

Environmental Impacts Research for Scroll Compressor Based on Life Cycle Assessment

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Abstract. This study intends to quantify the energy consumption and environmental emissions in the entire life cycle of a scroll compressor produced in a Chinese factory and to determine the stage with the largest environmental impact. The results show that energy consumption, CO₂ and dust are three predominant impacts along with the entire life cycle of the compressor. The usage process in the compressor life cycle consumes the maximum energy and brings about the largest environmental impacts, followed by raw material acquisition and components manufacturing.

Introduction

As environmental awareness increases, industries and businesses have become concerned about the issues of natural resource depletion and environmental degradation, many companies have found it advantageous to explore ways of moving *beyond* compliance using pollution prevention strategies and environmental management systems to improve their environmental performance. One such tool is LCA [1]. Life Cycle Assessment is a tool to assess the environmental impacts and resources used throughout a product's life cycle, i.e., from raw material acquisition, via reduction and use phases, to waste management [2]. According to EPA, the LCA process is a systematic, phased approach and consists of four components: goal definition and scoping, inventory analysis, impact assessment, and interpretation, as Fig. 1 is shown.

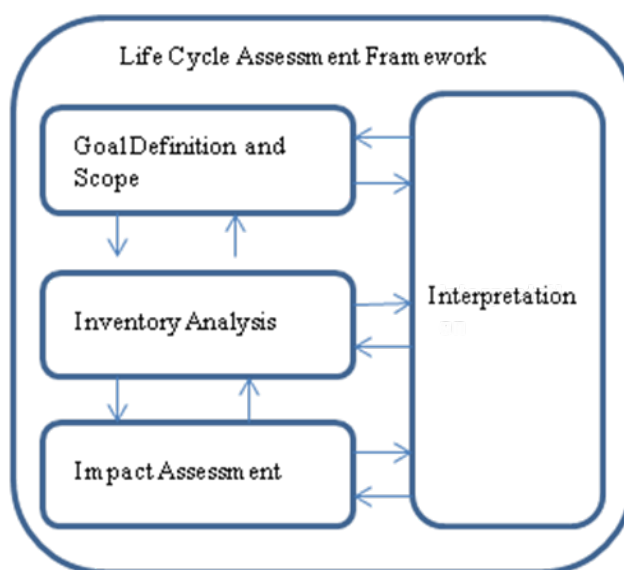


Fig. 1 Life Cycle Assessment Framework

Compressor, as an important component of air conditioner, has strong environmental impact due to its complicated and high precision component manufacturing processes and the large amount of natural resources consumed. Due to the complicated structure and heavy data mining work, the environmental analysis of compressor components has not been conducted intensively in China. No detailed and scientific environmental data can be referred to when drawing up the industrial standards for the Chinese government and decision-makers.

Compressor environment impact based on LCA

Goal and scope definition. The functional unit in this study is defined as “a C-SC 8HP compressor used for 6 years”, which is one component of an air conditioning.

The components considered in this LCA include motor assembly (rotor and stator), sustain assembly (main frame, bearing plate and balance), crank shaft, scroll assembly (orbit scroll and fixed scroll), housing assembly (end cap, bottom, bafflers), known as “five pieces”, which are 95.3% of the total mass of the compressor. The system boundary of this research is shown in Fig. 2.

