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APPENDICES

Appendix A Raw Data

Table A-1 The product distributions of aged rubber compounds

Sample	% Yield		
	Gas	Liquid	Solid
RCP[a]0[b]	20.7	39.2	40.1
RCP1	20.3	39.8	39.9
RCP2	17.1	42.4	40.5
RCP3	16.1	44.4	39.5
RCP4	25.3	35.0	39.7

[a] rubber compound

[b] aging times

Table A-2 The gas composition of aged rubber compounds showed in % volume from GC with FID

Gases	% Volume				
	RCP0	RCP1	RCP2	RCP3	RCP4
Methane	28.4	29.2	29.1	29.6	28.4
Ethylene	5.42	5.51	5.50	5.62	5.55
Ethane	13.3	13.7	13.4	13.6	13.2
Propylene	5.22	5.25	5.34	5.35	5.18
Propane	6.89	6.86	7.01	6.98	6.68
C_4	14.8	15.5	15.0	15.8	14.2
C_5	15.3	13.5	13.0	14.1	13.1
C_6	7.23	6.66	6.71	6.78	8.40
C_7	1.79	2.01	2.50	1.01	3.00
C_8	1.64	1.81	2.44	0.98	2.28

[a] rubber compound

[b] aging times

Table A-3 Amount of hydrocarbons in liquid products from pyrolysis of aged rubber compounds analyzed by DGC with FID

Carbon number	Boiling Point	% Mass				
		RCP[a]0[b]	RCP1	RCP2	RCP3	RCP4
6	69.9		0.05			0.33
7	98.4	0.26	0.79			0.92
8	125.1	1.18	0.92	1.10	0.7	1.06
9	150.1	1.33	1.07	1.47	1.0	1.20
10	173.6	1.47	1.23	1.62	1.1	1.34
11	195.6	1.61	1.39	1.77	1.3	1.48
12	216.3	1.76	1.56	1.91	1.4	1.63
13	235.8	1.90	1.73	2.05	1.6	1.77
14	254.0	2.03	1.90	2.19	1.8	1.91
15	271.3	2.16	2.07	2.32	1.9	2.05
16	287.5	2.29	2.24	2.44	2.1	2.18
17	302.8	2.41	2.41	2.56	2.3	2.31
18	317.4	2.52	2.58	2.68	2.4	2.43
19	331.1	2.64	2.74	2.79	2.6	2.56
20	344.2	2.75	2.91	2.90	2.8	2.68
21	356.6	2.86	3.07	3.00	3.0	2.80
22	368.5	2.96	3.23	3.10	3.1	2.92
23	379.9	3.07	3.38	3.20	3.3	3.04
24	390.8	3.17	3.53	3.31	3.5	3.16
25	401.2	3.27	3.67	3.41	3.7	3.28
26	411.3	3.37	3.80	3.51	3.8	3.41
27	421.0	3.47	3.91	3.61	4.0	3.53
28	430.5	3.55	4.00	3.70	4.2	3.66
29	439.6	3.63	4.06	3.79	4.3	3.79
30	448.4	3.69	4.08	3.86	4.4	3.92
31	457.0	3.73	4.05	3.91	4.4	4.03
32	465.4	3.74	3.96	3.92	4.4	4.13
33	473.5	3.70	3.81	3.88	4.3	4.20
34	481.3	3.62	3.60	3.77	4.1	4.21
35	489.0	3.48	3.34	3.58	3.8	4.13
36	496.4	3.28	3.04	3.30	3.4	3.92
37	503.5	3.03	2.70	2.94	3.0	3.54
38	510.4	2.73	2.36	2.53	2.6	3.01
39	517.0	2.40	2.03	2.09	2.1	2.40
40	523.2	2.07	1.71	1.68	1.7	1.78
41	529.1	1.74	1.42	1.31	1.4	1.25
42	534.7	1.44	1.17	1.00	1.1	0.85
43	539.8	1.17	0.95	0.75	0.8	0.56
44	544.5	0.94	0.76	0.55	0.6	0.37
45	548.6	0.73	0.60	0.40	0.5	0.24
46	552.2	0.57	0.47	0.29	0.4	0.16
47	555.2	0.42	0.35	0.21	0.3	0.10
48	557.5	0.30	0.25	0.14	0.2	0.06
49	559.1	0.19	0.16	0.09	0.1	0.04

[a] rubber compound

[b] aging times

Table A-4 Oil fractions from pyrolysis of aged rubber compounds shown in %Mass

Fraction	Boiling Point (°C)	% Mass				
		RCP[a]0[b]	RCP1	RCP2	RCP3	RCP4
Gasoline	69.6-149	2.71	2.78	2.50	1.56	3.45
Kerosine	149-232	6.41	5.60	7.04	5.08	5.92
Gas oil	232-343	16.9	16.9	18.0	16.0	16.2
Fuel Oil	343-371	6.73	7.28	7.06	7.08	6.62
Heavy vacuum gas oil	371-559.1	65.8	66.4	64.0	69.6	66.1

[a] rubber compound

[b] aging times

Table A-5 The product distributions of tire co-pyrolysed with various $\%SO_4^{2-}$ of ZrO_2/SO_4^{2-}

Sample	% Yield		
	Gas	Liquid	Solid
Tire	19.3	39.8	40.9
WTZ[a]0[b]	30.7	30.2	39.1
WTZ2	30.4	31.8	37.8
WTZ4	29.5	32.8	37.7
WTZ6	29.3	33.7	37.0
WTZ8	29.7	32.3	38.0

[a] Waste tire co-pyrolysed with ZrO_2/SO_4^{2-}

[b] % SO_4^{2-} of ZrO_2/SO_4^{2-}

Table A-6 The gas compositions of tire co-pyrolysed with ZrO_2/SO_4^{2-} at various $\%SO_4^{2-}$ shown in % volume from GC with FID

