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APPENDICES

APPENDIX A

CURE CURVE OF NR COMPOUNDS

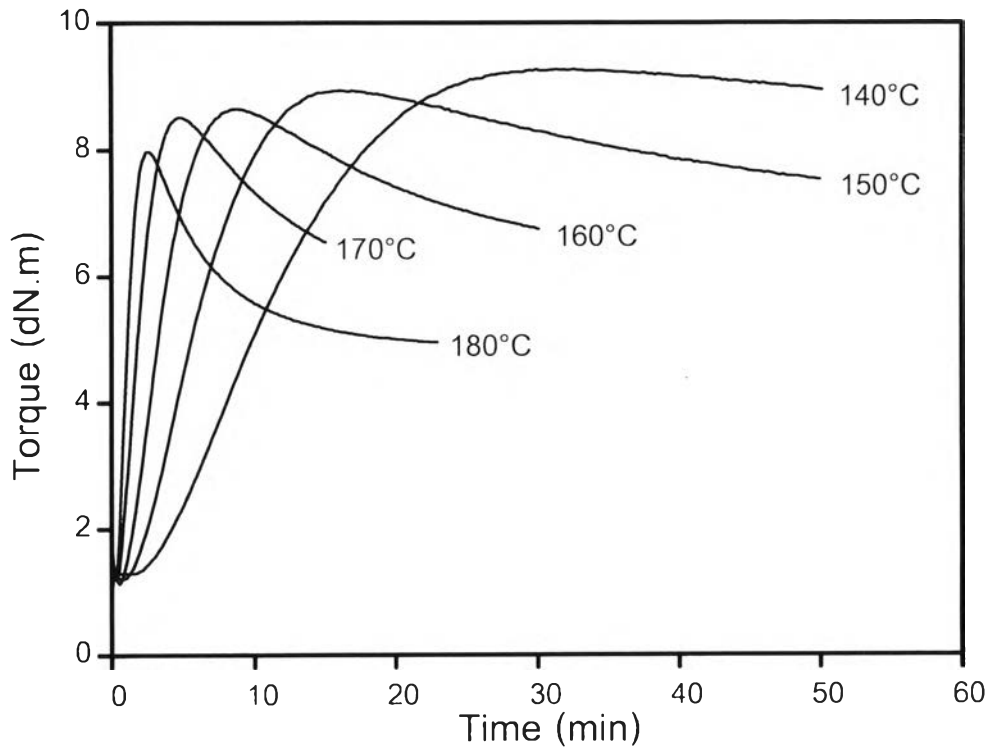


Figure A-1 Cure curve of N330 filled NR compound with 20 phr at different curing temperature

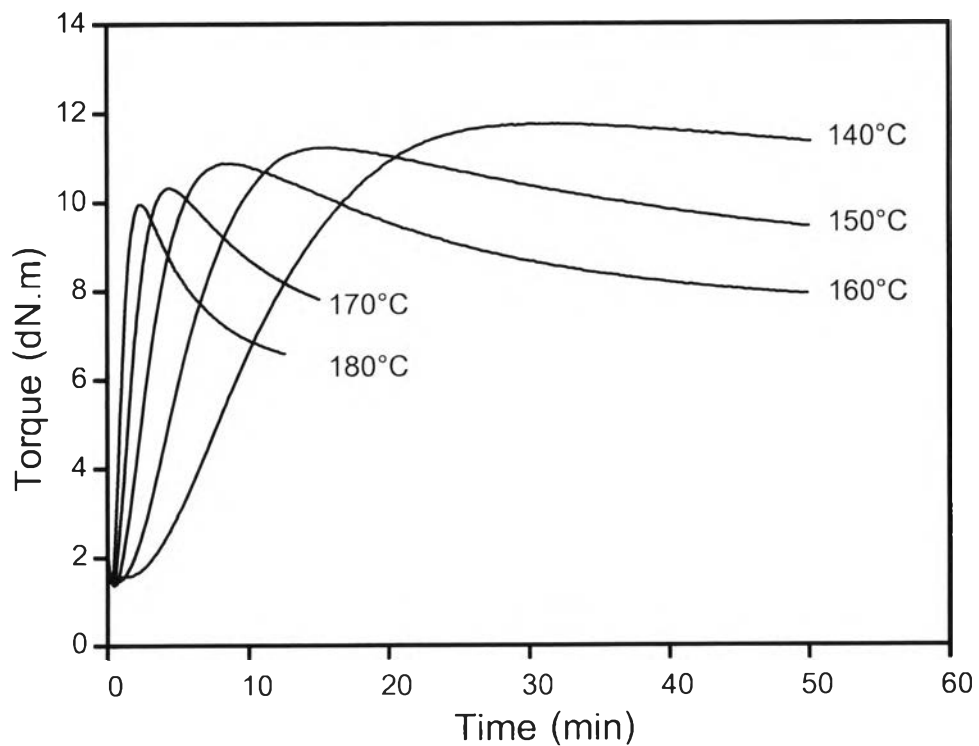


Figure A-2 Cure curve of N330 filled NR compound with 30 phr at different curing temperature

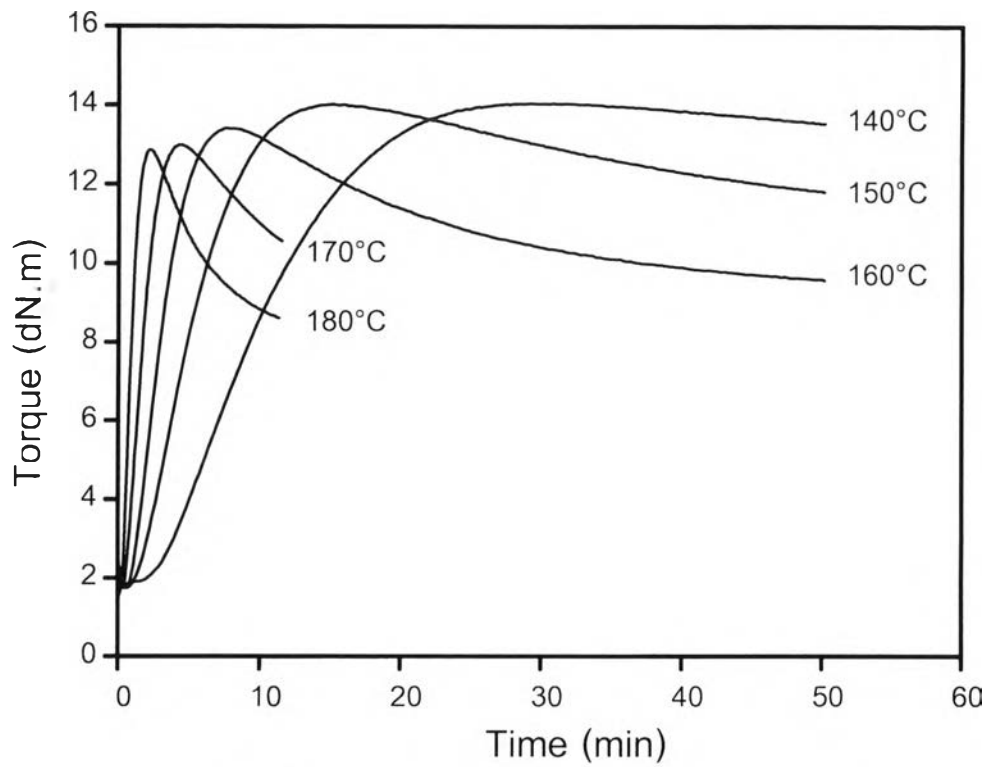


Figure A-3 Cure curve of N330 filled NR compound with 40 phr
at different curing temperature

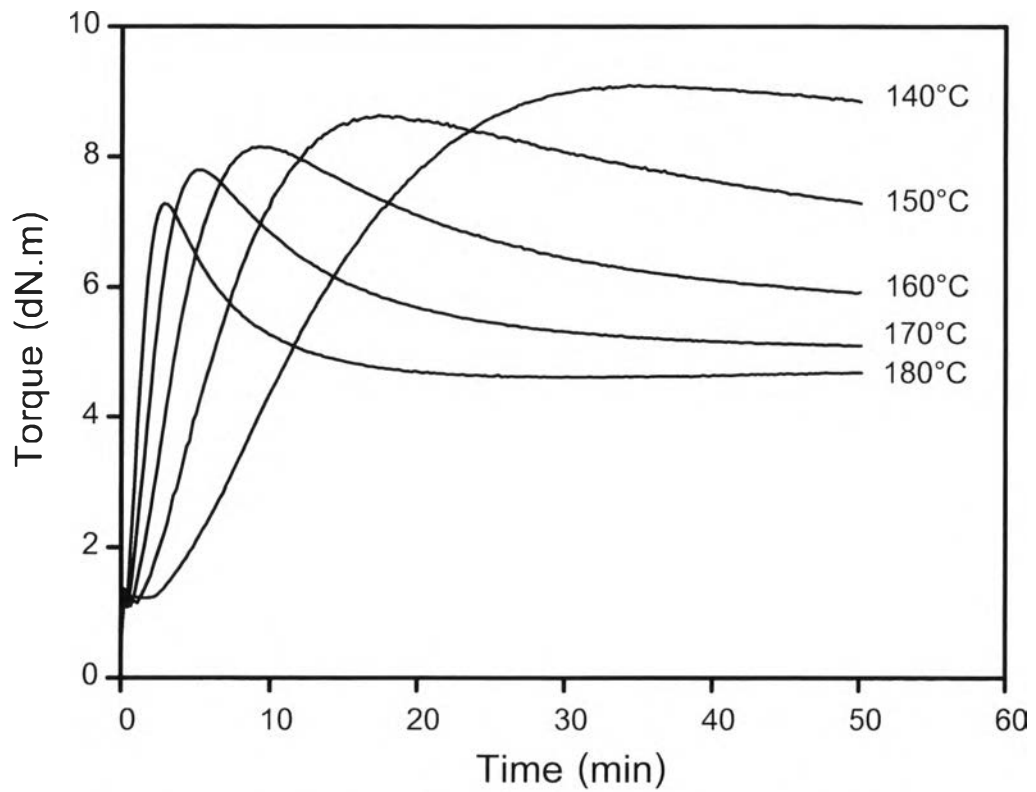


Figure A-4 Cure curve of N550 filled NR compound with 20 phr
at different curing temperature

