptions which have been determined are compared with an impact which is common for all impact categories. Normalization assists in assessing which of potential impacts are large and which are small by placing them in relation to the impacts from an average person.

- *Weighting*

Normalization assists in assessing which of potential impacts are large and which are small. But even if the potential impacts for two different impact categories are equally large on normalization, this does not automatically mean that the two potential impacts are equally serious. To be able to compare the potentials for the various impacts, an assessment must first be made of the seriousness of the impact categories relative to one another.

The mutual seriousness of the impact categories is expressed in a set of weighting factors with one factor per impact category within each of the main group environment, resources and working environment. Then the weighting can be made by multiplying the normalized impact potential by the weighting factor which associated with the impact category or resource consumption.

2.2.4 Interpretation (ISO 14043)

Interpretation step means that conclusions are drawn and that recommendations can be given.

A steadily increasing demand for recycling of polymers had resulted in a demand for methods making it possible to compare different disposal processes influence on the environment and on the resources (Molgaard, 1995). Ecoprofiles could be used for ranking of different disposal processes in an environmentally and resource compatible way. An ecoprofile was an assessment of the environmental and resource impacts a given disposal process, and those processes influenced by the disposal process. The article described ecoprofiles for six different ways of disposing the plastic fraction in municipal solid waste. The following disposal processes were studied: two different materials recycling processes that included separation of the plastic waste; material recycling without separation of the plastic waste; pyrolysis; incineration with heat recovery; and landfill.

Life cycle assessment of four types of floor covering was studied by Potting and Kornelis (1995). Four types of floor covering were linoleum, cushion vinyl, tufted carpet with woolen pile and tufted carpet with polyamide pile. The analysis related to all stages in the life-cycle (from "cradle to grave") and focused on floor coverings for domestic use. Each floor covering was assessed with regard to its environmental impact. A large part of the data was associated with the process energy requirement. The results of the impact assessment for linoleum differed considerably from other types of floor coverings. Linoleum turns out to be the most environmentally favourable floor covering. It was not possible to differentiate between the environmental impact of cushion vinyl, tufted carpet with a wollen pile and tufted carpet with polyamide pile.

Historically, LCA had mainly been applied to products; however, the literature suggested that it could assist in identifying more sustainable options in process selection, design and optimization. Azapagic (1999) reviewed some of these newly emerging applications of LCA. A number of case studies indicated that process selection must be based on considerations of the environment as a whole, including indirect releases, consumption of raw materials and waste disposal. The issues were discussed and demonstrated by the examples of end-of-pipe abatement techniques for SO_2, NO_x and VOC_s and processes for the production of liquid CO_2 and O_2. The integration of LCA into the early stages of process design and optimization was also reviewed and discussed. It was shown that a newly emerging Life Cycle process Design (LCPD) tool offered a potential for technological innovation in process concept and structure through the selection of best material and process alternatives over the whole life cycle.

Proto *et al.* (2000) analyzed the development opportunities in agricultural and manufacturing processes in view of new trends that were characterized by sustainable life-cycle assessments. The relation between agricultural resources, industrial activities and the environment had complex aspects because of many dynamic inter-relationship. Among the sectors that were showing a certain environmental sensibility, there is the textile one, and particularly the cotton sector. Today, the European commission has placed the environmental criteria on the elaboration of a lifecycle analysis for bed linen and T-shirt only. It is obvious, therefore, that one of the cotton sector's prime future aims is to achieve certification of its environmental quality.

Research and development of the object-oriented life-cycle assessment database were studied in the following year (Xu Jincheng *et al.*, 2001). The application of the object-oriented technique for the development of a LCA database was also discussed. A LCA database contained two parts: One was the database of material properties; the other was the database of environmental impacts. The database also contained a system to analyze the relationship between the environmental impacts and the processing technologies of the materials. The database was developed under Windows 98 and used VISUAL BASIS 5.0 as the main tool. In the same year, Corbiere-Nicollier *et al.* (2001) showed that environmental impacts were strongly reduced by bio-fibers replacing glass fibers as a reinforcement in plastics. This article aimed to determine the environmental performance of china reed fiber used as a substitute for glass fiber as a reinforcement in plastics and to identify key environmental parameters. A life cycle assessment (LCA) was performed on these two materials for an application to plastics transport pallets. The energy consumption and other environmental impacts were reduced by the used of raw renewable fibers, due to three important factors: the substitution of the glass fiber production by the natural fiber production, the indirect reduction in the use of polypropylene linked to the higher proportion of china reed fiber used, and the reduced pallet weight, which reduces fuel consumption during transport. Considering the whole life cycle, the polypropylene production process and the transport caused the strongest environmental impacts during the use phase of the life cycle. The potential advantages of the renewable fibers were effective only if a purer fiber extraction was obtained to ensure an optimal material stiffness.

Applications of the life cycle assessment to Naturework^{Tm} polylactide (PLA) production was studied by Vink *et al.* (2003). They explained including the role of life cycle assessment (LCA), a tool used for measuring environmental sustainability and identifying environmental performance-improvement objectives. An overview of applications of LCA to PLA production was give and insight into how they were utilized was provided. The first application reviewed the contributions to the gross fossil energy requirement for PLA (54 MJ/Kg) and the second one PLA was compared with petrochemical-based polymers using fossil energy use, global warming and water use as the three impact indicators. The last application gave more details about the potential reductions in energy use and greenhouse gasses.

The life cycle design (LCD) framework for enhancing design analysis and decision making was demonstrated through a collaborative effort between the university of Michigan, a cross functional team at Ford, and the US Environmental Protection Agency. The LCD framework was used to evaluate three air intake manifold designs: a sand cast aluminum, brazed aluminum tubular, and nylon composite (Keoleian and Kar, 2003). Life cycle inventory, life cycle cost and product/process performance analyzes highlighted significant tradeoffs among alternative manifolds, with respect to system design requirements. The life cycle inventory indicated that the sand-cast aluminum manifold consumed the most life cycle energy compared to the tubular brazed aluminum and nylon composite manifolds. The cast aluminum manifold generated the least life cycle solid waste. The nylon composite manifold had the highest estimated manufacturing costs but use the least phase gasoline costs.

The most fundamental aspect in the ISO 14001 standard environmental management systems-Specification with guidance for use was to find out ways by which an organization influenced environment to a significant degree. Zackrisson (2004) examined environmental data from companies manufacturing products mainly from metals and/or polymers. The data were collected in a uniform way by use of special guidelines. Weighting and valuation methods often used in the life cycle assessment were used to quantitatively compare and rank environmental aspects. The study results suggested that, in general, the largest environmental impact in the investigated manufacturing sub-vector could be associated with product use and/or disposal phases. This in turn showed a need for more attention on environmental work on the design for environment than what the ISO 14001 standard required. It was further suggested that weighting or valuation methods could aid in determining the significance of environmental impacts and aspects in the context of ISO 14001.

Natural fibers were emerging as low cost, lightweight and appearently environmentally superior alternatives to glass fibers in composites. Life cycle assessment was selected to study natural fiber and glass fiber composites and to identify key drivers of their relative environmental performance (Joshi *et al*, 2004). Natural fiber composites were likely to be environmentally superior to glass fiber composites in most cases for the following reasons: natural fiber production had lower environmental impacts compared to glass fiber production; natural fiber composites had higher fiber content for equivalent performance, reducing more polluting base polymer content; the light-weight natural fiber composites improved fuel efficiency and reduced emission in the use phase of the component, especially in auto applications; and end of life incineration of natural fibers resulted in recovered energy and carbon credits.