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Carbon Footprint of Production Processes of Polypropylene Nonwoven Shopping Bags

Abstract
This article reports on the carbon footprint of production processes of polypropylene nonwoven shopping bags made out of two different manufacturing technologies (Products A and B, made by the conventional sewing and thermal joining methods) assessed from their cradle to the gate stage using the Life Cycle Assessment (LCA) technique. This study was performed based on the comprehensive Life Cycle Inventory (LCI) of two different manufacturing sequences obtained from a detailed in-field study of the nonwoven PP bag manufacturing industry. The environmental impacts were quantified by means of the IPCC 2007 GWP V 1.1. method in SIMAPRO 7.2. The carbon footprint expressed in terms of the global warming potential (kg CO_2 values for 20 and 100 years), calculated by IPCC 2007 methods, was considered as a directive to compare the environmental impact of these bags, manufactured by the two different technologies, and a detailed explanation of the results is provided in this paper. From the results of carbon footprint modelling, product A, made by conventional sewing technology, was found to be better than product B, made by thermal technology. A detailed explanation of the results of the environmental performance of these bags as well as the hot-spots in both production technologies are discussed to a greater extent in this article.

Key words: *sewing technology, thermal attachment, global warming potential, SIMAPRO, life cycle impact assessment.*

Introduction

Climate change is of great concern nowadays, driving growing demand for carbon footprint information. The most commonly used phrase in environmental impact related issues is 'carbon footprint' and is now a buzz word widely used. A carbon footprint is a measure of the impact of human activities on the environment (in particular climate change) in terms of the amount of greenhouse gases produced through burning of fossil fuels for electricity, heating and transportation, etc. and has units of tonnes (or kg) of carbon dioxide as an equivalent [1]. The carbon footprint has become immensely popular in the last few decades across the globe and with climate change gaining significance carbon footprint calculations are in strong demand. It is conceived to be one of the pivotal global environmental issues, hence every industry and individual has to work upon it immediately to reduce the carbon footprint since its end results will be terrifying. To decipher it, industries need to concentrate on their production processes of various products to reduce the carbon footprints created by them and, as far as individuals are concerned, must work on the use and disposal phases of a product. Shopping bags have become inevitable products in our daily lives, hence deserving of a study on their carbon footprints.

After the implementation of a ban on free plastic bags in super- markets in many countries, the market potential of reusable bags has been increasing, and the importance of reusable bags on the environmental front is being realised by consumers. One of the very popular and commonly used reusable bags are nonwoven shopping bags, mostly made out of Polypropylene. The process flow starts from the manufacturing of raw material, i.e. polypropylene chips and then extends to the spun bonding process, followed by bag manufacturing processes such as cutting, screen printing, sewing and packaging.

Sewing is one of the techniques extensively used to join the separated (cut) parts in the form of stitches to form a useful product. For shopping bags at this stage, two sides of a bag are sewn together, and handles are attached to the body of the bag. The same operation has been replaced by a thermal technology, where a very high temperature is used as a means to achieve the operation performed by conventional sewing. However, it is a patented technology, hence many details about it cannot be discussed here. This research article details the environmental performance assessment of Nonwoven PP shopping bags produced by the two methodologies defined above. A large number of studies have been conducted to investigate the LCA of various shopping bags [2 - 10], most of which have focused on plastic and paper bags. However, very little work has been done on non-woven and woven bags compared to plastic and paper bags. Even among the few articles published about nonwoven bags, a comprehensive life cycle inventory (LCI) is not available on nonwoven bags exclusively, and there is a dearth of articles published on analysing hot-spots in the production processes of nonwoven bags. Also one of the authors' previous research works dealt with the carbon footprint of different grocery shopping bags (plastic, paper, nonwoven and woven bags) using a secondary data source for the cradle to gate stage. It was observed that when modelled at the full life cycle stage, nonwoven bags outperform all its counterparts for the functional unit assumed in that study [11]. Although they have lower life cycle impacts compared to other bags (plastic, paper, and woven), their individual environmental impact and hot-spots in the nonwoven shopping bag manufacturing process still need to be explored. Being the first article on this specific area, this research work gives a glimpse of detailed LCI of the nonwoven shopping bag manufacturing process, as well as a detailed explanation of the results.