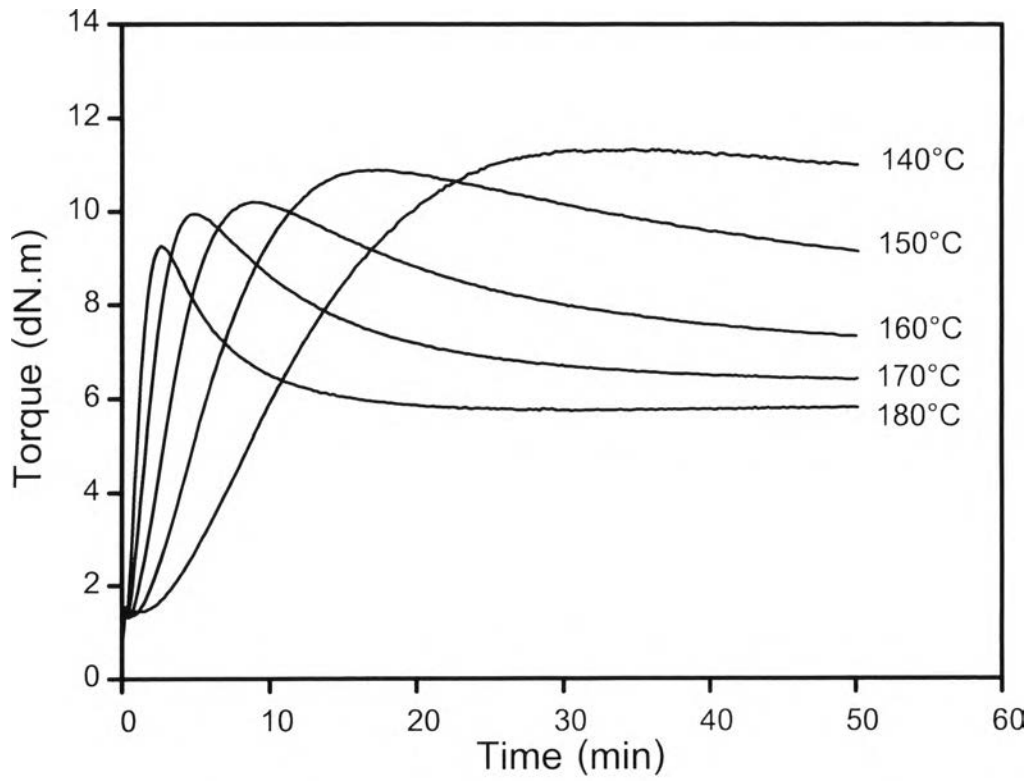


Figure A-5 Cure curve of N550 filled NR compound with 30 phr
at different curing temperature

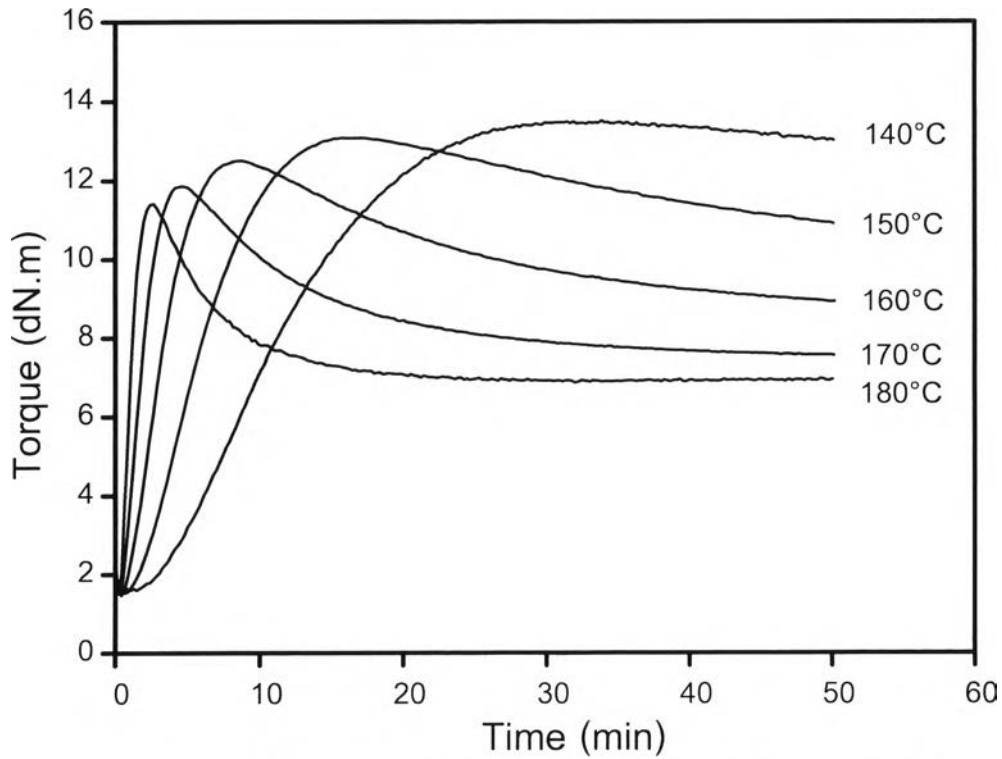


Figure A-6 Cure curve of N550 filled NR compound with 40 phr
at different curing temperature

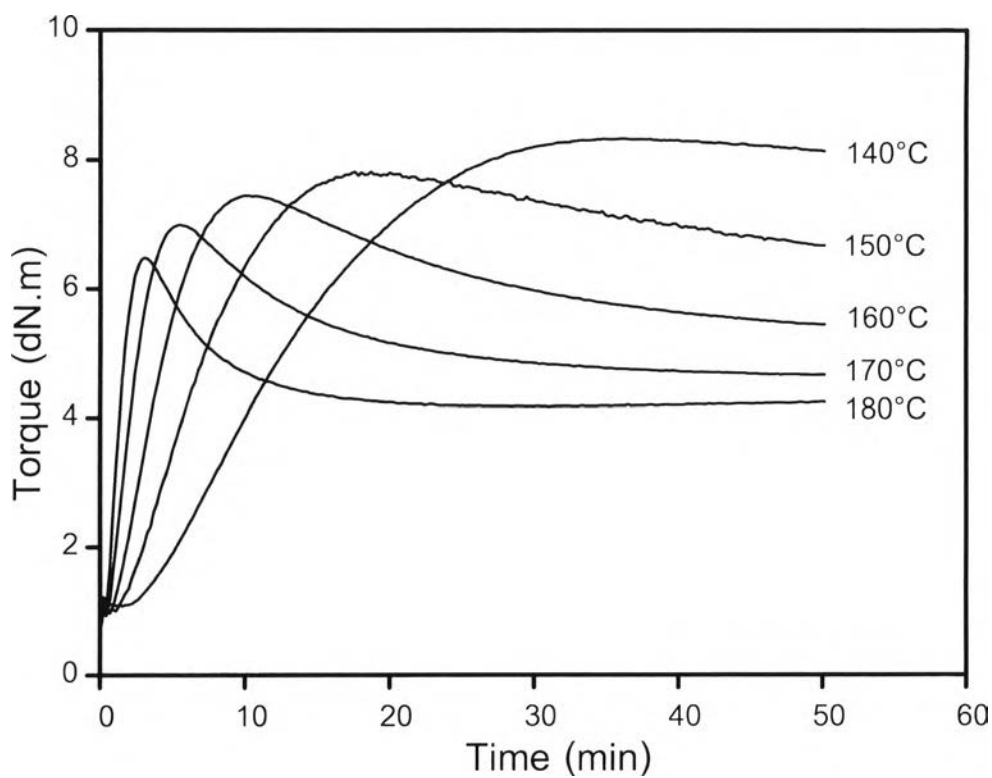


Figure A-7 Cure curve of N776 filled NR compound with 20 phr
at different curing temperature

