Proceedings of the 7th World Congress on New Technologies (NewTech'21)
~~Prague, Czech Republic~~ Virtual Conference – August, 2021
Paper No. ICEPR 113
DOI: 10.11159/icepr21.113

Devulcanized Rubber a Solution for Scrap Tire

Abdalrahman Alsulaili[1], Shoug Al Dabbous[1], Dalal Alsuwail[1], Rahaf Al Omar[1], Amina Al Helal[1], and , Muneera Hamadah[1]
[1] Civil Engineering Department, College of Engineering and Petroleum, Kuwait University, P.O.Box-5969, 13060, Safat, Kuwait
a.alsulaili@ku.edu.kw; shouq.aldabbous@ku.edu.kw; Dalalalsuwail@outlook.com; rahaf.alomar@eng.ku.edu.kw; aminaalhelal@outlook.com; Mshamadah@hotmail.com

Abstract - Waste is a major issue around the world with approximately 2.01 billion ton of waste generated annually. which can be Rubber waste from tires is known to be a massive environmental risk to the environment as it is non-biodegradable. However, rubber is an indispensable material of the technological development, from the simplest balloon to the complex rocket propellant. The majority of tires waste are dealt with a non-environmental manner, either dumped in landfills or burnt causing negative impact on human health and environment. Unfortunately, one of the largest tires landfill in the world is located in the state of Kuwait, AlRuhayah. This site host around 50 million dead tires. This study investigates the proper waste management of accumulate tires in Kuwait based on cost, profitability, environmental impact, efficiency, net energy produced, and operation and maintenance. A comparison between reusing, rethreading, pyrolysis, mechanical grinding and devulcanization methods were applied to seek the best method for tire waste management. Out of the eight adequate methods, devulcanization was the superior option due to its efficiency, profitability and least impact on environment. Precise calculations were made concerning different aspects such as transportation, structure and expenses. The total amount of revenue for this 10-year project is $75 million US Dollars and annually produce 24 million kg of rubber. This rubber can be further processed into green concrete, pavements and aerogel. The adaption of the proposed method is of great importance to regulatory bodies to regulate and reduce the tire waste and hence improve the environment and human health.

***Keywords*:** Scrap Tire, Devulcanization Waste Management.

1. Introduction

Around the world, 2.01 billion ton of waste is generated annually of which a minimum of ~33% is not properly managed in an environmental manner [1].

Non-biodegradable solid waste is consider a major source of pollution that cannot be composed by natural organisms such as glass, plastic, paper, artificial rubber [2]. The best solution for this kind of waste is recycling and reusing, which in turn positively affect the environment and human health. One of the main non-biodegradable solid waste is tire waste that is massively available in the open landfills. In fact, 500 million of tires are discarded annually around the globe [3]. These landfills have a severe impact on environment through tire fires [4] and land contaminations [5]. Kuwait has a real case example of a tire landfill (sometimes called, tire graveyard), which contains 50 million tires. This landfill is located in Sulaibiya, Al Jahra and can remotely been seen from space. This site is a source of pollution and is sensitive to massive fire crisis, as evidenced by the huge fire that occurred in 2012 and recently in 2021. This study investigates the proper waste management of accumulate tires in Kuwait based on cost, profitability, environmental impact, efficiency, net energy produced, and operation and maintenance, using eight methods (i.e., reusing, rethreading, pyrolysis, grinding and devulcanization).

2. Methodology

2.1 Comparative Analysis Criteria

A comparative analysis between the eight recycling methods was conducted following the criteria that are mention in Table 1. These criteria were proposed according to the available literature.

Table 1: Criteria percentages.

Criteria	Percentage	Justifications
Cost	20%	Economically feasible
Profitability	5%	The profit isn't as main criteria because we care about improving the environment more than gaining profit
Environmental impact	30%	-Lifelong effect -People's health -Creatures existence -Global warming
Efficiency	20%	-Recyclable -Long term -Less maintenance period --Adequate product -Produces the amount of work in the shortest period of time
Net energy produced	10%	Energy production
Operation and maintenance	15%	-Life span -Acceptable spare parts -Easy to operate -Maintenance cost

2.2. Economic Analysis

The selected recycling method was then economically analysed to calculate the expenses (i.e., fixed and variable cost) and revenue for a 10 years project using the following equations:

$$\textit{Fixed cost} = \textit{Weekly payroll+ structure cost+ machines and material cost+ renting warehouse area} \quad (1)$$

$$\textit{Variable cost} = \textit{total transportation cost+ total maintenance.} \quad (2)$$

$$\textit{Total revenue} = 10\% \textit{ of total machine cost+} \sum \textit{(material production kg/year X material market price)} \quad (3)$$

3. Results

3.1 Comparative Analysis

Table 2 illustrates the comparative analysis of the eight recycling methods by studying six criteria. The total percentage of recycling methods selection criteria ranged from 57.5% (pyrolysis) to 87.5% (devulcanization).

Table 2: Comparative analysis results of the eight recycling methods.

