Journal of Environmental Sciences Vol.16, No.1, pp.100—103, 2004

ISSN 1001—0742
CN11—2629/X

Article ID: 1001-0742(2004)01-0100-04 CLC number: X32 Document code: A

Life cycle assessment of mobile phone housing

YANG Jian-xin[1], WANG Ru-song[1], FU Hao[2], LIU Jing-ru[1]

(1. Research Center for Eco-Environmental Sciences(RCEES), Chinese Academy of Sciences, Beijing 100085, China. E-mail: yangjx@mail.rcees.ac.cn; 2. MATC-A, Motorola (China) Electronics Ltd., TEDA, Tianjin 300457, China)

Abstract: The life cycle assessment of the mobile phone housing in Motorola(China) Electronics Ltd. was carried out, in which materials flows and environmental emissions based on a basic production scheme were analyzed and assessed. In the manufacturing stage, such primary processes as polycarbonate molding and surface painting are included, whereas different surface finishing technologies like normal painting, electroplate, IMD and VDM etc. were assessed. The results showed that housing decoration plays a significant role within the housing life cycle. The most significant environmental impact from housing production is the photochemical ozone formation potential. Environmental impacts of different decoration techniques varied widely, for example, the electroplating technique is more environmentally friendly than VDM. VDM consumes much more energy and raw material. In addition, the results of two alternative scenarios of dematerialization showed that material flow analysis and assessment is very important and valuable in selecting an environmentally friendly process.

Keywords: life cycle assessment(LCA); housing production; dematerialization

Introduction

Life cycle assessment(LCA) is a systematic method used to assess the environmental impact of all mass and energy flows of the life cycle of a product/process. LCA is very helpful in alternative product/process comparison or improvement from the environmental point of view.

As a global leading company in the electronic manufacturing area, Motorola always puts great efforts to minimize the negative impact of its products. In order to identify and diagnose the impacts of manufacturing processes for developing environmental friendly phone-housing production technologies, Motorola and the Research Center for Eco-Environmental Sciences(RCEES), the Chinese Academy of Sciences jointly initiated a LCA study on mobile phone housing.

1 Inventory analysis

1.1 Goals and scope

Currently, four kinds of finishing methods are very popular in plastic housing decoration. They are painting, vapor-deposited metal (VDM), electroplating (e-plating) and in-molding decoration (IMD) (Schnecke, 2000). To cover all the four technologies in this study, the Kramer, a product of Motorola, was selected as the research target product. The Kramer housing assembly is composed of front cover housing, back cover housing, front flip, back flip, ring and lens. The flips and cover housings are decorated with normal painting, the ring is decorated by either e-plating or VDM, while the lens is made by IMD (Fig. 1).

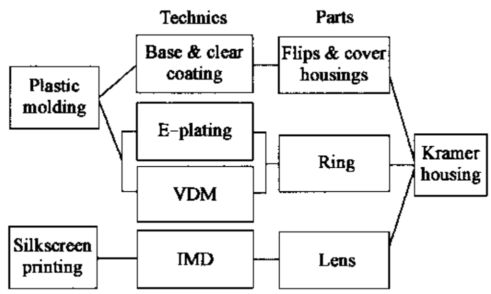

Fig.1 Production process of Kramer housing

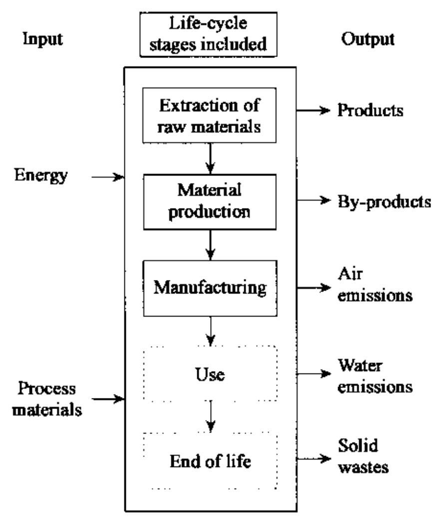

Fig.2 System boundary of study

The life cycle stages included in this study are shown in Fig. 2. The objective of this study is to identify the alternative housing manufacturing processes and innovations from the environment and resource points of view.