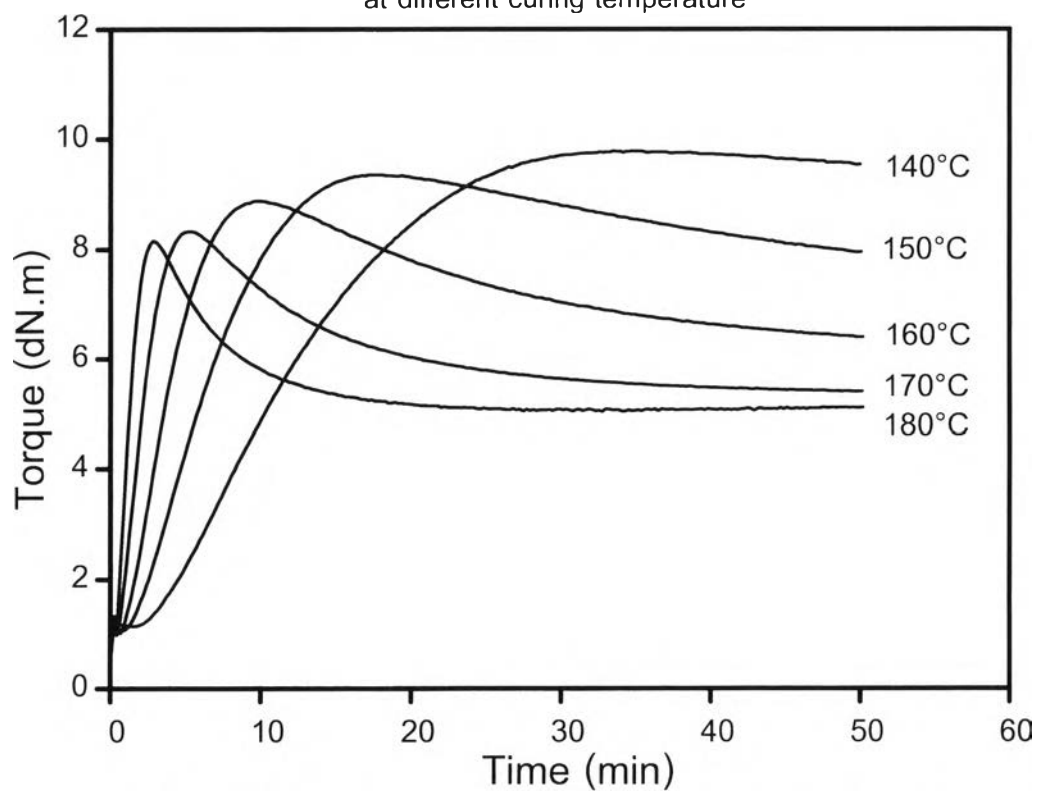


Figure A-8 Cure curve of N776 filled NR compound with 30 phr
at different curing temperature

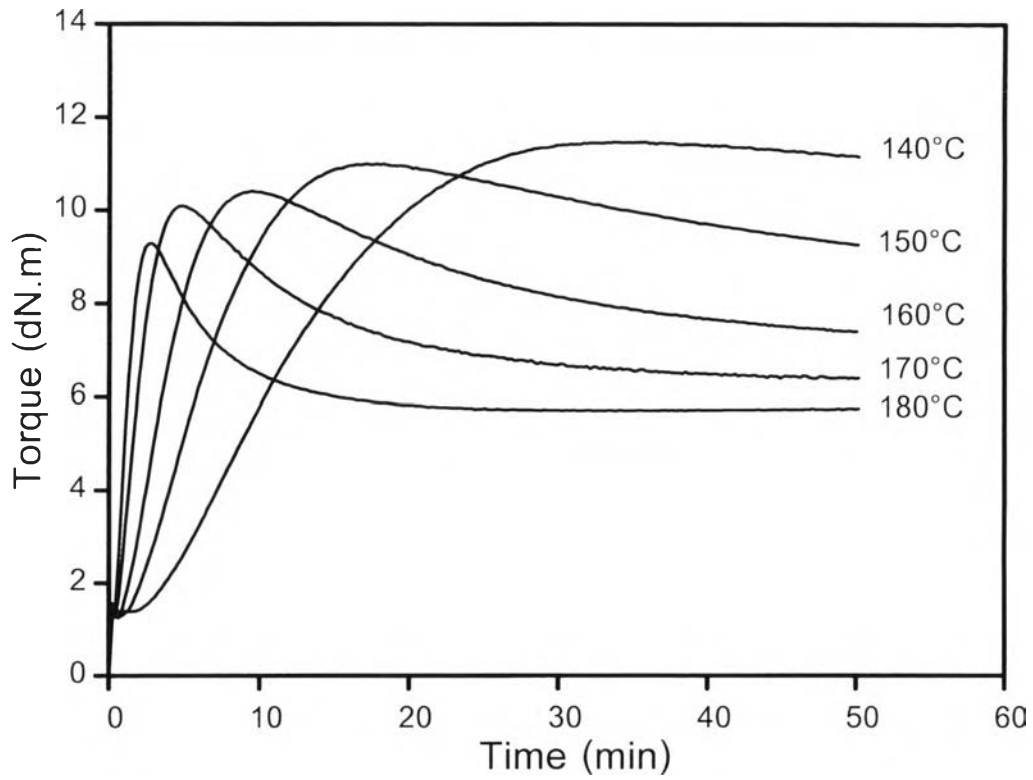


Figure A-9 Cure curve of N776 filled NR compound with 40 phr
at different curing temperature

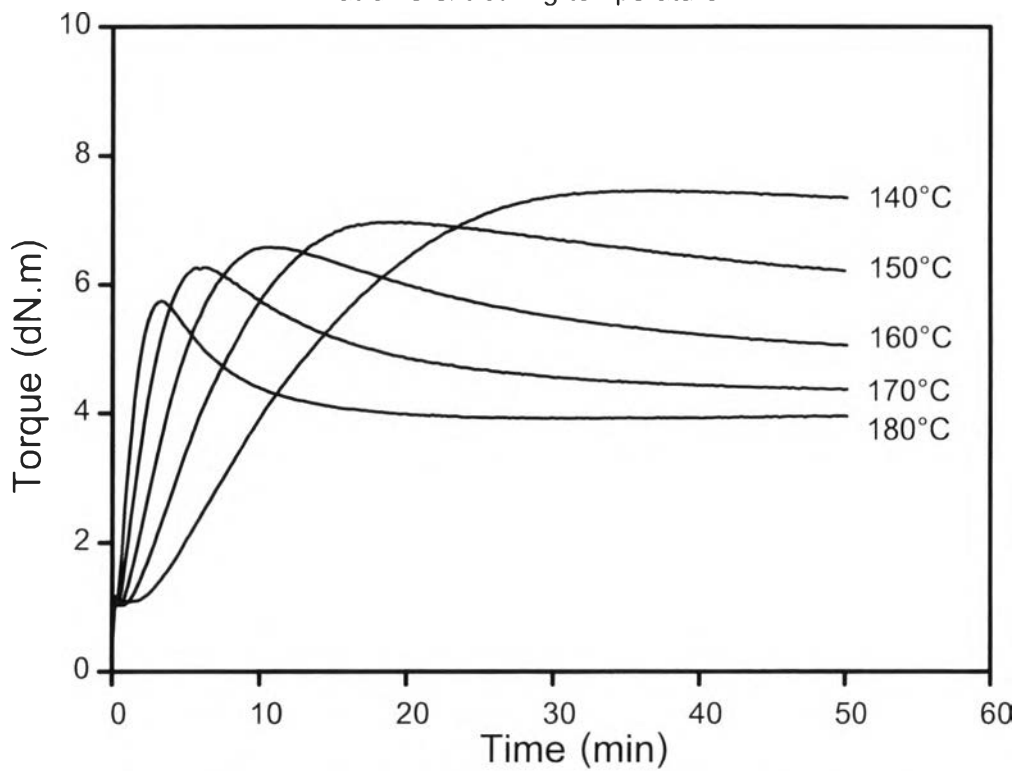


Figure A-10 Cure curve of N990 filled NR compound with 20 phr
at different curing temperature

