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PYROLYSIS OF RUBBER WASTE

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Abstract. Laboratory experiments of thermal destruction of waste tires (scraps of 200 × 300 mm) under standard conditions in retorts with external heating (final temperature 520°C) were carried out. The oil yield was 40–50% on processed rubber basis. Approximately 1/3 of the total oil obtained was the fraction boiling at up to 200°C. The solid residue formed 35% of the initial rubber material. The ash content of the solid residue was 6% and the gross heat of combustion was 28.5 MJ/kg. Metallics present in tire scraps was easily removable.

Key words: waste tires, pyrolysis, solid residue, rubber oil, physical and chemical characteristics.

INTRODUCTION

Rubber waste, especially used tires of cars and other vehicles, has become one of the most serious ecological problems nowadays [1–3]. One can find a large number of patents in which different solutions to the problem are suggested. However, according to the published information no single acceptable solution exists as yet.

In Estonia retorting of crushed tires together with oil shale (in the ratio 1:10) has found industrial use in the solid heat carrier unit at the Estonian Power Plant [4]. This process yields valuable oil. Soot from rubber retorting and metallics

mixed with ash from the solid residue, the so-called black ash, burnt in a fluidized bed furnace are transported to an ash dump. Joonas and co-workers [5] studied possibilities of the utilization of waste tires in vertical retorts widely used in the Estonian oil shale industry. In both cases [4, 5] waste tires were crushed before treatment. This required additional energy and expensive crushing equipment. We studied the possibilities of complete utilization of waste tires without previous crushing using a laboratory retort.

EXPERIMENTAL

To study the possibilities of thermal destruction of tire scraps, a series of laboratory experiments of retorting under standard conditions in retorts with external heating (final temperature 520°C) were carried out. The dimensions of the retort were as follows: height 390 mm, length in the hot zone 250 mm, and diameter 109 mm.

A tire (isoprene type rubber; C, 82.1%; H, 7.2%; scrap 200 × 300 mm; weight 640–835 g) was rolled up and used for one experiment. Rectification of total rubber oil was performed using an APH-2 device.

RESULTS AND DISCUSSION

Ten experiments of laboratory retorting of 7678.0 g of waste tire with a 660.4 g content of metal yielded 3161.0 g of oil, 329.0 g of water, 660.4 g of metal, 2538.8 g of solid residue, and 162.0 g of ash. The main products of thermal destruction were rubber oil and solid residue (respectively 41% and 35% on initial rubber basis). Recalculation of these data to metallic free rubber material showed that the yield of oil might be 45%, which is a very good result.

For the characterization of rubber oil its physical and chemical characteristics were determined and compared with the corresponding parameters of Estonian shale fuel oil (Table 1). It is interesting to say that the sodification temperature of rubber oil was very low (−46°C). The high iodine value (87.3 g of iodine per 100 g of oil) points to a high content of unsaturated compounds.

The rectification of total rubber oil into fractions (Table 2) showed that the gasoline fraction boiling at up to 200°C formed 32.5% of the total oil. The composition of rubber oil fractions will be presented elsewhere.

The solid residue formed at retorting was crumbly and the dry matter and metallics present in the tire scraps were easily removable. The ash content of the solid residue was 6.02% and the gross heat of combustion was 28.5 MJ/kg. The elementary composition of the solid residue (in %) was as follows: C, 88.5; H, 1.70; N, 0.12; and S, 1.09. The main constituent of solid residue was undoubtedly carbon black, which is added to rubber mass.

Table 1. Physical and chemical characteristics of total rubber oil and shale fuel oil

Parameter	Rubber oil	Shale fuel oil
Density, d_{20}^{20} , g/cm ³	0.8980	0.9725
$d_{4,20}^{20}$, g/cm ³	0.8995	—
Kinematic viscosity,		
v_{20} , cSt	4.1	42.1
v_{40} , cSt	2.6	—
Flash point, °C	+5 (in closed crucible)	+26 (in open crucible)
Moisture, W%	0.24	0.43
Sulphur, %	0.64	0.81
Cl ⁻ and SO ₄ ²⁻ , %	0	0.07
Active sulphur compounds	0	0
Sodification temperature, °C	-46	-34
pH of water under oil	3.82	—
Acidity, recalculated to HCl%	0.11	—
Iodine value, g of iodine per 100 g of oil	87.3	—

— not determined.

Table 2. Material balance of rectification of waste tire oil

Material	Into		Product	Out	
	g	%		g	%
Retorting oil	1760.0	100.0	Water	4.1	0.2
incl. water	4.3	0.2	Oil fractions, °C		
oil	1755.7	99.8	to 160	347.5	19.7
Total	1760.0	100.0	160-180	180.6	10.3
			180-200	44.3	2.5
			200-240	51.3	2.9
			240-260	130.2	7.4
			260-280	181.0	10.3
			280-300	85.8	4.9
			300-320	26.2	1.5
			320-340	74.3	4.2
			340-360	92.2	5.3
			Total oil	1213.4	69.0
			Distillation residue	542.5	30.8
			Total	1760.0	100.0

CONCLUSION

The results of laboratory retorting showed that the utilization of large tire scraps is technically possible with oil, solid residue, and metal produced.

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KASUTATUD KUMMIJÄÄTMETE TERMILISEST DESTRUKTSIOONIST

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Korraldati katseseeria, et uurida autorehvi tükkide (200 × 300 mm) termilist lagundamist laboratoorses retordis (lõpptemperatuuriga 520°C). Põhilisteks utteproduktideks olid õli ja poolkoks vastavalt 45 ja 38% metallivaba kummimaterjali kohta. Saadud poolkoks oli metallkoordist kergesti eraldatav ja sisaldas peamiselt kummimassile lisatud tahma. Kummiõli tehnilistest parameetritest äratas tähelepanu õli madal hangumistemperatuur (–46°C) ja suur joodiarv (87,3 g 100 g õli kohta), mis viitas õli kõrgele küllastumatuse astmele. Õli rektifikatsioonil saadi alla 200°C keeva osa (bensiinifraktsiooni) üle 30% summaarsest õlist.