Gases	% Volume					
	Tire	WTZ[a]0[b]	WTZ2	WTZ4	WTZ6	WTZ8
Methane	28.9	26.6	25.7	25.7	24.7	24.9
Ethylene	6.25	6.65	6.22	6.22	6.16	6.63
Ethane	14.5	13.3	13.4	13.5	13.2	13.5
Propylene	5.47	5.34	5.15	5.23	5.15	5.40
Propane	6.33	5.50	5.67	5.85	5.68	5.72
C_4	17.0	20.4	18.8	18.8	19.5	20.4
C_5	8.94	9.76	11.4	11.5	12.6	10.3
C_6	7.16	7.42	7.19	7.43	7.55	7.52
C_7	1.97	1.67	2.03	2.09	1.84	2.03
C_8	3.46	3.35	4.44	3.68	3.62	3.60

[a] Waste tire co-pyrolysed with ZrO_2/SO_4^{2-}

[b] % SO_4^{2-} of ZrO_2/SO_4^{2-}

Table A-7 Amount of hydrocarbons in liquid products from pyrolysis of tire co-pyrolysed with ZrO_2/SO_4^{2-} at various $\%SO_4^{2-}$ analyzed by DGC with FID

Carbon number	Boiling Point (°C)	%Mass					
		Tire	WTZ[a]0[b]	WTZ2	WTZ4	WTZ6	WTZ8
6	69.9				0.22		0.20
7	98.4			0.41	0.50		0.61
8	125.1	0.88	0.90	0.72	0.65	0.91	0.76
9	150.1	1.80	1.07	0.90	0.83	1.32	0.94
10	173.6	1.95	1.23	1.11	1.05	1.55	1.14
11	195.6	2.09	1.40	1.34	1.29	1.79	1.36
12	216.3	2.23	1.58	1.60	1.56	2.04	1.59
13	235.8	2.36	1.76	1.88	1.85	2.29	1.84
14	254.0	2.48	1.95	2.17	2.16	2.54	2.10
15	271.3	2.60	2.13	2.47	2.49	2.78	2.36
16	287.5	2.71	2.32	2.77	2.81	3.00	2.62
17	302.8	2.81	2.50	3.07	3.13	3.21	2.87
18	317.4	2.90	2.68	3.35	3.44	3.40	3.12
19	331.1	2.99	2.86	3.62	3.71	3.55	3.34
20	344.2	3.08	3.03	3.85	3.96	3.68	3.54
21	356.6	3.16	3.20	4.05	4.15	3.78	3.72
22	368.5	3.23	3.37	4.20	4.30	3.85	3.86
23	379.9	3.30	3.52	4.31	4.40	3.88	3.97
24	390.8	3.37	3.67	4.37	4.44	3.88	4.04
25	401.2	3.43	3.80	4.38	4.42	3.86	4.07
26	411.3	3.49	3.91	4.33	4.35	3.80	4.06
27	421.0	3.53	4.00	4.24	4.23	3.73	4.02
28	430.5	3.57	4.06	4.11	4.07	3.62	3.94
29	439.6	3.58	4.08	3.94	3.87	3.50	3.82
30	448.4	3.58	4.06	3.74	3.65	3.37	3.68
31	457.0	3.54	3.99	3.51	3.41	3.21	3.51
32	465.4	3.47	3.87	3.27	3.16	3.05	3.32
33	473.5	3.37	3.71	3.02	2.90	2.88	3.12
34	481.3	3.22	3.50	2.76	2.65	2.70	2.90
35	489.0	3.03	3.25	2.51	2.40	2.51	2.68
36	496.4	2.81	2.97	2.27	2.16	2.33	2.46
37	503.5	2.56	2.67	2.03	1.93	2.15	2.24
38	510.4	2.28	2.37	1.81	1.72	1.96	2.02
39	517.0	2.01	2.08	1.60	1.52	1.79	1.82
40	523.2	1.73	1.79	1.41	1.33	1.61	1.62
41	529.1	1.47	1.53	1.23	1.16	1.45	1.43
42	534.7	1.23	1.29	1.06	1.01	1.28	1.25
43	539.8	1.02	1.08	0.91	0.86	1.13	1.09
44	544.5	0.83	0.89	0.77	0.73	0.98	0.93
45	548.6	0.66	0.72	0.65	0.61	0.83	0.78
46	552.2	0.52	0.57	0.53	0.50	0.69	0.64
47	555.2	0.40	0.44	0.42	0.39	0.56	0.51
48	557.5	0.29	0.32	0.31	0.29	0.42	0.38
49	559.1	0.18	0.21	0.20	0.19	0.28	0.25

[a] Waste tire co-pyrolysed with ZrO_2/SO_4^{2-}

[b] % SO_4^{2-} of ZrO_2/SO_4^{2-}

Table A-8 Oil fraction of tire co-pyrolysed with ZrO_2/SO_4^{2-} at various $\%SO_4^{2}$shown in %Mass by model

Fraction	Boiling Point (°C)	% Mass					
		Tire	WTZ[a]0[b]	WTZ2	WTZ4	WTZ6	WTZ8
Gasoline	69.6-149	2.59	1.90	1.98	2.16	2.17	2.46
Kerosine	149-232	8.24	5.70	5.58	5.40	7.26	5.59
Gas oil	232-343	19.8	17.5	21.3	21.7	22.3	20.0
Fuel Oil	343-371	7.39	7.60	9.54	9.78	8.81	8.77
Heavy vacuum gas oil	371-559	61.7	67.6	62.7	61.4	60.6	63.7

[a] Waste tire co-pyrolysed with ZrO_2/SO_4^{2-}

[b] % SO_4^{2-} of ZrO_2/SO_4^{2-}

Table A-9 The product distributions of tire co-pyrolysed with various catalyst : tire ratios