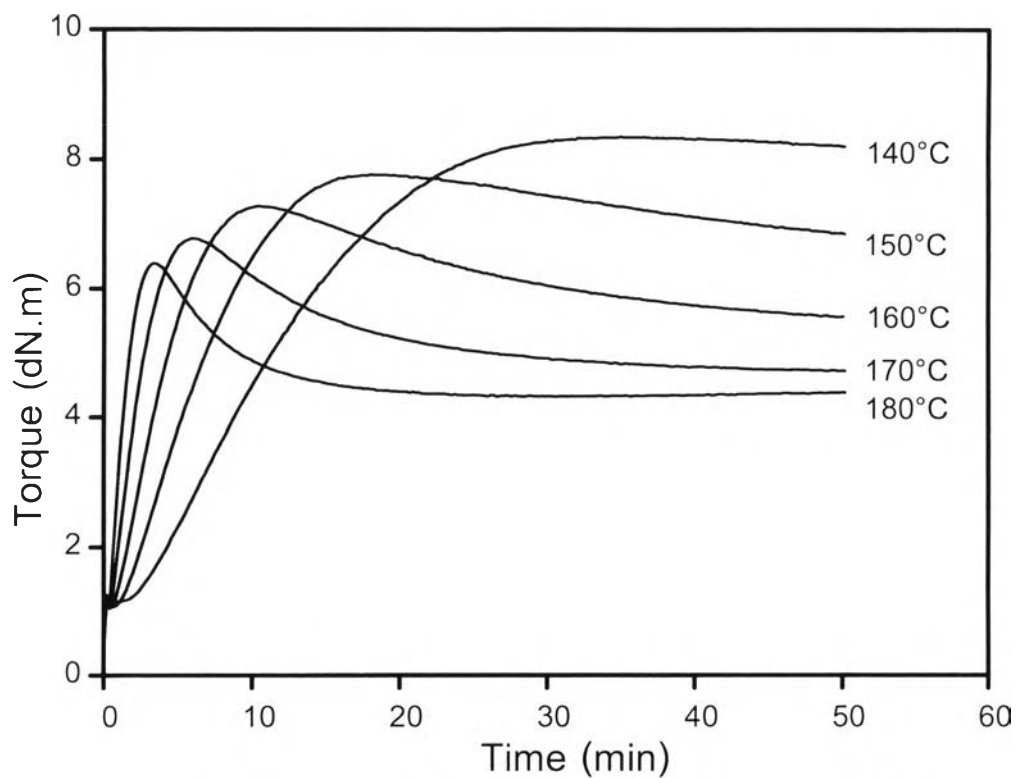


Figure A-11 Cure curve of N990 filled NR compound with 30 phr
at different curing temperature

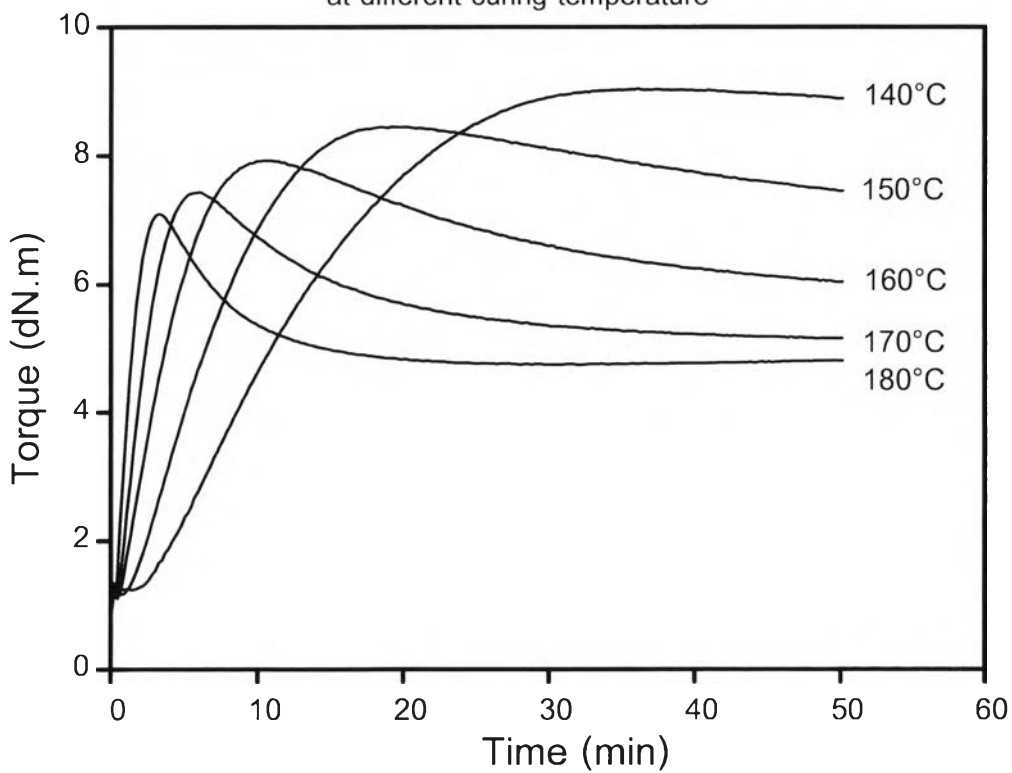


Figure A-12 Cure curve of N990 filled NR compound with 40 phr
at different curing temperature

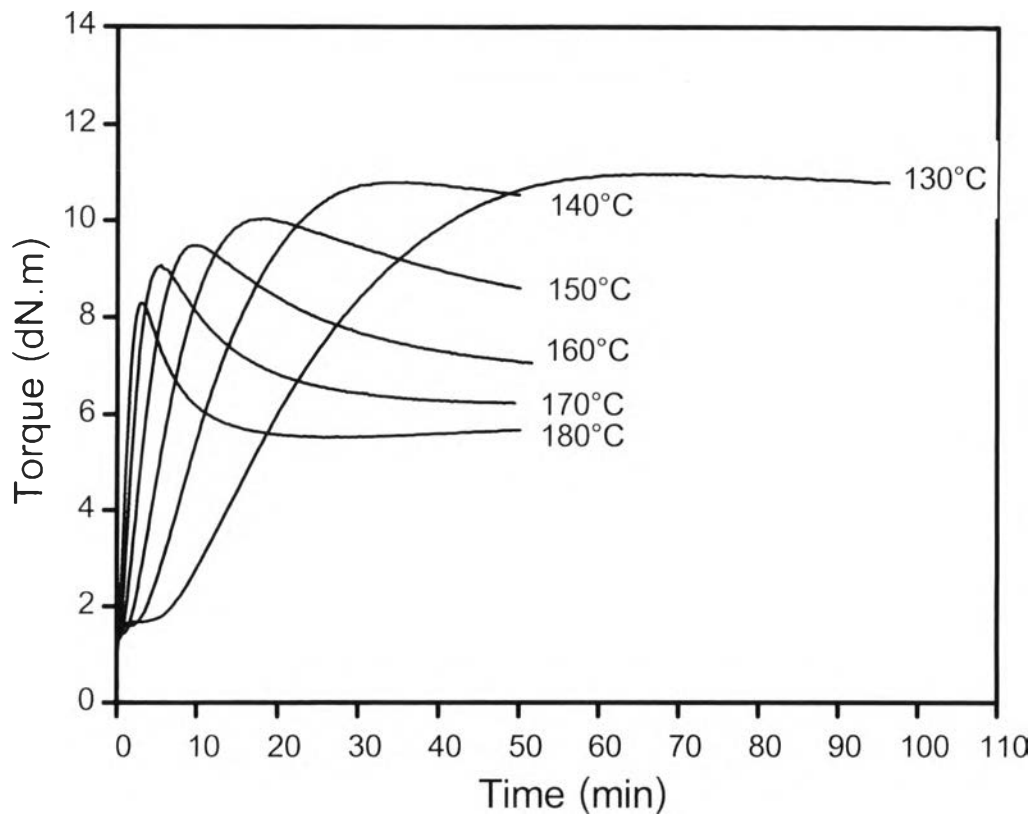


Figure A-13 Cure curve of gN330 filled NR compound with 20 phr
at different curing temperature

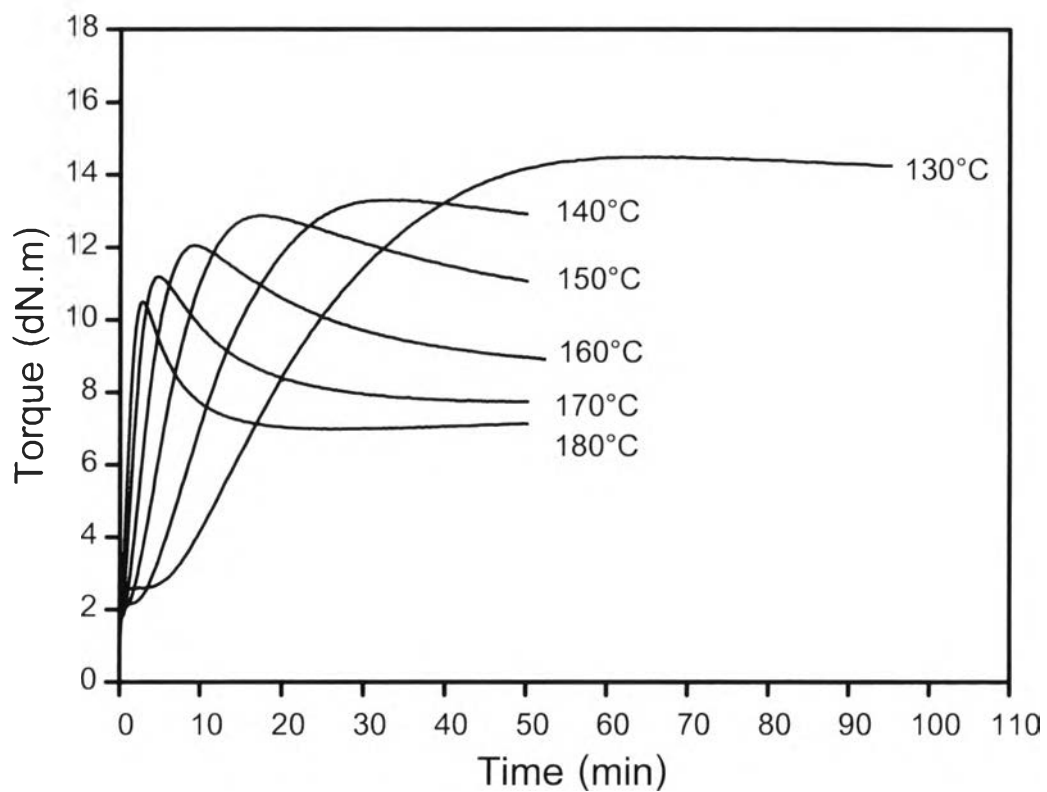


Figure A-14 Cure curve of gN330 filled NR compound with 30 phr
at different curing temperature

