



Effective and green tire recycling through microwave pyrolysis

Yu-zhe ZHANG, Ting-ting BIAN, Yi ZHANG, Xu-dong ZHENG, Zhong-yu LI*

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Recycling system; Waste Tires; Microwave; Thermolysis

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➤ Microwave Thermolysis

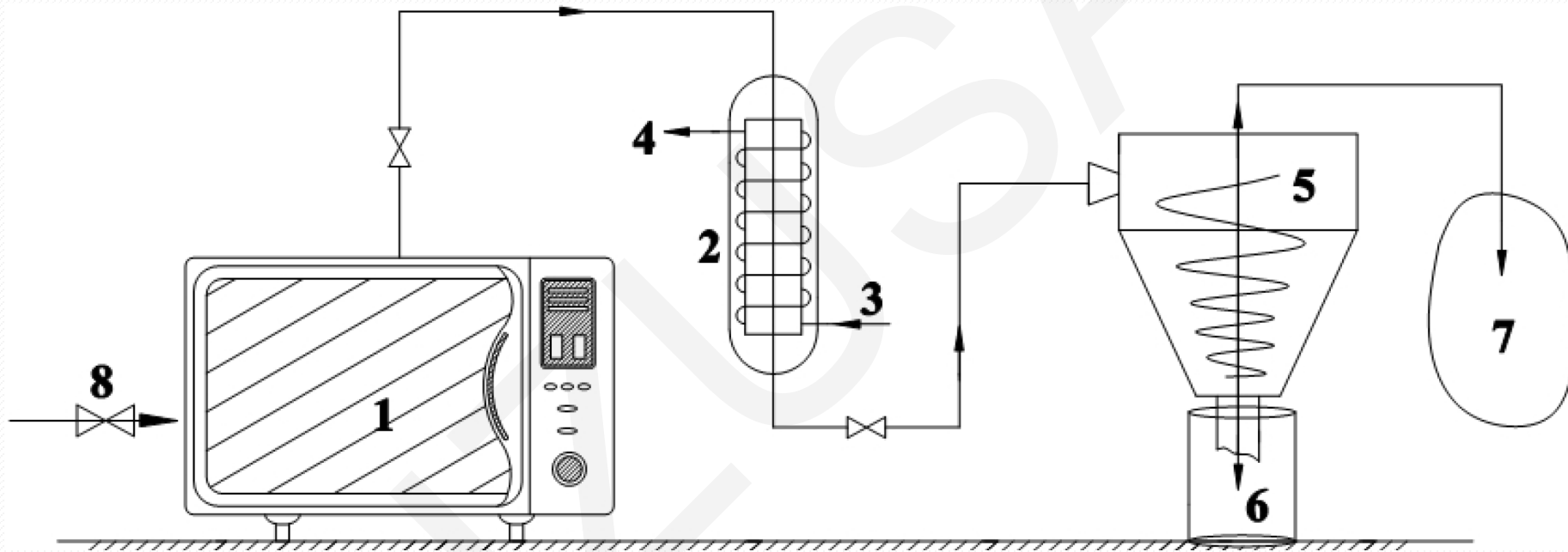


Figure 1. Diagram of the microwave pyrolysis system for tire.

(1) Microwave oven, (2) condenser, (3) inflow condensation water, (4) outflow condensation water, (5) oil-gas separator, (6) oil chamber, (7) reservoir bag, (8) air inlet, which replacing the air with

➤ Calculation Formula

$$\epsilon = \epsilon_0 \epsilon_r = \epsilon_0 (\epsilon_r' - j\epsilon_r'')$$

The permittivity (ϵ) A

$$\epsilon'' = \frac{1}{2\pi f \epsilon_0 R \left(\frac{\pi D^2}{4L} \right)}$$

The dielectric loss factor (ϵ_r'') B

$$D_p = \frac{\lambda_0}{2\pi(2\epsilon_r')^{\frac{1}{2}}} \left\{ \left[1 + \left(\frac{\epsilon_r''}{\epsilon_r'} \right)^2 \right]^{\frac{1}{2}} - 1 \right\}^{-\frac{1}{2}}$$