Recycling ways/ criteria	Cost	Profitability	Environmental impact	Efficiency	Net energy produced	Operation and maintenance	Total percentage %
Reusing	20%	0%	30%	5%	9.5%	2.5%	67%
Rethreading	15%	0%	30%	5%	9.5%	2.5%	62%
Water-jet grinding	10%	0%	30%	10%	5%	5%	60%
Mechanical grinding	10%	0%	30%	10%	5%	5%	60%
Cryogenic grinding	10%	0%	30%	10%	5%	5%	60%
Wet grinding	10%	0%	30%	10%	5%	5%	60%
Pyrolysis	10%	2.5%	12.5%	15%	7.5%	10%	57.5%
Devulcanization	15%	2.5%	25%	20%	10%	15%	87.5%

3.2 Expenses and Revenue

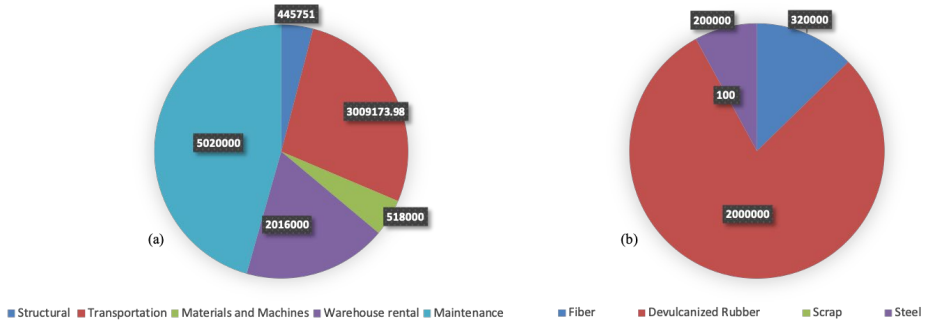

Fig. 1: (a) Expenses and (b) revenue of the project.

Figure 1 shows the total expenses cost of the structure, transportation, materials and machines, warehouse rental and maintenance, as well as an annual project revenue in term of fiber (i.e., 6 million kg), rubber (i.e., 24 million kg), steel (i.e., 6 million kg) and scrap. The total expenses equate 11 million KD per 10 years, while the total revenue was 25 million KD per 10 year, which was calculated using equation 1-3.

3.3 Discussion

By comparing the analysis results, all methods were sufficient and ranged from 57.5% to 87.5%. The devulcanization method showed the best option out of the studied methods in term of its cost (i.e., 15%), profitability (i.e., 2.5%), environmental impact (i.e., 25%), efficiency (i.e., 20%), net energy produced (i.e., 10%), and operation and maintenance (i.e., 15%), with the highest total of 87.5%. Therefore, devulcanization method was selected for further economical analysis in term of expenses and revenue. The expenses were evaluated according to structure, transportation, materials and machines, warehouse rental and maintenance costs. The structure expense reveled a total cost of 445751 KD. The transportation expenses were obtained by calculating labor, trucks, sensors, belt, and fuel costs with respective cost of 1996800, 200926, 47.98, 36400, and 775000 KD. Materials and machines expenses were computed by estimating the cost of keya screw extruder (i.e., 8000KD), twin shaft machine (i.e., 9000KD), Tires (i.e., 500000KD), and other materials (i.e., 1000KD), with a total cost equating 518000 KD. Finally, the warehouse rental and maintenance costs were 2016000 and 5020000 KD. On the other hand, the revenue of the tires recycling using devulcanization method were estimated by calculating the revenue from fiber, rubber, scrap, and steel. The corresponding revenues were 320000, 2000000, 100, 200000 KD. The recycling of tires using devulcanization method yielded a total profit of 14 million KD with a payback period of 4 years in the project lifetime.

4. Conclusions

A solution to a crucial environmental problem (i.e., tires graveyard) in Kuwait was proposed. The adaption of the proposed method is of great importance to regulatory bodies to regulate and reduce the tire waste and hence improve the environment and human health. This method will be beneficial to the environment, economy, health as well as providing space for residential use.

References

[1] S. Kaza, L. Yao, P. Bhada-Tata and F. Van Woerden, "What a waste 2.0: a global snapshot of solid waste management to 2050," World Bank Publications, Washington, DC, 2018.

[2] A. Bharadwaj, D. Yadav and S. Varshney, "Non-Biodegradable waste-ITS impact &safe disposal," *Int. J. Adv. Technol. Eng. Sci,* vol. 3, no. 1, 2015.

[3] B. S. Thomas and R. C. Gupta, "A comprehensive review on the applications of waste tire rubber in cement concrete.," *Renewable and Sustainable Energy Reviews,* vol. 54, pp. 1323-1333, 2016.

[4] D. M. Shane, "Westley Tire Fire, Stanislaus County, California," in *In INTERNATIONAL OIL SPILL CONFERENCE*, 2001.

[5] J. J. Evans, "Rubber Tire Leachates in the Aquatic Environment," in *In: Ware G.W. (eds) Reviews of Environmental Contamination and Toxicology*, New York, NY, Springer, 1997.