The use phase of Kramer housing is not included because it is less important from the environmental perspective. The end of life is also excluded from this study because on the one hand, the disposal of housing in the end of life is quite seldom currently in China and the relevant information is unavailable, on the other hand, the focus of this study is the processes identification instead of the impact assessment of housing within its whole life.

As for the energy input, the overheads of the facilities such as air conditioner, clean room as well as lighting are included. The transportation processes during material extraction and material production are included. But the transportation processes during the

Foundation item: Motorola(China) Electronics Ltd. Project "Environmental life-cycle assessment on finishing technologies"

manufacturing stage(factory inside and inter-factory) are excluded because the freight is much smaller and the distance is much shorter.

The function unit for this study is 10000 finished Kramer housing assemblies.

1.2 Methods and data sources

The energy production and use data were directly taken from the database in the Boustead Model(Boustead, 1991), which were developed and incorporated into the Boustead Model by RCEES within the European Community INCO project "Eco-comparability of industrial processes for the production of primary goods". The raw material production data were mainly collected from the open literature. The processing data for housing manufacturing, including molding, painting (base coating and clear coating), silkscreen printing, e-plating as well as the VDM etc. were mainly collected from the Motorola's suppliers in China.

The inventory was calculated based on the Boustead model. The impact assessment phase was conducted based on the EDIP methodology (Wenzel, 1997) and on Chinese factors(Yang, 2001).

In the existing basic production system, the molded plastic parts with runner (intermediate product) is directly delivered to the next operations(e-plating or VDM) as the input. In the end of electroplating line, the decorated runner is cut off as waste, then the finished parts are dispatched to the assembling procedure. It is clear that the electroplating finishes some wastes(runners) alone with products, which not only leads to some additional costs, but more important, causes additional environmental burdens.

In order to deeply examine the above problem, two scenarios were developed based on the existing production scheme(System A). Scenario B assumes that the existing molding process is kept unchanged but the total runners(including housing runner, ring runner and lens runner) are cut off by 25% before the intermediate product enter the following process like coating or electroplating. Scenario C assumes that the runner from the molding process is reduced by 25%.

1.3 LCI results

Life cycle inventory results are mainly associated with energy consumption, primary material use and environmental emissions.

The gross energy requirement for producing 10 k Kramer housings is about 55.8 PJ, of which about one half from coal, and 30% from electricity. From the industrial process perspective, nearly 80% energy is consumed for fuel production and fuel use. If electricity consumption was traced down to primary energy, then natural gas consumption ranks first instead of coal, because a large amount of polycarbonate(PC) is used in housing manufacturing, which is mainly synthesized or derived from oil and natural gas (Table 1).

Table 1 Primary energy consumption for housing production(MJ)

Primary energy	Fuel production	Fuel use	Transport energy	Feedstock energy	Total
Coal	8426.0	5871.1	5.4	-0.13	14302.3
Oil	924.8	4135.5	276.3	4673.2	10009.8
N.gas	1683.1	15679.0	5.3	9420.3	26787.6
Hydro	677.8	311.0	0.1	-	988.9
Nuclear	1820.4	814.1	2.5	-	2637.1
Others	848.9	168.1	0.02	41.3	1058.4
Total	14381.1	26978.7	289.5	14134.6	55783.9

The raw materials used are shown in Table 2. In terms of quantity used, the fresh water and sodium chloride used dominate. But if the scarcity of resources, like minerals is considered, the valuation will be different.

The environmental emissions from the Boustead model are assigned to three categories: solid wastes, air emissions and water emissions. The major part of solid wastes is mineral wastes, which are mainly from the mining process. Other wastes include mixed industrial wastes, slag/ash, inert chemicals, wasted plastics and regulated chemicals. The wastes from the housing manufacturing are not negligible because 10000 finished Kramer housings weights 229 kg, but it leads to 275.3 kg wastes within the whole life cycle.

Table 2 Raw material used for housing production

Raw material	kg per 10 k housing
Baryte	5.20
Limestone	5.40
Zn	2.40
Sn	0.01
Fe	0.38
Pb	0.00
Cu	1.20
Ni	1.30
Bauxite	0.23
Sand (SiO_2)	0.23
Sodium chloride	287.00
S(elemental)	5.50
Fresh water	45700.00

The air emissions from the life cycle stages of housing include 18 emissions, mainly including CO_2, CO, dust, SOx, NOx, HC and methane etc., of which cause not only global impacts, but also regional and local impacts. The water emissions are mainly associated with organic pollutants(COD, BOD) and heavy metals.