The penetration depth (D_p) C

$$RL = 20 \log \frac{\left| \sqrt{\frac{\mu_r}{\epsilon_r}} \tanh\left(j \frac{2\pi f}{c} \sqrt{\mu_r \epsilon_r} d\right) - 1 \right|}{\left| \sqrt{\frac{\mu_r}{\epsilon_r}} \tanh\left(j \frac{2\pi f}{c} \sqrt{\mu_r \epsilon_r} d\right) + 1 \right|}$$

The reflection loss (RL) D

➤ Optimal Conditions


As shown in Fig. 2 (a) and (b), there are four different stages. Up to 350 °C, 350 to 450 °C, 450 to 650 °C and above 650 °C. The relative dielectric constant values vary differently with temperature at each stage.

As shown in Fig. 2 (c) and (d), the only difference is that the dielectric loss peak ranges from 450 to 650 °C.

These results suggest that **915-MHz** is the better microwave frequency to use in the recycling system.

Fig. 2. Temperature dependences of dielectric properties of the waste tire samples. Insets: Magnification patterns as temperature varies from 24 to 350 °C.

➤ Optimal Conditions



As shown in Fig. 3, the penetration depth at 915 MHz is always larger than that at 2466 MHz. Based on that, the maximum microwave absorption can be achieved when the frequency is 915 MHz.

Thus, the changes in microwave penetration depth of the tire rubber during the pyrolysis process also show that **915 MHz** is the optimal condition for the recycling of waste tires.

Fig. 3. Temperature dependence of microwave penetration depth of tire

➤ Optimal Conditions

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➤ The components of the product

Table 1. Pyrolysis oil components

Components	Content (%)	Main components	Content (%)
Aliphatic Hydrocarbon	19.8	Pentacosane	1.158
		N-hexacosane	0.923
		1-methyl-4 isopropyl cyclopropane	0.896
		N-heptacosane	0.704
		N-heptadecane	0.452
		DL-limonene	0.421
		Main components	Content (%)
		O-xylene	5.336
Aromatic hydrocarbon	55.2	Methylbenzene	5.268
		Ethylbenzene	2.303
		Trimethylbenzene	2.052
		Trimethyl-naphthalene	1.763
		Benzene	1.532
		Main components	Content (%)
Heteroatom/Polar substance	12.6	Hexahydro-2h-azoketone	4.651
		4-Methylquinoline	2.397
		4-Methylbenzyl phenol	0.319
Asphaltene	12.4	/	/

The product of the waste tire after microwave pyrolysis comprises **35% carbon black, 40% oil and 25% gas**. As shown in Table 1, the oil are composed of 19.8 % aliphatic hydrocarbon, 55.2 % aromatic hydrocarbon, 12.6 % heteroatom/polar substance and 12.4 % asphaltene.

➤ The components of the product

Table 2. Properties of pyrolysis carbon black

Properties	Pyrolysis carbon black
Iodine absorption value g/kg	167
Total surface area 10^3 m ² /kg	63
Adsorption ratio surface area 10^3 m ² /kg	59
External surface area 10^3 m ² /kg	43
Ash content %	10.9

Table 3. Components of pyrolysis gas

Components	Content (%)
Carbon monoxide	3.87%
Hydrogen	8.13%
Methane	29.36%
Hydrogen sulfide	0.102%
Ethane	12.68%
Ethylene	20.03%
Pentane	0.633%

Based on the investigation of the optimal condition of microwave absorption, a proper microwave pyrolysis recycling system was designed for waste tire. This system is efficient at recycling the waste tire rubber into valuable carbon black, oil and gas products. In general, the product of the waste tire after microwave pyrolysis is environmentally friendly, clean and recyclable.



Conclusions

- I . Microwave thermolysis serves as an ideal recycling process for used tires.

- II . The maximum microwave absorption can be achieved when the waste tire thickness is increased to 5 mm at 915 MHz and 592.1 °C , with RL values of -17.30 dB.

- III . A waste tire recycling system will be designed for the waste tires. It has been shown that this system can efficiently recycle the value contents from waste tires such as carbon black, scrap steel, and oil.