Research methodology

Products selected for this study

This research article aims to quantify the life cycle impacts of nonwoven shopping bags manufactured by Action Nonwovens Co, Shenzhen, China. This study mostly aims to compare the life cycle impacts of the two products selected for this study, produced by major technologies used to manufacture shopping bags (thread sewing and thermal attachment). The following product types were considered for LCA study.

1. **Product A - Sewn bag**,
   Fabric weight: 100 g/m2;
   Size: 43(L)×38(H)×24(D) in cm
2. **Product B - Thermo bonded with cutting,**
   Fabric weight: 75 g/m2;
   Size: 36(L)×42.5(H)×19.5(D) in cm.

The processing sequence of the products considered for this study is presented in ***Figure 1***.

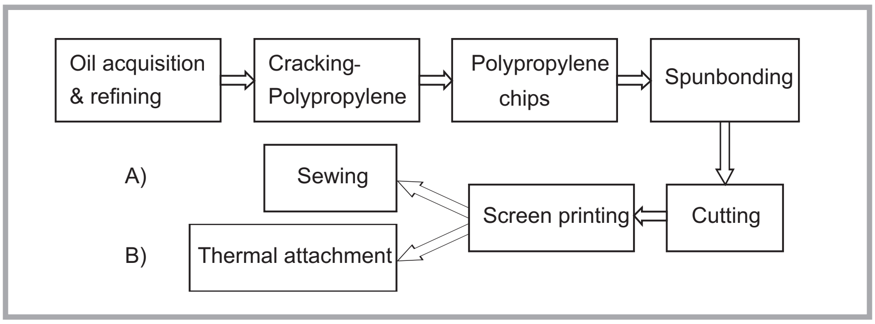

Figure 1. *Manufacturing process of nonwoven bags – sewing technology- Product A, thermal attachment- product B.*

Life Cycle & Carbon Footprint Assessments

LCA is a well-known tool to assess the environmental impacts of products and processes. Life-cycle assessment (LCA) is an analytical tool which can help in understanding environmental impacts from the moment of acquisition of raw materials to final disposal [12]. According to ISO 14040 and ISO 14044, an LCA study essentially consists of four interconnected steps/phases [13, 14]:

- Goal and scope definition
- Inventory analysis
- Impact Assessment
- Interpretation.

The carbon footprint of products can be assessed by measuring the emission of green-house gases (GHG) throughout the entire life cycle of products. The main greenhouse gases in the earth's atmosphere are water vapour, carbon dioxide, methane, nitrous oxide, ozone and CFC's (Chlorofluorocarbons). The major effect of these gases is global warming. The same can be measured by the 'Global Warming Potential' (GWP), which is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming [15]. Among all GHG's, carbon-di-oxide serves as a reference to compare the GWP of other gases. The global warming potential of different greenhouse gases can be obtained from the Inter Governmental Panel on Climate Change (IPCC) report [16].