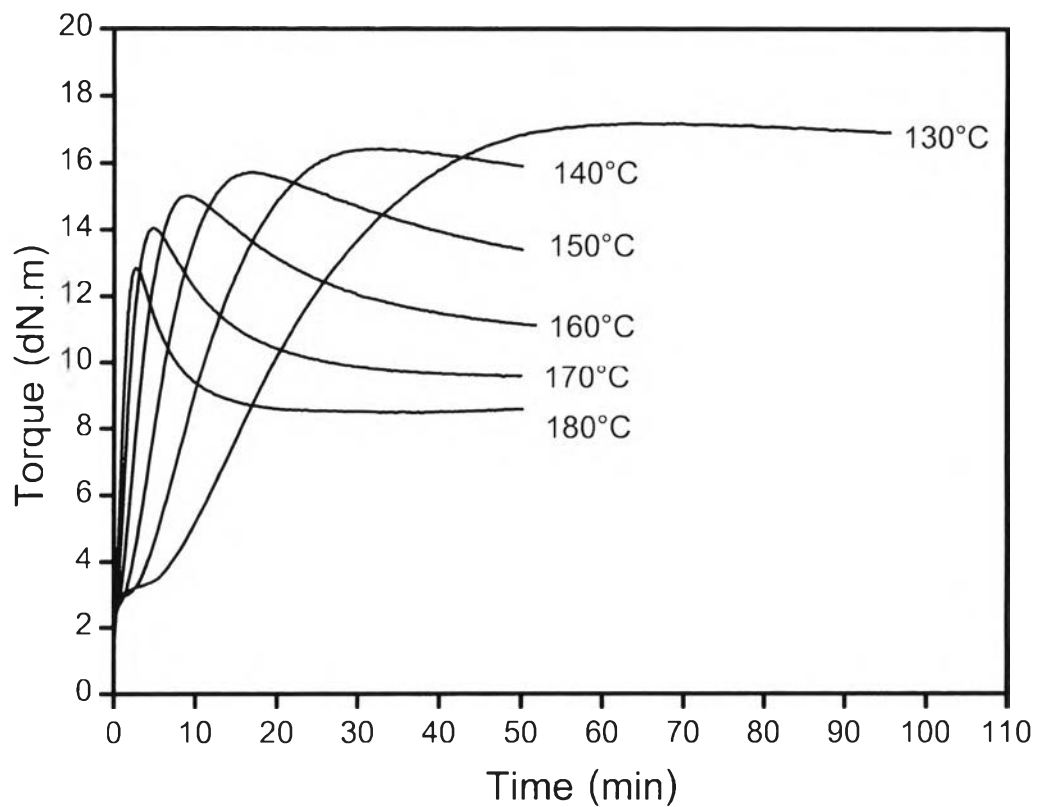


Figure A-15 Cure curve of gN330 filled NR compound with 40 phr
at different curing temperature

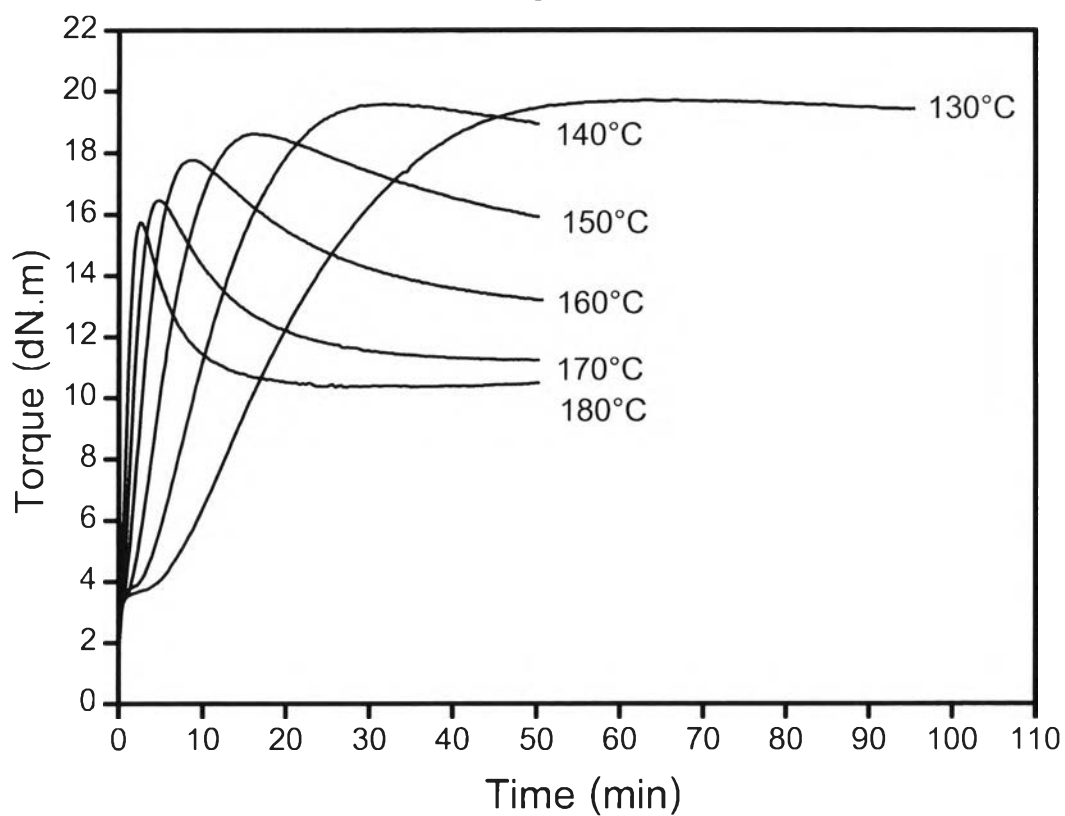


Figure A-16 Cure curve of gN330 filled NR compound with 50 phr
at different curing temperature

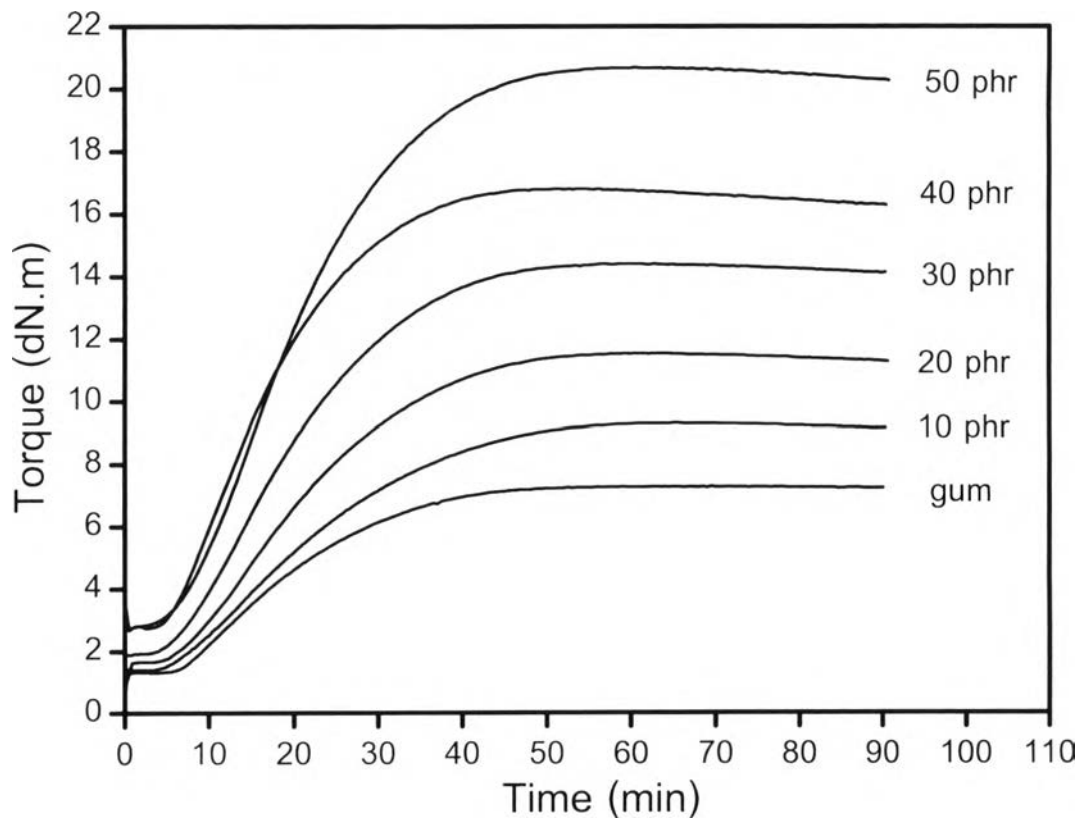


Figure A-17 Cure curve of N330 filled NR compound cured at 130°C with various loading