Sample	% Yield		
	Gas	Liquid	Solid
R 0.00[a]	19.2	39.8	40.8
R 0.11	20.3	40.2	39.5
R 0.25	18.5	40.6	40.9
R 0.50	29.5	32.8	37.7
R 1.00	28.3	35.8	35.9

[a] ratio of catalyst to tire

Table A-10 The gas composition of tire co-pyrolysed with various catalyst: tire ratio shown in %volume from GC with FID

Gases	% Volume				
	R 0.00[a]	R 0.11	R 0.25	R 0.50	R 1.00
Methane	10.5	11.12	12.2	8.88	7.57
Ethylene	3.98	4.12	4.32	3.75	3.62
Ethane	9.86	10.4	10.7	8.79	7.49
Propylene	5.22	5.41	5.70	4.74	4.27
Propane	6.33	6.65	6.66	5.55	4.60
C_4	22.0	23.5	25.4	23.1	23.1
C_5	14.6	14.7	14.6	17.9	14.2
C_6	14.0	13.1	12.8	13.8	14.5
C_7	4.48	4.19	2.89	4.48	5.21
C_8	8.95	6.78	4.74	9.00	15.4

[a] ratio of catalyst to tire

Table A-11 Amount of hydrocarbons in liquid products from pyrolysis of tire co-pyrolysed with various catalyst : tire ratio analyzed by DGC with FID

Carbon number	Boiling Point	% Mass				
		R 0.00[a]	R 0.11	R 0.25	R 0.50	R 1.00
6	69.9			1.03	0.22	
7	98.4		0.35	0.38	0.50	
8	125.1	0.88	1.28	0.53	0.65	
9	150.1	1.80	1.46	0.74	0.83	
10	173.6	1.95	1.65	1.00	1.05	0.50
11	195.6	2.09	1.84	1.31	1.29	1.17
12	216.3	2.23	2.03	1.68	1.56	1.35
13	235.8	2.36	2.21	2.10	1.85	1.53
14	254.0	2.48	2.40	2.56	2.16	1.72
15	271.3	2.60	2.57	3.05	2.49	1.91
16	287.5	2.71	2.74	3.54	2.81	2.11
17	302.8	2.81	2.90	4.02	3.13	2.31
18	317.4	2.90	3.05	4.45	3.44	2.51
19	331.1	2.99	3.19	4.80	3.71	2.71
20	344.2	3.08	3.32	5.06	3.96	2.91
21	356.6	3.16	3.42	5.21	4.15	3.11
22	368.5	3.23	3.52	5.24	4.30	3.30
23	379.9	3.30	3.59	5.17	4.40	3.49
24	390.8	3.37	3.65	5.00	4.44	3.67
25	401.2	3.43	3.68	4.75	4.42	3.84
26	411.3	3.49	3.69	4.44	4.35	3.99
27	421.0	3.53	3.68	4.10	4.23	4.12
28	430.5	3.57	3.64	3.73	4.07	4.22
29	439.6	3.58	3.57	3.37	3.87	4.28
30	448.4	3.58	3.48	3.01	3.65	4.29
31	457.0	3.54	3.37	2.67	3.41	4.26
32	465.4	3.47	3.23	2.36	3.16	4.17
33	473.5	3.37	3.07	2.07	2.90	4.03
34	481.3	3.22	2.89	1.81	2.65	3.84
35	489.0	3.03	2.70	1.57	2.40	3.59
36	496.4	2.81	2.50	1.37	2.16	3.32
37	503.5	2.56	2.29	1.18	1.93	3.01
38	510.4	2.28	2.08	1.02	1.72	2.69
39	517.0	2.01	1.87	0.87	1.52	2.37
40	523.2	1.73	1.67	0.75	1.33	2.06
41	529.1	1.47	1.48	0.64	1.16	1.77
42	534.7	1.23	1.29	0.54	1.01	1.50
43	539.8	1.02	1.12	0.46	0.86	1.26
44	544.5	0.83	0.95	0.38	0.73	1.04
45	548.6	0.66	0.80	0.31	0.61	0.85
46	552.2	0.52	0.66	0.25	0.50	0.68
47	555.2	0.40	0.52	0.20	0.39	0.52
48	557.5	0.29	0.39	0.15	0.29	0.38
49	559.1	0.18	0.26	0.10	0.19	0.25

[a] ratio of catalyst to tire

Table A-12 Oil fraction of tire co-pyrolysed with various catalyst: tire ratio shown in %Mass by model

Fraction	Boiling Point (°C)	% Mass				
		R 0.00 [a]	R 0.11	R 0.25	R 0.50	R 1.00
Gasoline	69.6-149	2.59	3.00	2.64	2.16	-
Kerosine	149-232	8.24	7.34	5.67	5.40	4.23
Gas oil	232-343	19.8	20.3	27.5	21.7	16.2
Fuel Oil	343-371	7.39	8.02	12.1	9.78	7.43
Heavy vacuum gas oil	371-559	61.7	61.3	51.1	61.4	72.8

[a] ratio of catalyst to tire

Table A-13 The organic carbon in solid residues of aged rubber compounds, tire co-pyrolysed with ZrO_2/SO_4^{2-} at various $\%SO_4^{2-}$, tire co-pyrolysed with various catalyst: tire ratios shown in % weight

Sample	% Weight	
	Inorganic Residue	Organic Carbon
RCP[a]0[b]	7.85	92.2
RCP1	8.33	91.7
RCP2	8.10	91.9
RCP3	8.30	91.7
RCP4	8.30	91.7
Tire	16.5	83.5
WTZ[c]0[d]	16.2	83.8
WTZ2	18.3	81.7
WTZ4	16.1	83.9
WTZ6	17.2	82.8
WTZ8	21.3	78.7
R 0.00[e]	16.5	83.5
R 0.11	15.2	84.8
R 0.25	16.9	83.1
R 0.50	16.1	83.9
R 1.00	17.8	82.2