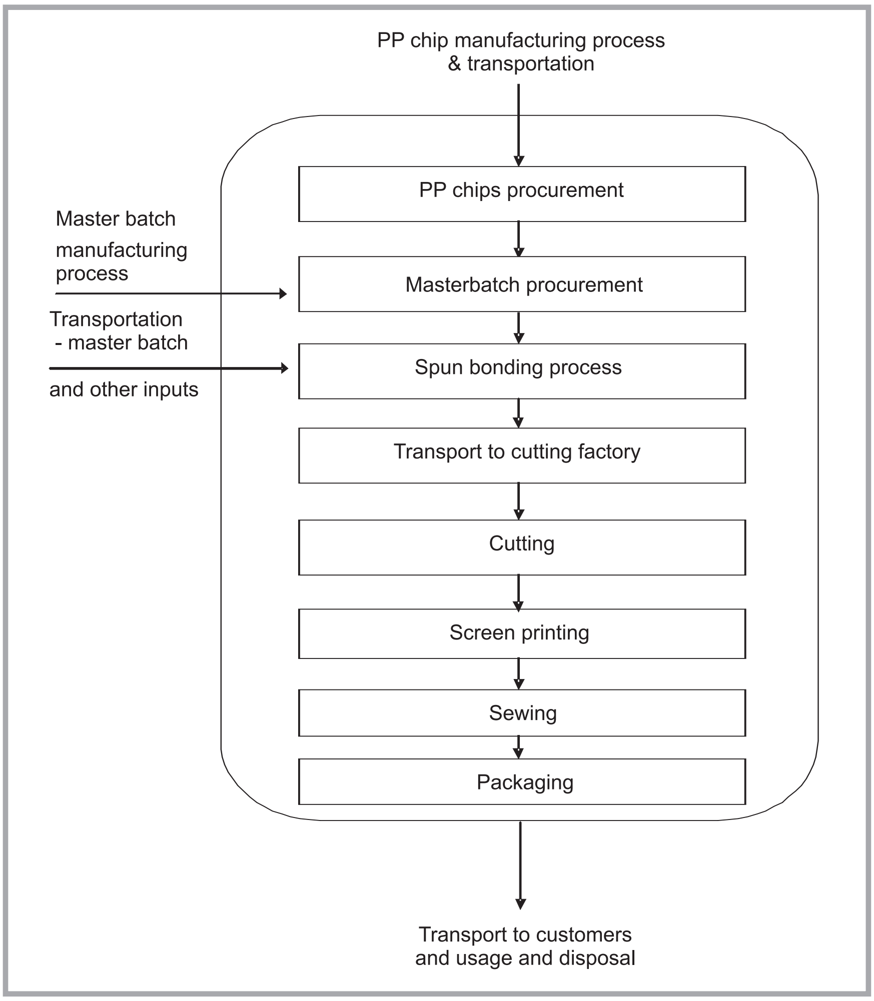

Figure 2. *Scope and boundaries of the system under study.*

Life cycle assessment of nonwoven shopping bags

Goal and scope

The goals and scope of this study are as follows: a) to review the inventory of inputs and outputs for the two different kinds of shopping bags selected for this study; b) the main goal of this study is to find hot-spots in the two major techniques of producing nonwoven shopping bags discussed above; c) the study concerns the calculation of the carbon footprint of manufacturing 1 Kg of the two types of shopping bags, mentioned as Products A and B.

The boundaries of the present study are presented in graphical format in ***Figure 2***. Although this study does not directly report the inventory of PP and master batch, their associated inventory is taken from the dataset library of SIMAPRO software. The original transportation of PP and master batch from the manufacturing plants to the factory has not been included in this study, nor has the final transport of shopping bags to the customer.

Life cycle inventory

The Life Cycle Inventory (LCI) of the two products - A and B - considered for this study is listed in ***Table 1*** (see page 14).

For both products, a shipping distance of 6km from the spun bonding factory and 15 km transport of chemicals and other ancillaries for cutting in the screen print-

Table 1. LCI of products A & B for 1 bag in each category.

Life Cycle Inventory	Product A	Product B
Weight of 1 bag, g	79.2	55.4
1. Spun-bonding		
Inputs:		
PP chips, g	82.12	64.2
Masterbatch, g	1.16	0.91
Electricity		
Manufacturing, kWh	0.0892	0.0697
Lighting, kWh	0.00163	0.00127
Cleaning, kWh	0.0002	0.00015
Water(Cleaning), g	1.01	0.79
NaOH(Cleaning), g	0.0021	0.0016
Paper Tubes, g	2.97	2.32
Plastic Sheet (PE), g	0.58	0.45
Outputs:		
Fabrics –Standard Quality, g	79.7	62.3
Fabrics of low quality and multi colour ones, g	2.37	1.85
Fabrics- Waste, g	3.60	2.82
2. Cutting		
Inputs:		
Spunbonded fabrics, g	79.7	62.3
Electricity, kWh	0.00267	0.00267
Outputs:		
Cut pieces of fabrics	75.4	51.67
Waste fabrics, g	4.26	10.58
3. Screen Printing		
Inputs		
Fabrics(PET mesh) for Screen, g	1.44	0.72
Aluminum for Screen, inches	3.34	1.67
Wood for Screen, inches	0.0001	0.00005
PE Film, g	0.3	0.2
Printing ink, g	3.30	
Electricity(Lighting & Fan), kWh	0.0178	
Silicone Spray, g	0.16	
ABS-Cyanoacrylate, g	0.06	
Cyclohexanone	3.0	
Autotype Plus 7000 Direct, g	0.4	
Emulsion		
Isophorone, g	0.65	
Adhesive, g	2.5	
Water(Cleaning), g	0.63	
Fluid Waste (Water), g	45.8	
Solid Waste (Chemicals & others), g	4.17	
4. Sewing		
Inputs:		
Electricity, kWh	0.0081	NA
Thread used, g	0.5	NA
5. Thermal Bonding		
Inputs:		
Electricity, kWh	NA	0.0305
Waste Fabric	NA	NIL
6. Packaging		
Inputs:		
Paper Box Input, g	8.21	8.21
Plastic Sheet (PE), g	0.5	0.5