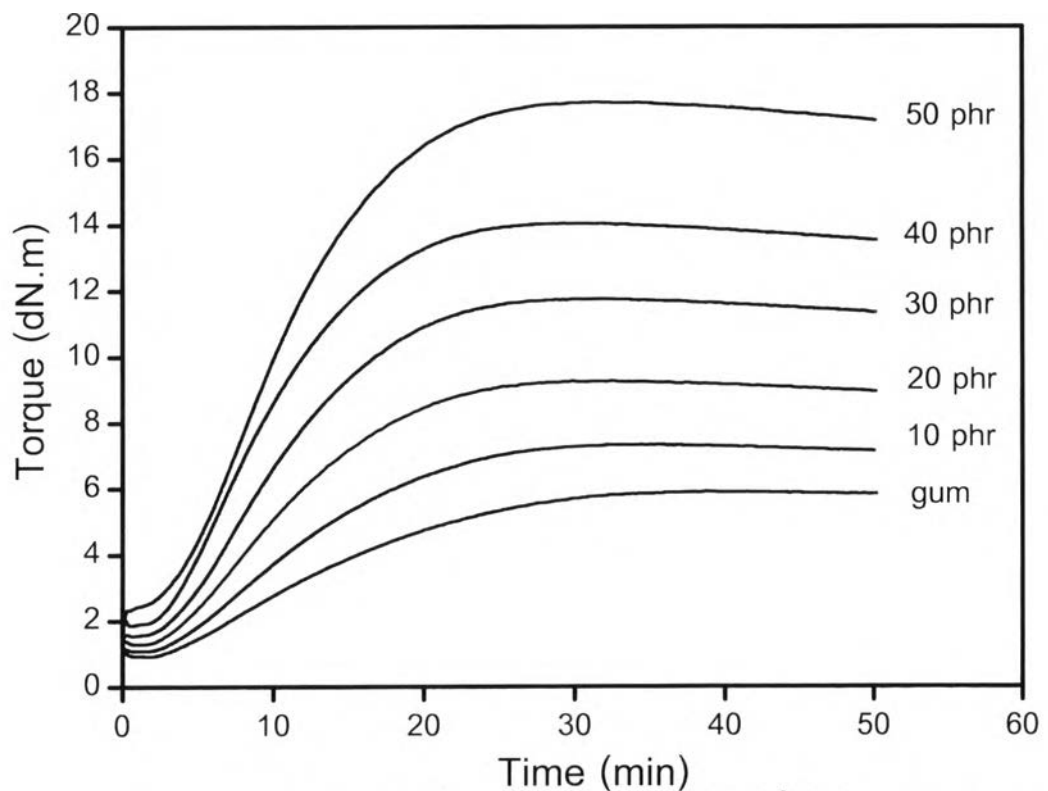


Figure A-18 Cure curve of N330 filled NR compound cured at 140°C with various loading

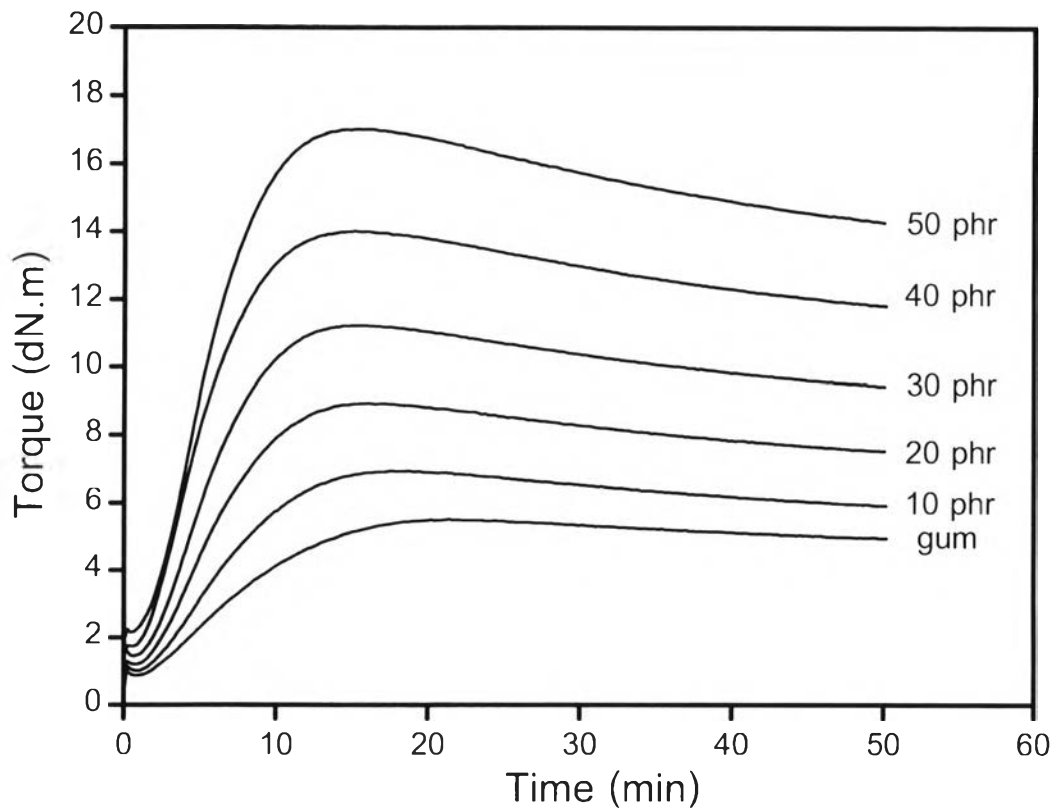


Figure A-19 Cure curve of N330 filled NR compound cured at 150°C with various loading

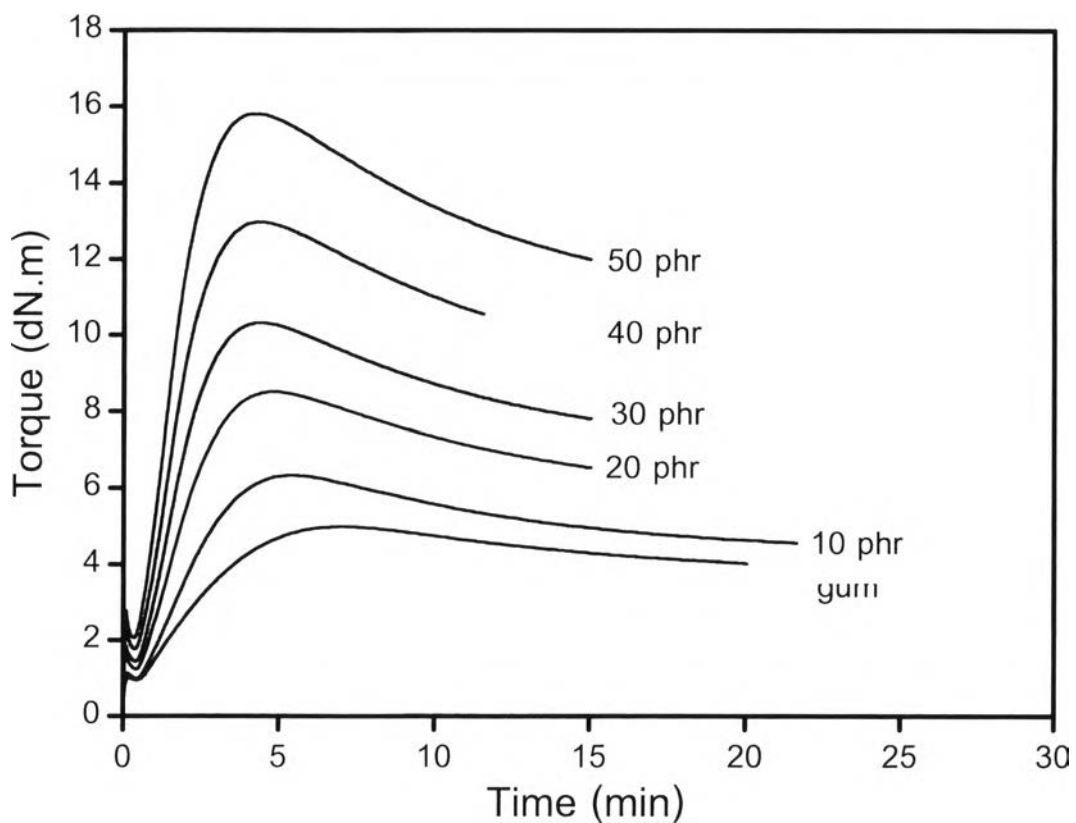


Figure A-20 Cure curve of N330 filled NR compound cured at 170°C with various loading