2 Impact assessment

Based on the EDIP methodology developed by Danish researcher (Wenzel, 1997) and relating Chinese indicators developed by RCEES (Yang, 2001), the resources and environmental impacts were assessed separately.

In order to understand the impacts of technique alternatives, rings decorated by the e-plating and VDM are modeled separately. The results showed that e-plating system consumed only 69.85% of energy that the VDM system used.

According to EDIP method, the weighted resource consumption is given the unit "milli person-reserve," mPR_{W90}, i.e. the fraction of per thousand of known global person-reserves in the world in 1990. In the primary resources consumption in the basic product system (e-plating ring), nickel constitutes the most significant contributor. Zinc, natural gas, and copper follow subsequently in the ranking order(Fig. 3). But in the VDM system, tin plays a dominate role. Further, tin in VDM is more important than nickel in Scenario B. Also, zinc in the VDM system is almost double of that in the e-plating system. The gas, oil and coal consumptions within the VDM system are higher than those in e-plating system. In a word, VDM technique consumes much more resources than that the e-plating technique.

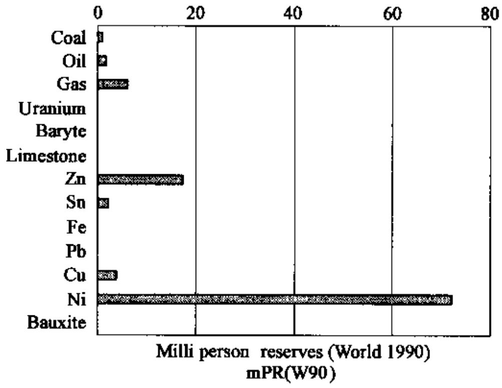

Fig. 3 Weighted resource consumptions

In this study, the environmental impacts were expressed in mPE_{T2000}, which stands for person-equivalent based on target emissions in China in the year 2000, the detail calculation method can be found in the literature (Yang, 2001). Fig. 4 shows that the most significant environmental problem associated with the housing manufacturing is the photochemical ozone formation. Ranking below the ozone formation, are acidification, global warming, and nutrient enrichment. It also means that the regional impacts are greater than global impacts in the system studied. In order to further understand where the environmental impacts come from, the photochemical ozone formation was traced back within the life cycle. The operations in the scope of this study were assigned to four types, fuel production, fuel use, industrial process and transportation process. The result shows the industrial process is the key source for the potential photochemical ozone formation.

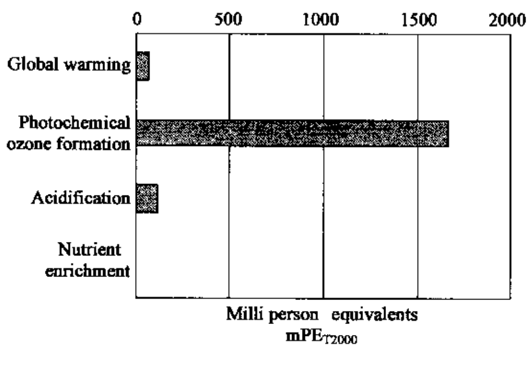

Fig. 4 Weighted environmental impacts

3 Life cycle interpretation

3.1 Analysis of housing decoration techniques

From the environmental point of view, the housing decoration techniques have great significance within the whole life cycle of housing. The traditional decoration technique is painting (base coating and clear coating), which mainly leads to VOC emission, a key contributor to photochemical oxidant potential. VDM is a new high-quality decoration technique, but it consumes too much energy compared with painting. Electroplating is specifically suitable for producing metal-looking surface, but it is apt to cause heavy-metal water pollution. The IMD combines molding and silkscreen printing into one stage. The VOC emissions from the ink during the silkscreen printing process are not negligible as well.