[a] rubber compound

[b] aging times

[c] Waste tire co-pyrolysed with ZrO_2/SO_4^{2-}

[d] % SO_4^{2-} of ZrO_2/SO_4

[e] ratio of catalyst to tire

Table A-14 The curve fitting and equation of % OFF of aged rubber compounds

$y = y_o + \frac{a}{\left[\left(1+e^{-\left(\frac{x-x_o}{b}\right)}\right)\right]}c$	Parameter	Coefficient	R^2
RCP[a]0[b]	a	107.393	0.99972174
	b	24.0125	
	c	0.1656	
	x_o	520.173	
	y_o	-5.5975	
RCP1	a	105.0765	0.99985130
	b	28.5676	
	c	0.2358	
	x_o	502.1591	
	y_o	-2.9175	
RCP2	a	106.7039	0.99976428
	b	18.5555	
	c	0.1231	
	x_o	512.8172	
	y_o	-7.0524	
RCP3	a	104.1937	0.99988707
	b	22.4441	
	c	0.1941	
	x_o	503.9794	
	y_o	-3.282	
RCP4	a	102.3127	0.99934792
	b	12.7777	
	c	0.093	
	x_o	514.9334	
	y_o	-3.6839	

[a] rubber compound

[b] aging times

Table A-15 The curve fitting and equation of % OFF of tire co-pyrolysed with ZrO_2/SO_4^{2-}

$y = y_o + \frac{a}{\left[\left(1+e^{-\left(\frac{x-x_o}{b}\right)}\right)\right]}c$	Parameter	Coefficient	R^2
Tire	a	113.6842	0.99982224
	b	28.6036	
	c	0.1704	
	x_o	514.6187	
	y_o	-10.2836	
WTZ[a]0[b]	a	108.8422	0.99979960
	b	34.2582	
	c	0.2924	
	x_o	498.7826	
	y_o	-3.5788	
WTZ2	a	110.1107	0.99965825
	b	52.404	
	c	0.5982	
	x_o	448.9839	
	y_o	-1.6004	
WTZ4	a	108.5783	0.99976101
	b	53.9779	
	c	0.6577	
	x_o	439.5238	
	y_o	-0.9782	
WTZ6	a	118.3624	0.99965237
	b	64.3649	
	c	0.609	
	x_o	459.7268	
	y_o	-4.0596	
WTZ8	a	111.9381	0.99969754
	b	55.0624	
	c	0.5873	
	x_o	461.7913	
	y_o	-1.5148	

[a] Waste tire co-pyrolysed with ZrO_2/SO_4^{2-}

[b] % SO_4^{2-} of ZrO_2/SO_4^{2-}

Table A-16 The curve fitting and equation of % OFF of tire co-pyrolysed with various catalysts to tire ratios

$y = y_o + \frac{a}{\left[\left(1+e^{-\left(\frac{x-x_o}{b}\right)}\right)\right]}c$	Parameter	Coefficient	R^2
R 0.00[a]	a	113.6842	0.99982224
	b	28.6036	
	c	0.1704	
	x_o	514.6187	
	y_o	-10.2836	
R 0.11	a	114.3135	0.99989275
	b	47.974	
	c	0.3653	
	x_o	492.6158	
	y_o	-5.3311	
R 0.25	a	101.797	0.99959161
	b	50.9986	
	c	0.7776	
	x_o	397.0371	
	y_o	0.3322	
R 0.50	a	108.5783	0.99976101
	b	53.9779	
	c	0.6577	
	x_o	439.5238	
	y_o	-0.9782	
R 1.00	a	111.2513	0.99960512
	b	34.6044	
	c	0.3263	
	x_o	500.8223	
	y_o	-4.5886	

[a] ratio of catalyst to tire

Appendix B Physical Properties

Table B-1 The hardness of aged rubber compounds

Sample	Hardness (shore A)						
	1	2	3	4	5	AVG.	STD.
RCP[a]0[b]	58.0	58.0	58.5	58.0	58.0	58.1	0.204
RCP1	62.0	62.0	62.0	62.0	62.0	62.0	0
RCP2	66.0	66.5	66.5	66.0	66.0	66.2	0.258
RCP3	68.0	68.0	68.0	68.0	68.0	68.0	0
RCP4	70.0	70.0	70.0	70.0	70.0	70.0	0

[a] Rubber compound
[b] aging times

Table B-2 The density of aged rubber compounds

Sample	Density (g/cc)				
	1	2	3	AVG.	STD.
RCP[a]0[b]	1.239834393	1.24534461	1.245049321	1.243409442	0.002530814
RCP1	1.237459796	1.241800467	1.242757106	1.240672456	0.00230502
RCP2	1.251036116	1.240566038	1.235078457	1.24222687	0.006619692
RCP3	1.244422027	1.239434955	1.239396628	1.241084537	0.002360014
RCP4	1.242640792	1.244173068	1.241659566	1.242824475	0.00103432

[a] Rubber compound
[b] aging times

Table B-3 The density of swollen rubber compounds

Sample	Density (g/cc)					
	1	2	3	4	AGV.	STD
RCP[a]0[b]	1.008584196	1.007169306	1.004974351	1.004119581	1.006211858	0.002037461
RCP1	1.035743241	1.035366267	1.029147216	1.034911069	1.033791948	0.003115124
RCP2	1.033267483	1.033441252	1.037319296	1.041489628	1.036379415	0.003886497
RCP3	1.036946658	1.044645918	1.042548775	1.048187445	1.043082199	0.004705959
RCP4	1.050863684	1.052344822	1.061418902	1.067201518	1.057957231	0.007729975