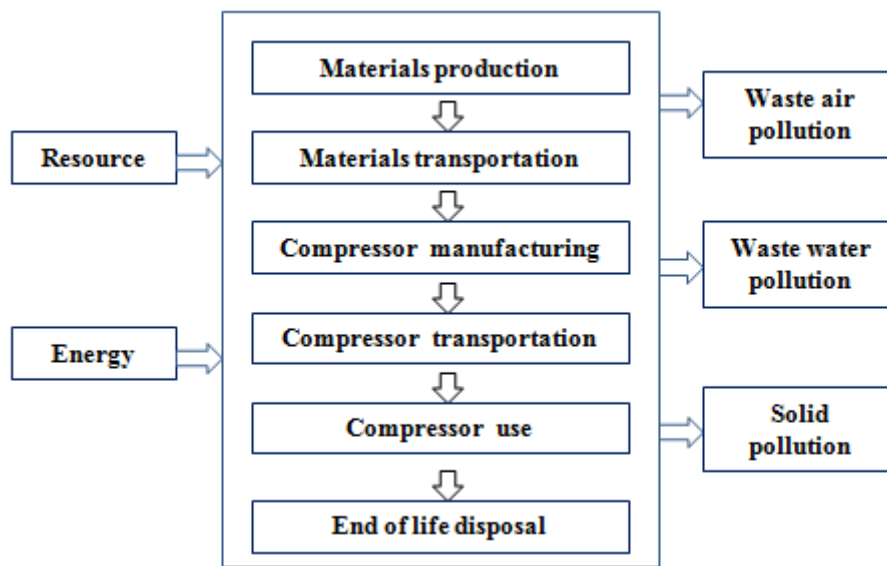


Fig. 2 System boundary of compressor

Life cycle inventory analysis

The LCA analysis includes six processes: materials production, materials transportation, compressor manufacturing, compressor transportation, compressor use, and end-of-life disposal. The database CLCD can be used for the data calculation of energy consumption and environment emission [3].

Materials production. The main materials and the mass of compressor are that, steel 12.51, cast iron 19.28 kg. During the materials production stage, the main energy consumption is coal, natural gas and crude oil, the main emission is CO₂、SO₂、N₂O、CH₄ and other waste water.

Materials transportation. The main materials supplier of Sanyo Compressor Co., Ltd is Anshan Ansteel Group, the transport distance is 300 km from Dalian and the materials are transported by truck (carrying capacity: 10t, the ship consumes gasoline only). The corresponding transportation unit in CLCD can provide the energy inputs and emission outputs in materials transportation.

Compressor manufacturing. The specific energy consumption data during compressor manufacturing stage is obtained from the on-site measurement, the energy consumption is that, motor assembly (29.1kwh); sustain assembly (3.6kwh), crankshaft (3.3kwh), scroll assembly (3.9 kwh), housing assembly (3.1kwh), complete machine assembly (3.5kw), 46.5 kwh totally.

Transportation of scroll compressor. Compressors are generally as one parts of the air conditioner, and be sold to Zhuhai Gree Electric Appliances with the truck (carrying capacity: 10t, the ship consumes gasoline only) to be assembled to air conditioner. The distance from Dalian to Zhuhai is about 2500km.

Use of the scroll compressor. This scroll compressor is generally used in commercial air-conditioner; the energy consumption of the compressor during use stage is mainly the electrical energy consumption. The average service life of the commercial air-conditioner is 6 years, which include 120 working days each year, and 8 working hours one day. The power of the compressor is 3.675 kw/h, therefore, the total energy consumption of the compressor in usage stage is calculated as: $3.675 \times 8 \times 120 \times 6 = 21,168 \text{ kwh}$.

End of life disposal. In the end of disposal processing stage, 90% parts are collected for recycling, including disassembly, classification, cleaning, melting and other steps. The equipment selected in this process is GW-1T metal melting furnace with the power of 600kw, the energy consumption is 500kW/h. Its electricity consumption per tons of steel (alloy), and cast iron are 600 kwh, 560 kwh respectively [4]. The energy consumed in metal recycling is calculated as:

$$(12.51 \times 0.9) \times 0.6 + (19.28 \times 0.9) \times 0.56 = 16.47 \text{ kwh.}$$

According to above analysis, the energy consumption and environmental emissions inventory are shown in Table 1.

Table 1. Energy consumption and environmental emissions of each stage engine

Impact category	Material production		Transportation	Manufacturing	Use	End of disposal	Total
	Steel	Cast iron					
Energy (Coal kgce)	13.36	22.66	7.26	16.83	7660.70	5.96	7726.77
Waste emission (kg)	CO ₂	28.23	42.52	12.20	36.68	51.10	183.63
	SO ₂	0.07	0.09	0.02	0.12	0.52	0.86
	N ₂ O	0.03	0.05	0.20	0.10	0.21	0.63
	CH ₄	0.06	0.10	0.08	0.11	0.19	0.58
	Dust	0.18	0.26	0.01	0.48	0.47	1.57

Environmental impact assessment

The corresponding proportion for each stage of the statistics is shown in Fig. 3.