ing process is common. Road transport by means of diesel trucks is applicable to both the products under study.

Carbon footprint assessment

Carbon footprint assessment was performed with the aid of SIMAPRO 7.2 software from Pre Consultants, Netherlands. The IPCC 2007 GWP V 1.1. method, a successor of the IPCC 2001 method, developed by the Intergovernmental Panel on Climate Change, was utilised to calculate the global warming potential (GWP) for 100 and 20 years [17]. IPCC characterisation factors for the direct (except CH_4) global warming potential of air emissions were considered in this method to calculate the carbon footprint values [18].

- **GWP – IPCC 2007 results - 100 Years**
  The results of global warming potentials (GWP) expressed in terms of $kgCO_2$ equivalents can be seen from ***Table 2***.
- **GWP – IPCC 2007 results - 20 Years**
  The results of global warming potentials (GWP) expressed in terms of $kgCO_2$ equivalents can be seen from ***Table 2***.

Hot spots in production

In continuation to the carbon footprint assessment, hot-spots in the production processes of both products – A and B were found and discussed in detail.

- **IPCC 2007 – 100 Years**
  The process contribution of products A and B in the IPCC 2007 method for 100 years is plotted in ***Figures 3.a***.
- **IPCC 2007 – 20 Years**
  The process contribution of products A and B in the IPCC 2007 method for 100 years is plotted in ***Figures 3.b.***

Life cycle interpretation

From ***Table 2***, one can understand the $kgCO_2$ equivalents (Global Warming Potentials - GWP) of both products A and B for 100 and 20 years, respectively. From this, it can be easily understood that product A is better than product B in terms of the contribution to global warming. The primary and other reasons for each product contributing to GWP can be seen from ***Figures 3*** for 100 and 20 years. For all products in most cases, transportation by diesel truck, the consumption of electricity for the production process of shopping bags, and the energy intensive PP chip manufacturing process are found to be major contributors to global warming.

Table 2. GWP potentials (100 a - 100 years and 20 a - 20 years).

Impact category, unit	A	B
IPCC GWP 100 a, kg CO_2 eq	60.7	86.3
IPCC GWP 20 a, kg CO_2 eq	62.5	88.6

Product A, made by conventional sewing technology, occupied a significant position as far as better environmental performance is concerned, as compared to B.

From the detailed LCI analysis and carbon footprint assessment, it is apparent that Product A outperforms its opponent in terms of GWP, due to lesser energy consumption, specifically during the sewing process, compared to B, made by thermal technology. The other major difference which attributes to the better position of Product A in terms of a lesser carbon footprint produced can be well understood from the life cycle inventory listed in ***Table 1***.

Conclusions and recommendations

This study details the life cycle assessment of two types of shopping bags manufactured by two different technologies. This is a cradle-to-gate assessment study, conducted within certain boundaries initially explained. The scenario could be different if the nonwoven shopping bags are compared with other types of shopping bags. However, in this case two different variants of nonwoven shopping bags are compared in terms of the manufacturing impact when producing 1 kg of each type – A and B. Also hot-spots in the manufacturing sequences of both products were studied.