[a] Rubber compound
[b] aging times

Table B-4 The measured volume fraction of rubbers in the swollen vulcanizate samples

Sample	Volume Fraction				
	1	2	3	AVG.	STD.
RCP[a]0[b]	0.21751766	0.214568292	0.225971065	0.217421739	0.006185663
RCP1	0.23861812	0.234085349	0.2375742	0.242550156	0.011742915
RCP2	0.238899118	0.239254006	0.243600826	0.242456918	0.004311751
RCP3	0.241365059	0.243064589	0.246494374	0.245245132	0.003852256
RCP4	0.253084582	0.252952635	0.252491639	0.252062162	0.001582133

[a] Rubber compound
[b] aging times

Table B-5 The C_1 value of aged rubber compounds

Sample	C_1 Value				
	1	2	3	AVG.	STD.
RCP[a]0[b]	0.648618943	0.634072258	0.691375067	0.65802209	0.029786194
RCP1	0.758352834	0.733926052	0.75268501	0.748321299	0.012784694
RCP2	0.759882817	0.761817743	0.785757113	0.769152558	0.014412475
RCP3	0.773388548	0.78277983	0.801940236	0.786036205	0.014551725
RCP4	0.839546295	0.838783062	0.836119812	0.838149723	0.001798898

[a] Rubber compound
[b] aging times

Table B-6 Crosslink density value of rubber compounds

Sample	Crosslink Density ($x10^4$ mol/cm^3)				
	1	2	3	AVG.	STD.
RCP[a]0[b]	1.957781	1.927572	2.052238	1.979196665	0.065034
RCP1	2.219735	2.155632	2.204529	2.193298815	0.033495
RCP2	2.223853	2.22911	2.296238	2.249733478	0.040359
RCP3	2.261084	2.287692	2.343931	2.297569108	0.042297
RCP4	2.462549	2.460024	2.451253	2.457941788	0.005929

[a] Rubber compound

[b] aging times

Table B-7 The molecular weight per crosslink

Sample	Molecular weight per crosslink (x 10^{-4} g/mol)				
	1	2	3	AVG.	STD.
RCP[a]0[b]	0.2553912	0.25939374	0.24363651	0.25280715	0.00819027
RCP1	0.22525211	0.23195051	0.2268058	0.22800281	0.00350596
RCP2	0.22483503	0.22430475	0.21774751	0.22229576	0.00394782
RCP3	0.22113283	0.21856089	0.21331687	0.2176702	0.00398338
RCP4	0.20304167	0.20325007	0.20397732	0.20342302	0.00049122

[a] Rubber compound
[b] aging times

Appendix C Chromatograms

Max. Torque	Min. Torque	TC10	TC50	TC90
57.00	13.97	4.71	6.58	10.96

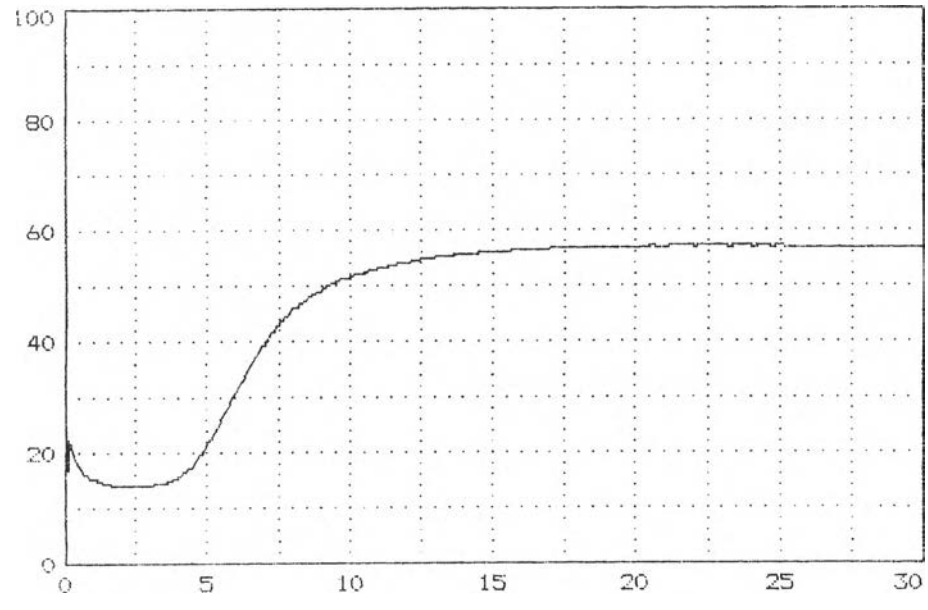

Figure C-1 Chromatogram of cure time of non-aged rubber compound.

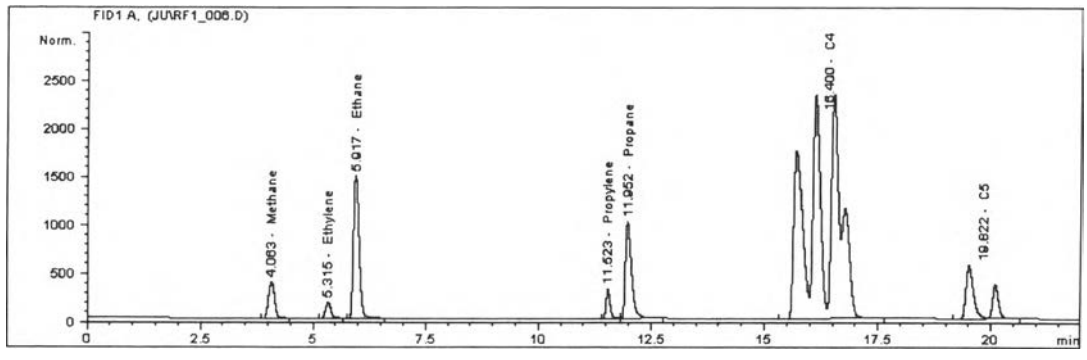

Figure C-2 Chromatogram of standard gas for GC calibration.