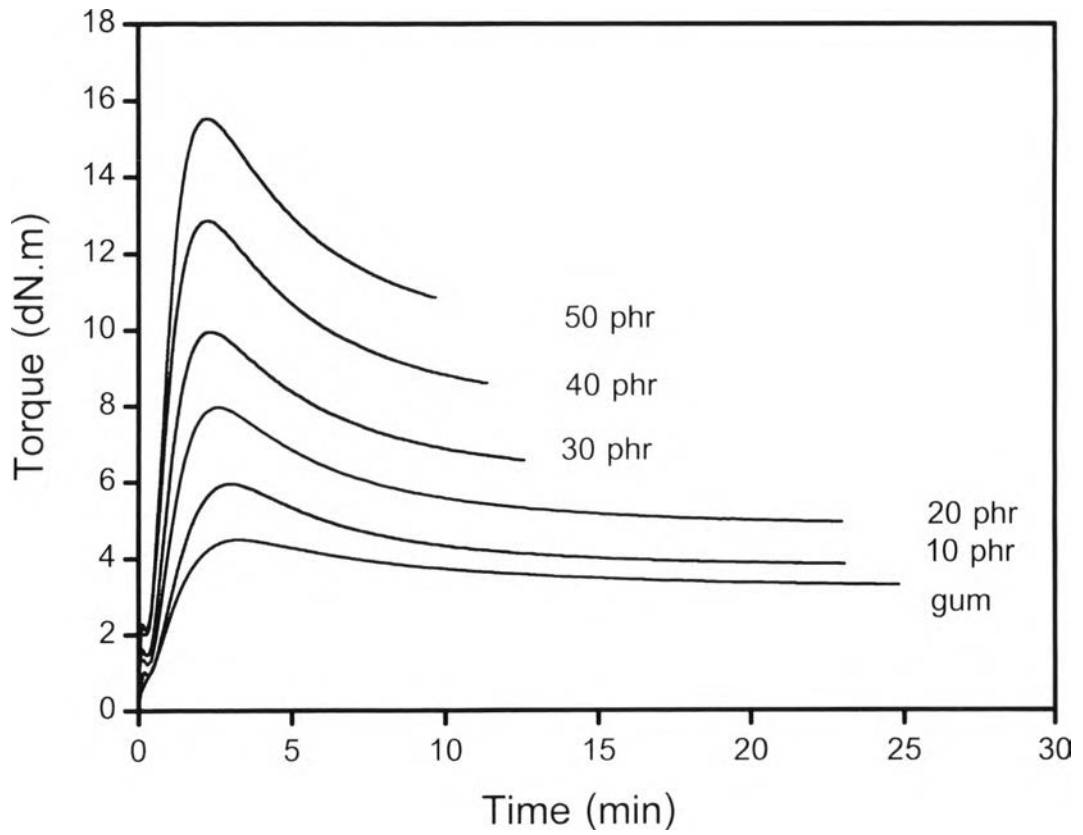


Figure A-21 Cure curve of N330 filled NR compound cured at 180°C with various loading

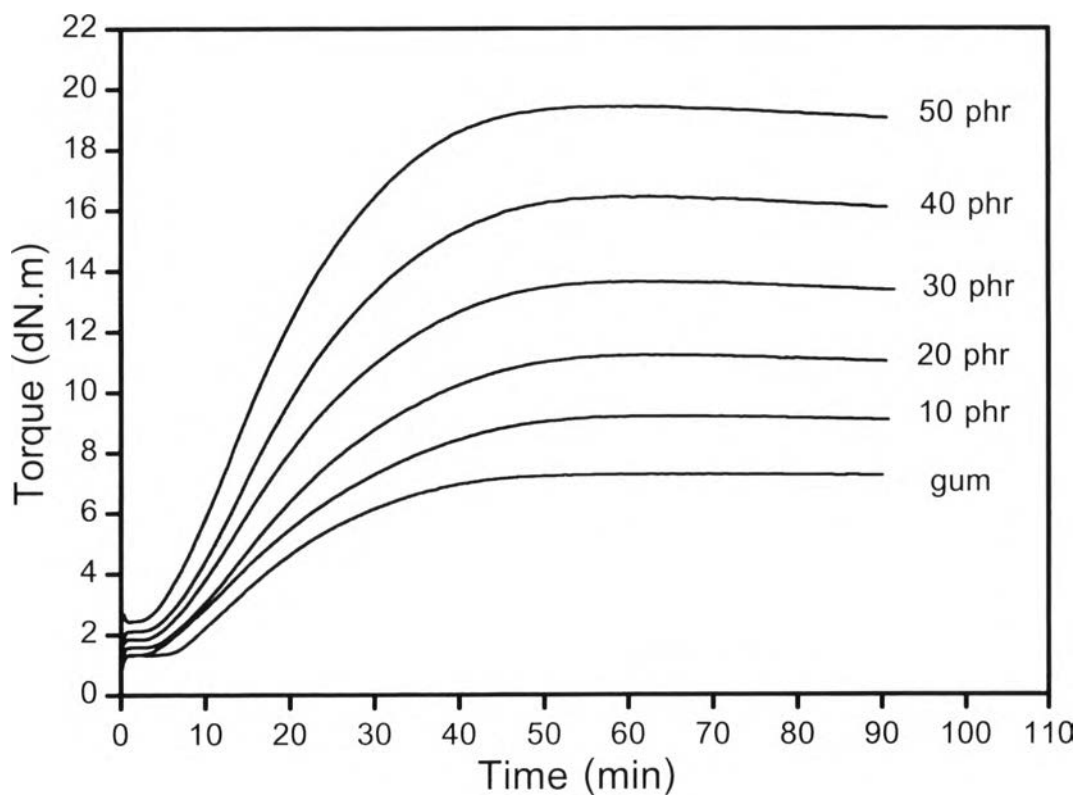


Figure A-22 Cure curve of N550 filled NR compound cured at 130°C with various loading

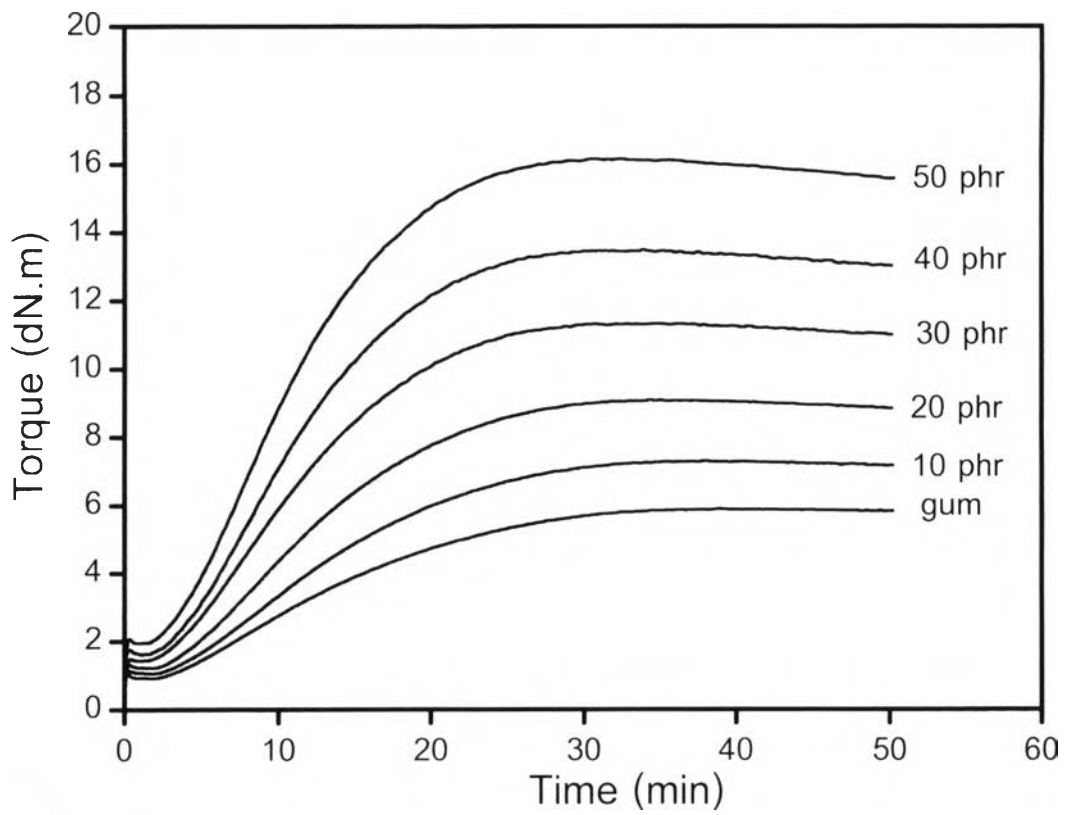


Figure A-23 Cure curve of N550 filled NR compound cured at 140°C with various loading