For the decoration of 1 m^2 Kramer plastic surface, the POCP caused by e-plating, VDM, painting and IMD, are presented in Fig. 5. Evidently, VDM always has the biggest contribution to the environmental impact. Compared with painting and IMD, e-plating has a bigger impact on global warming potential (GWP), acidification potential (AP), whereas, IMD has a bigger impact on photochemical ozone formation potential (PCOP) than e-plating and painting.

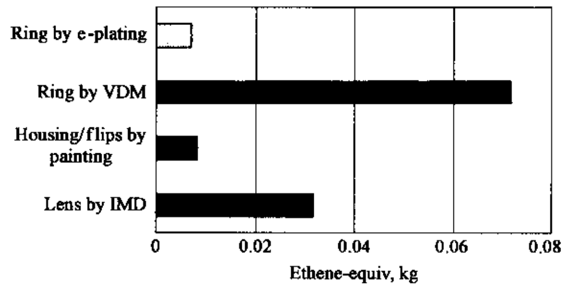

Fig. 5 PCOP for decoration of 1 m^2 plastic surface

3.2 Scenario analysis on dematerialization

The mix of energy use for three scenario systems varies not much. Scenario B and C reduce the gross energy consumption to 2142 MJ and 5062 MJ, respectively, as compared with the basic Scenario A. However, materials saved in alternative scenarios are significant. For example, the total amount of runner reduced for Scenario B and C is 12.45 kg, whereas the total amount of primary materials saved is 5 times of and 11 times of it, respectively. The dominant materials saved are fuels like coal. If the fresh water is under consideration, the saved amount of resources is 1400 kg and 3900 kg, respectively (Table 3).

Table 3 Material saved in alternative scenarios

Raw materials	Scenario B	Scenario C
	Material saved, kg	Material saved, kg
Coal	23	51
Oil	8	20
Gas	20	49
Uranium	0.0002	0.0005
Baryte	0.2000	0.4000
Limestone	0.3000	0.7000
Zn	0.0000	0.1000
Sn	0.0010	0.0025
Fe	0.0200	0.0400
Pb	0.0000	0.0001
Cu	0.1000	0.2100
Ni	0.1000	0.2000
Bauxite	0.0100	0.0200
NaCl	10.00	24.00
S(elemental)	0.30	0.70
Total	62	146
Fresh water	1400	3900

Additionally, air emissions from the alternative scenarios are changed. Scenario B can reduce the air emission by 135 kg, which is more than ten times of the runner cut-off. Scenario C reduces the air emission by 385 kg, which is more than 30 times of the runner cut-off. Of the air emission reduced, over 97% is CO_2, that implies the alternative scenario have great contribution for the mitigation of the global warming potential.

4 Conclusions

The study on the impacts of different processing techniques showed that electroplating is more environmentally friendly than VDM. The energy consumption in VDM will be a "hot spot" for improving the environmental performance of VDM technology. From the perspective of resources conservation, VDM consumes much more resources as compared with e-plating.

Dematerialization is a powerful strategy for resource conservation by reducing the material flow in the process or replacing materials with information or services. One of active potential solutions is to reduce the output of by-product or waste flows from specific processes like molding. A more important and valuable solution is to link industrial processes with the help of material flow analysis and assessment so as to reduce both the material input and waste output to a minimum. The result from scenario analysis showed that the dematerialization strategies should be started from the upper stream of an industrial processing chain, and be carried out throughout the whole life stages. In some cases dematerialization should be started at the product design and process design stages.

LCA is an effective tool to identify environmental burden and dematerialization solutions. It should be disseminated among designers, managers and staff to foster the life cycle management in Motorola Company and in China as well.

References:

Boustead I, Hancock G F, 1979. Handbook of industrial energy analysis[M]. New York: EllisHorwood, Chichester/John Wiley.

Schnecke D, Stutz M, 2000. Metal coated plastic housings: evaluation of the environmental impact[M]. Dublin: International Hermes Symposium.

Wenzel H, Hauschild M, Alting L, 1997. Environmental assessment of products. Volume 1: methodology, tools and case studies in product development[M]. London, United Kingdom Chapman: Hapman & Hall.

Yang J, Nielsen P H, 2001. Chinese life cycle impact assessment factors[J]. Journal of Environmental Sciences, 13(2): 205—209.

(Received for review September 6, 2002. Accepted September 29, 2002)