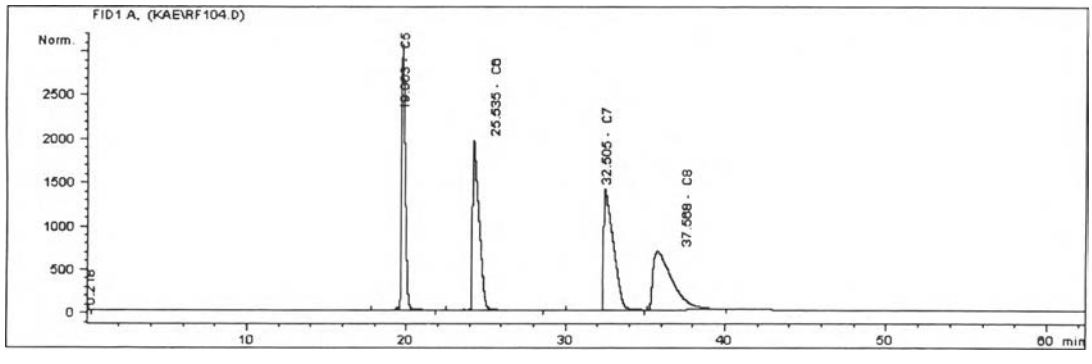

Figure C-3 Chromatogram of liquid standard for calibration GC.

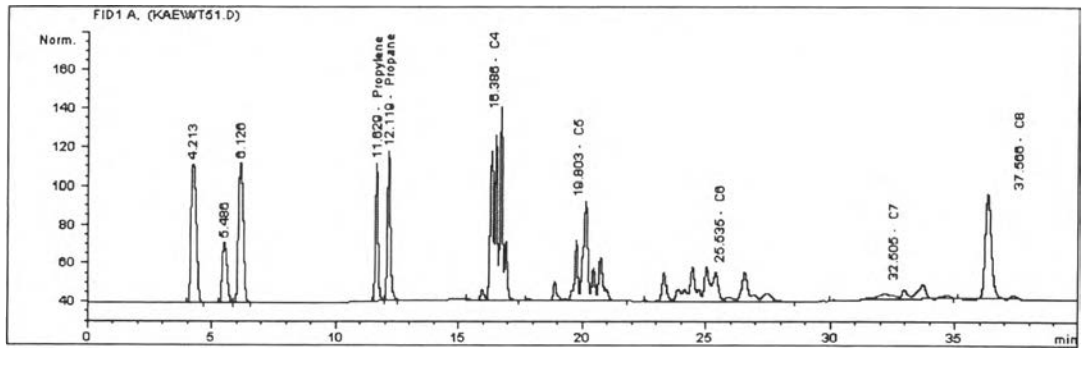

Figure C-4 Chromatogram of gas product from pyrolysis of waste tire analyzed by GC.