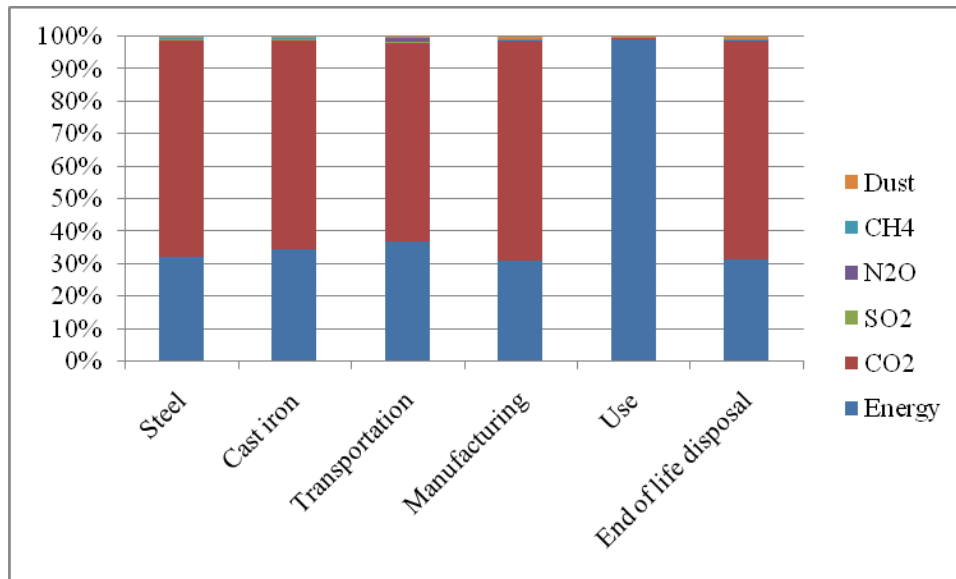


Fig. 3 Compressor energy consumption and environmental emissions proportion for each stage

From Table 1 and Fig. 3, it can be seen that the energy consumption of a new compressor in the life cycle is mostly in the use stage; it is accounted for 99.14.3% of total energy consumption, which is followed by material production, accounted for 0.46% of total energy consumption. For the five kinds of gases (CO₂, SO₂, CH₄, NO_x, dust), CO₂ and dust are the two predominant

emissions. In use stage, waste gas emissions are the most, and in disposal stage, waste gases account for only a small part. Therefore, great efforts should be made in the use stage to improve the energy-saving and emission reduction.

Conclusion

We have successfully conducted an LCA for an original manufactured compressor produced in Dalian Sanyo Co., Ltd, China. The final environmental impacts of the entire life cycle of the diesel compressor show that the use manufacturing stages are predominant impacts along the entire compressor life. The usage process in the engine life cycle consumes the most energy and brings about the largest environmental impact.

This paper applied the typical LCA to complex mechanical products in strict accordance with ISO 14040, the methods dealing with the unit processes can be regarded as a reference for LCA case studies.

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References

- [1] M.A. Curran, Environmental Protection Agency. Life cycle assessment: principles and practice. United States: EPA; May 2006.
- [2] G. Finnveden, M.Z. Hauschild, T. Ekvall, Recent developments in Life Cycle Assessment. *Environ. Manage.* 91 (2009) 1–21
- [3] X.L. Liu, H.T. Wang, J.Chen, Method and basic model for development of Chinese reference life cycle database, *Act. Sci. Circum.* 30 (2010) 2136-2144.
- [4] T. Li, Z.C. Liu, H.C. Zhang, Q.H. Jiang, Environmental emissions and energy consumptions assessment of a diesel engine from the life cycle perspective. *Clean. Prod.* 53 (2013) 7-12.