In this article, along with the presentation of the comprehensive life cycle inventory of the cradle-to-gate stage of the manufacturing production processes of polypropylene nonwoven shopping bags, two major technologies involved in manufacturing nonwoven shopping bags in the attachment phase were compared, i.e. thread sewing and thermal attachment technologies.

As far as GWP is concerned, Product A seems to be better, and the major contributors to GWP are the transportation and consumption of electricity for the production process, the PP chip manufacturing process itself, and so on.

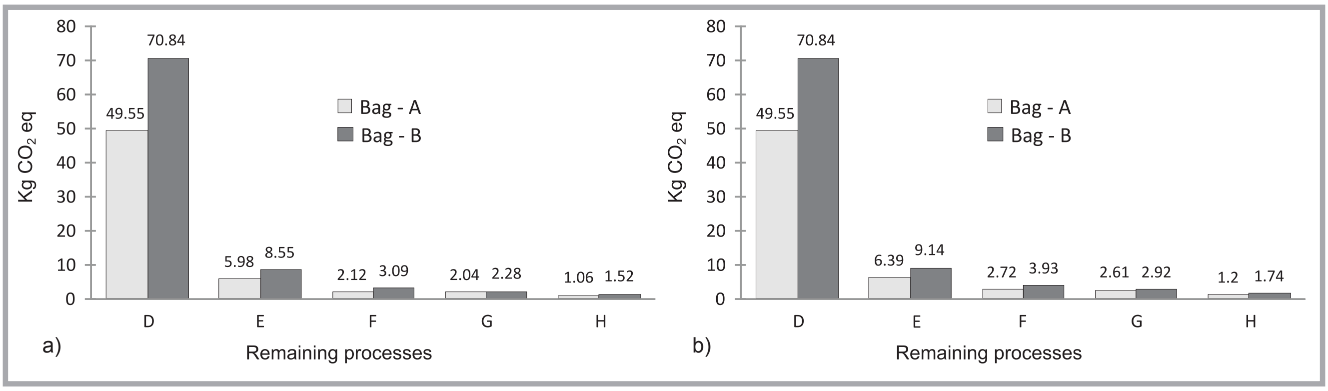

Figure 3. *GWP – product A & B for 100 years (a) and GWP – product A & B for 20 years (b); Note: D - Truck (diesel), E - Distillate fuel oil (FAL), F - electricity, hard coal, at power plant (CNS), G - polypropylene, granulate, at plant (RERU), H - reamianing processes.*

Certain areas of hot-spots may not be controlled directly, such as the PP production process, electricity consumed for the PP and dyes manufacturing processes, and so on. But some processes such as the local transportation of fabrics from one station to another and transportation involved in the procurement of inventories for the manufacturing processes are under direct control. Regarding local transportation, which is one of the major impacts here, it is better to look for the nearest company to reduce the impact of transportation. Although the spun bond fabrics must be transported to a cutting factory, any alternative measures of transportation using renewable energy sources could be of great help to cut down carbon emissions. Moreover any alternatives/technologies to reduce power consumption need to be found to lessen the energy impacts. Furthermore an energy audit can be recommended for this factory. Although the majority of fabric waste is recycled, this study does not report the usage of recycled PP in its manufacturing phase, which was difficult to account. If this is included, the impacts will be reduced to a certain level and, at the same time, can be quantified.

In terms of product technology, it is recommended to choose sewing technology, which in this study was found to be better in terms of carbon emissions. Customers can also be encouraged to opt for products made by this technology.

Acknowledgments

The authors are grateful to Hong Kong Polytechnic University for providing funding for this research through project RP7Q. The authors would also like to thank Mr. Yang, President of Nonwovens Association of Hong Kong, for kindly permitting us to conduct this study at his factory, National Bridge Industrial (Shenzhen) Co. Ltd., located in Shenzhen. The authors would also like to express their sincere thanks to all the staff of the National Bridge Industrial (Shenzhen) Co. Ltd., for their timely help in conducting this study on their factory premises.

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Received 06.06.2011 Reviewed 19.10.2011