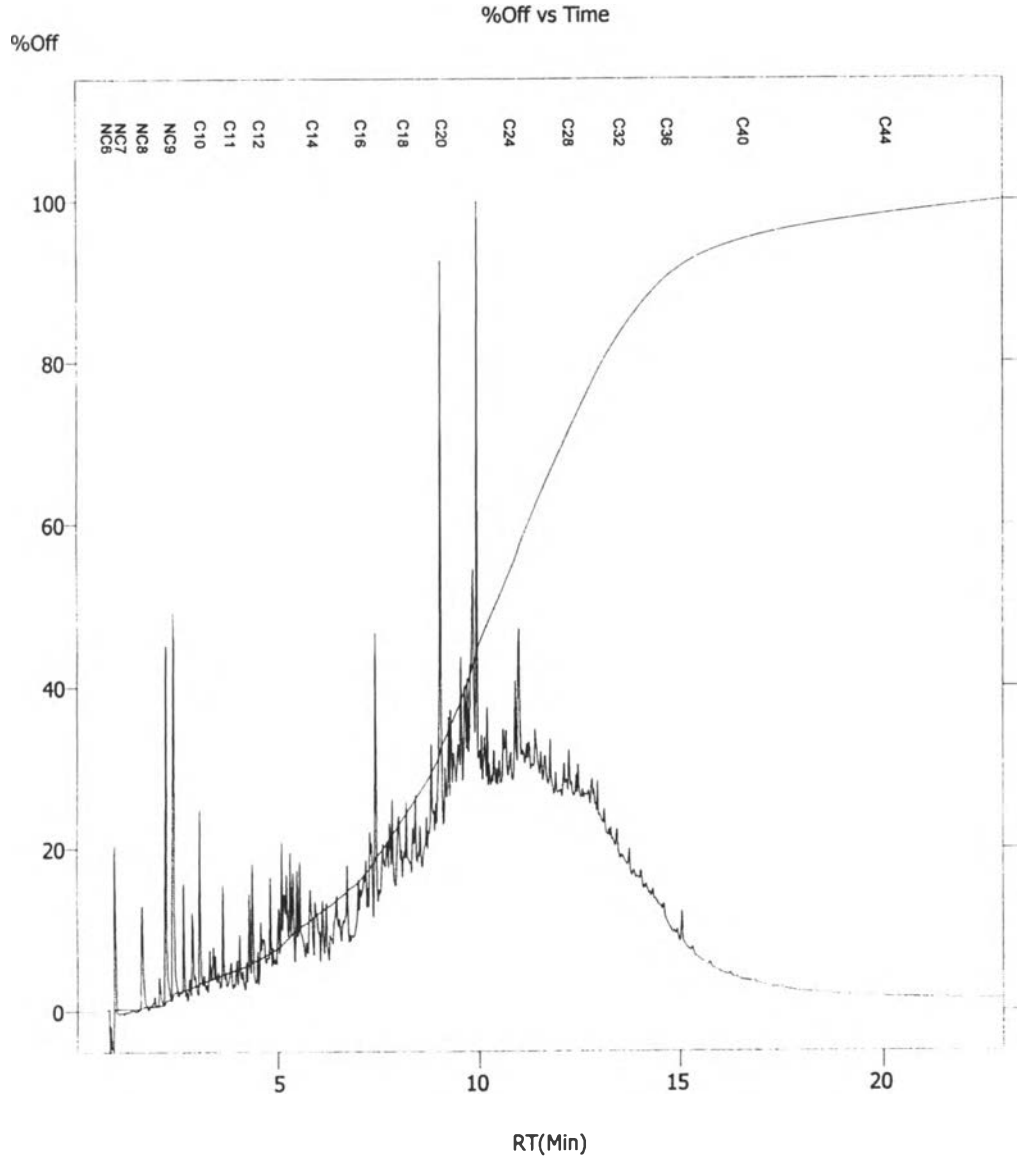

Figure C-5 Chromatogram of liquid sample from pyrolysis of waste tire with catalyst to tire ratio at 0.25.

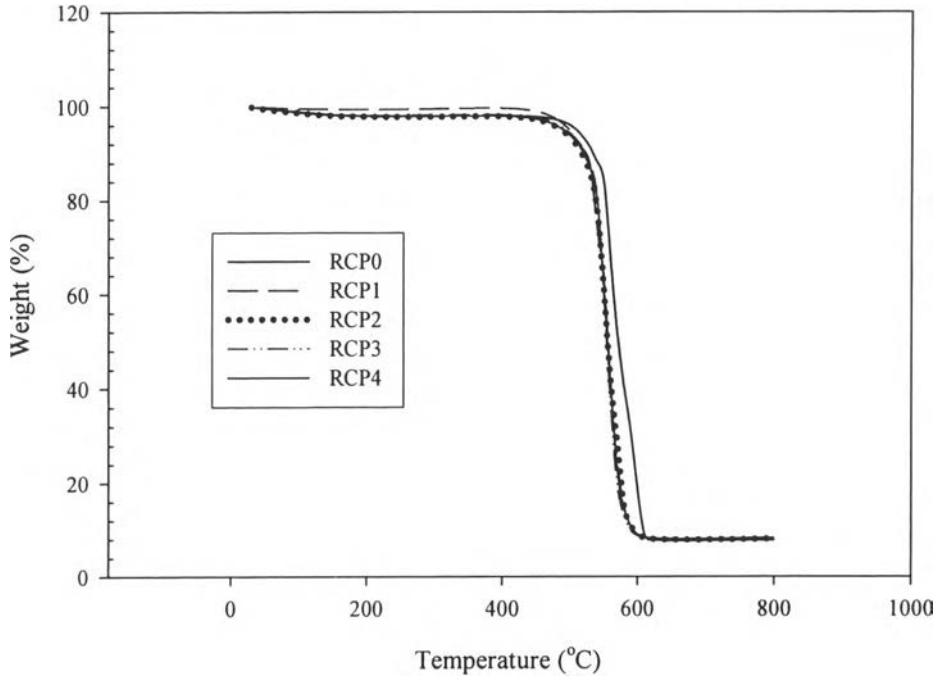

Figure C-6 TGA curves of solid residues of aged rubber compound.

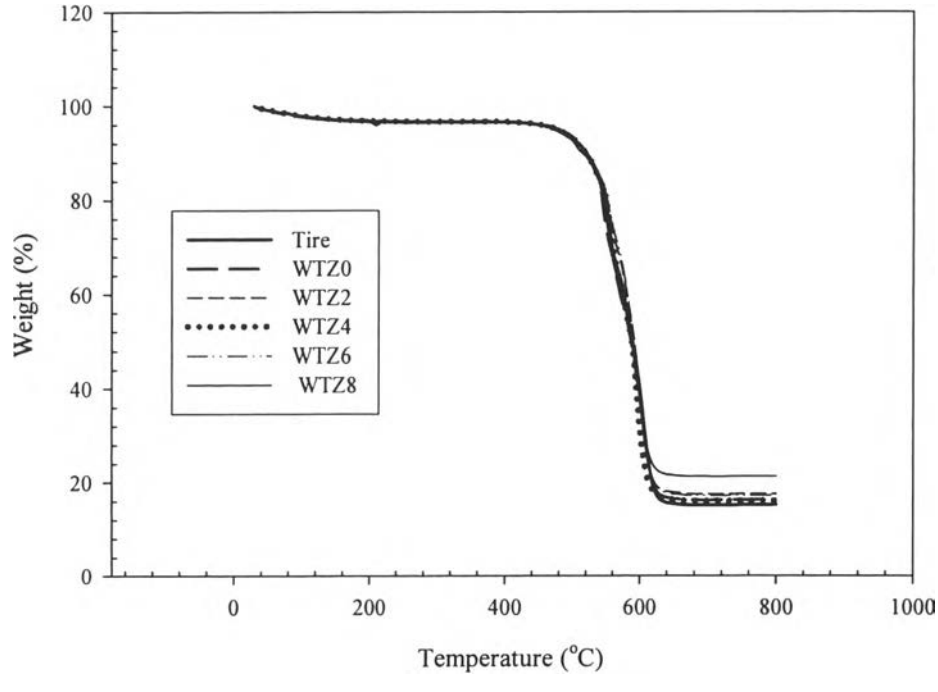

Figure C-7 TGA curves of solid residues of tire co-pyrolysed with various ZrO_2/SO_4^{2-}.

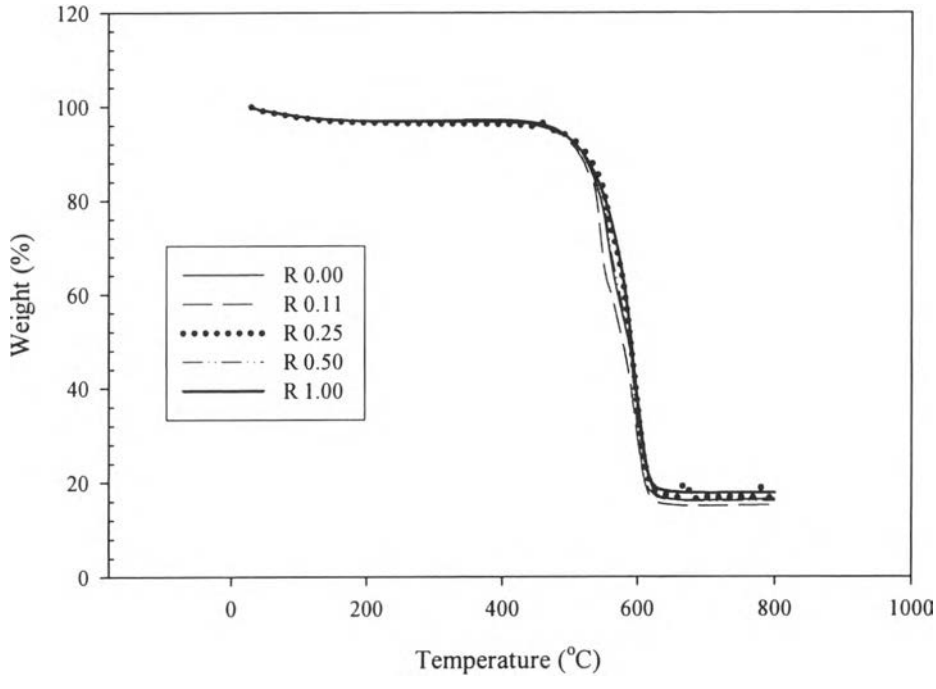

Figure C-8 TGA curves of solid residues of tire co-pyrolysed with various catalyst to tire ratio.

Appendix D Standard for gas chromatography

Table D-1 Standard Refinery Gas Compositions for gas chromatography calibration

Approximate concentration % volume/volume

Compositions	% volume/volume
Hydrogen	15
Nitrogen	15
Carbon dioxide	5
Carbon monoxide	5
Methane	5
Ethane	1
Ethylene	10
Propane	1
Propylene	5
Iso-butane	10
N-butane	5
Butane	10
Trans-2-butene	5
Cis-2-butene	5
N-pentane	1
Iso-pentane	2

Table D-2 Liquid for gas chromatography calibration

Liquid standard	Density @ 20°C
N-pentane	0.626
N-hexane	0.659
N-heptane	0.684
Iso-octane	0.6919

Table D-3 ASTM Method D2887 Column Test Mixture

This ULTRA standard (TM) solution was gravimetrically prepared, and the analyte concentrations were verified using high resolution gas chromatography.

Components	Carbon number	% By weight
N-hexane	6	6.0
N-heptane	7	6.0
N-octane	8	8.0
N-nonane	9	8.0
N-decane	10	12.0
N-undecane	11	12.0
N-dodecane	12	12.0
N-tetradecane	14	12.0
N-hexadecane	16	10.0
N-octadecane	18	5.0
N-eicosane	20	2.0
N-tetracosane	24	2.0
N-octacosane	28	1.0
N-dotriacontane	32	1.0
N-hexatriacontane	36	1.0
N-tetracontane	40	1.0
N-tetratetracontane	44	1.0

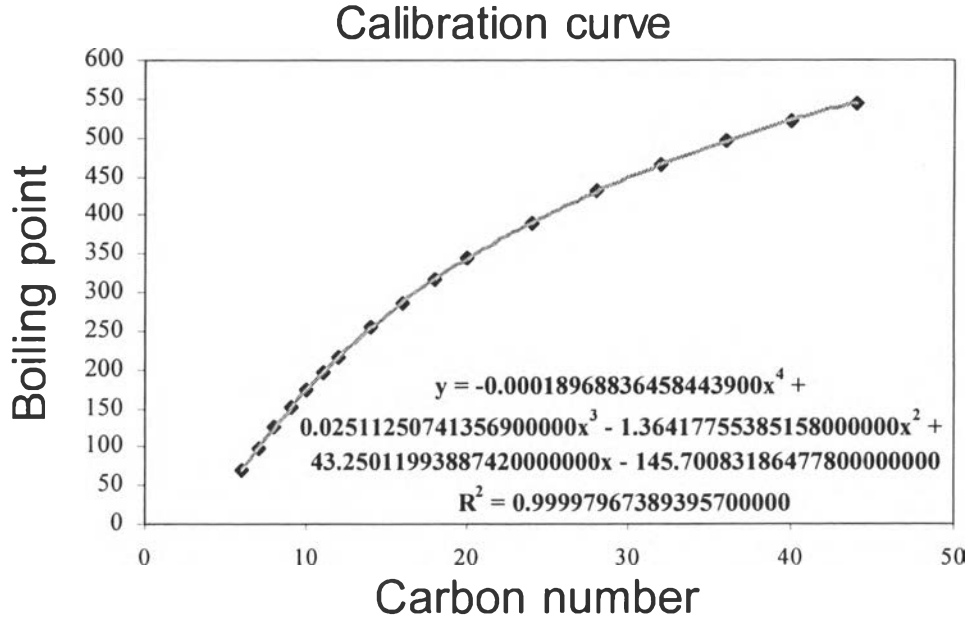

Figure D-1 GC calibration curve of ASTM D2887 Column Test Mixture with the equation of fitted curve.

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