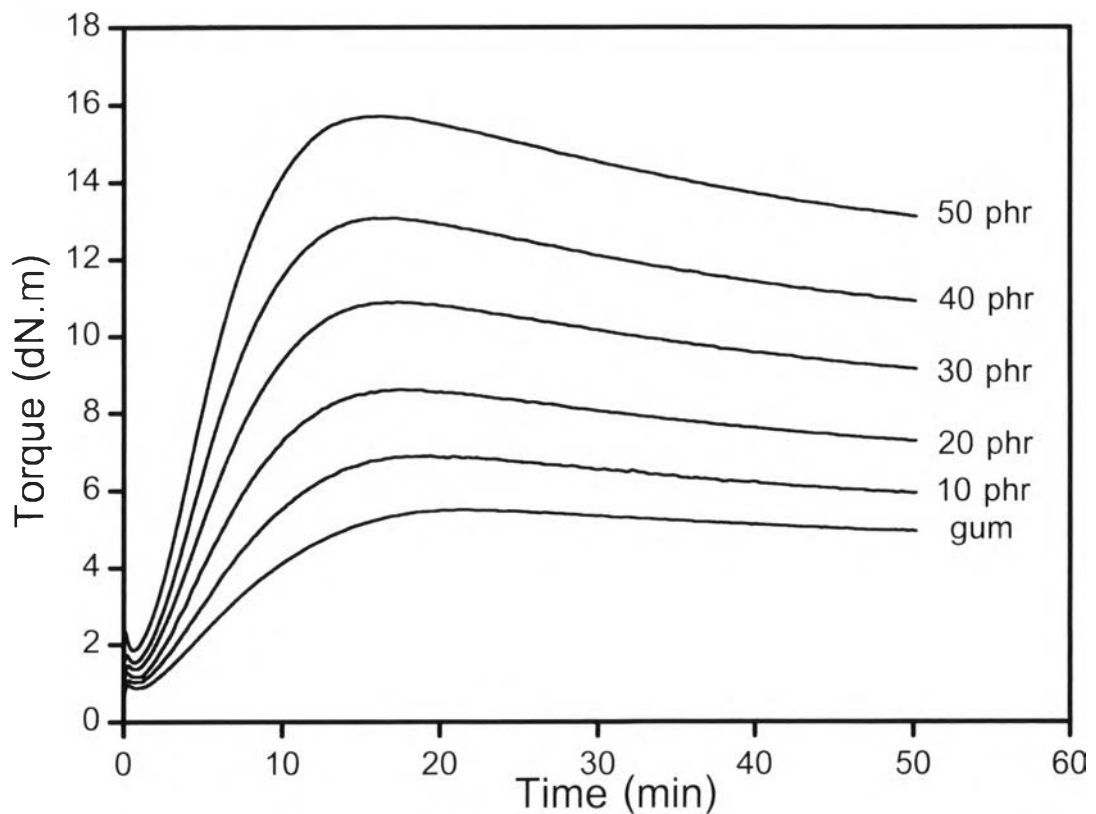


Figure A-24 Cure curve of N550 filled NR compound cured at 150°C with various loading

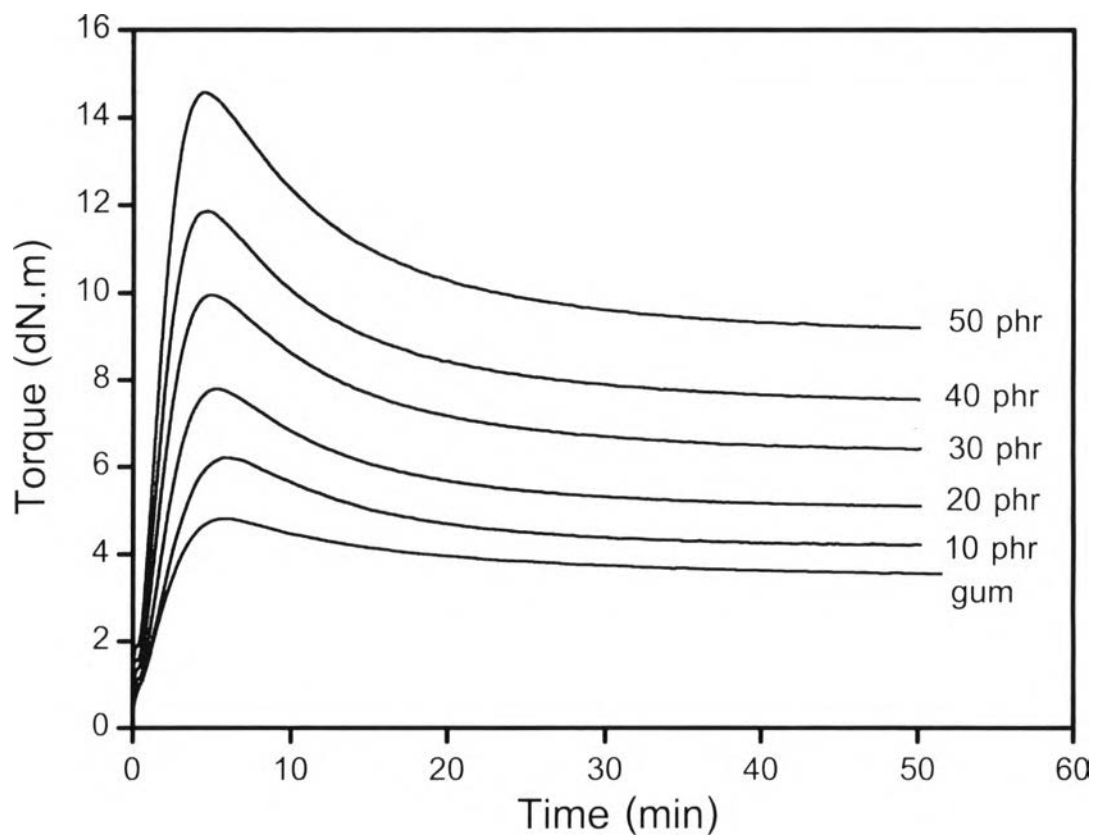


Figure A-25 Cure curve of N550 filled NR compound cured at 170°C with various loading

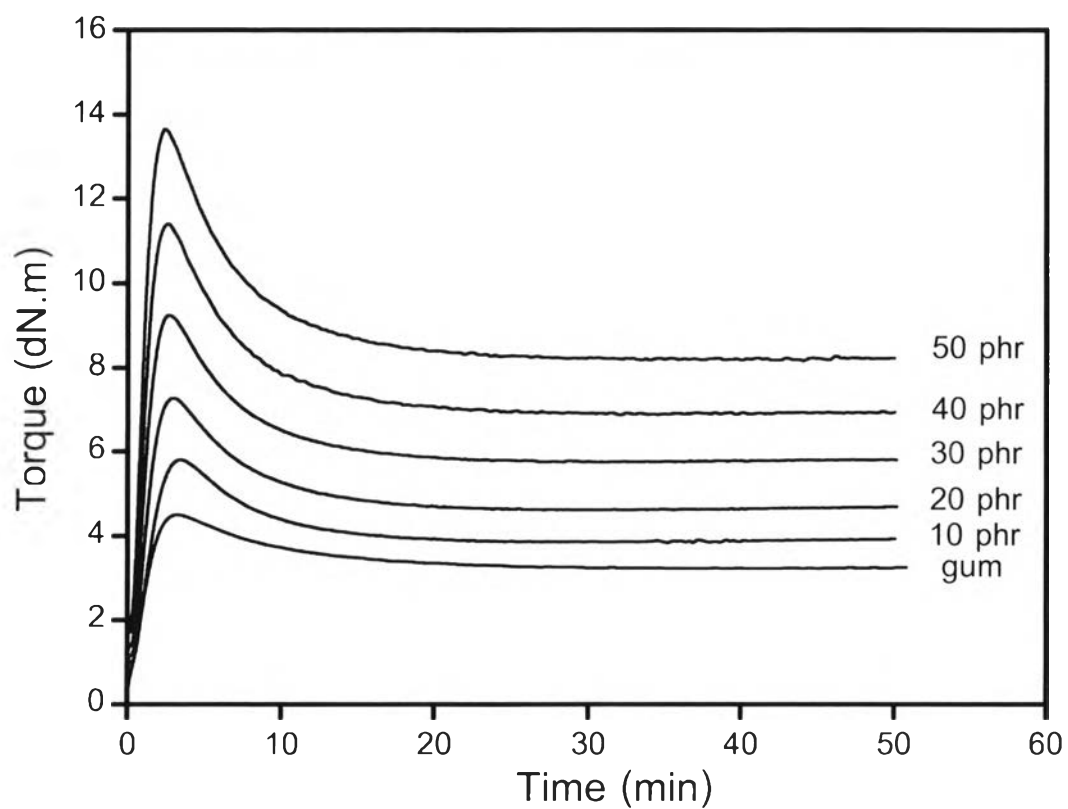


Figure A-26 Cure curve of N550 filled NR compound cured at 180°C with various loading

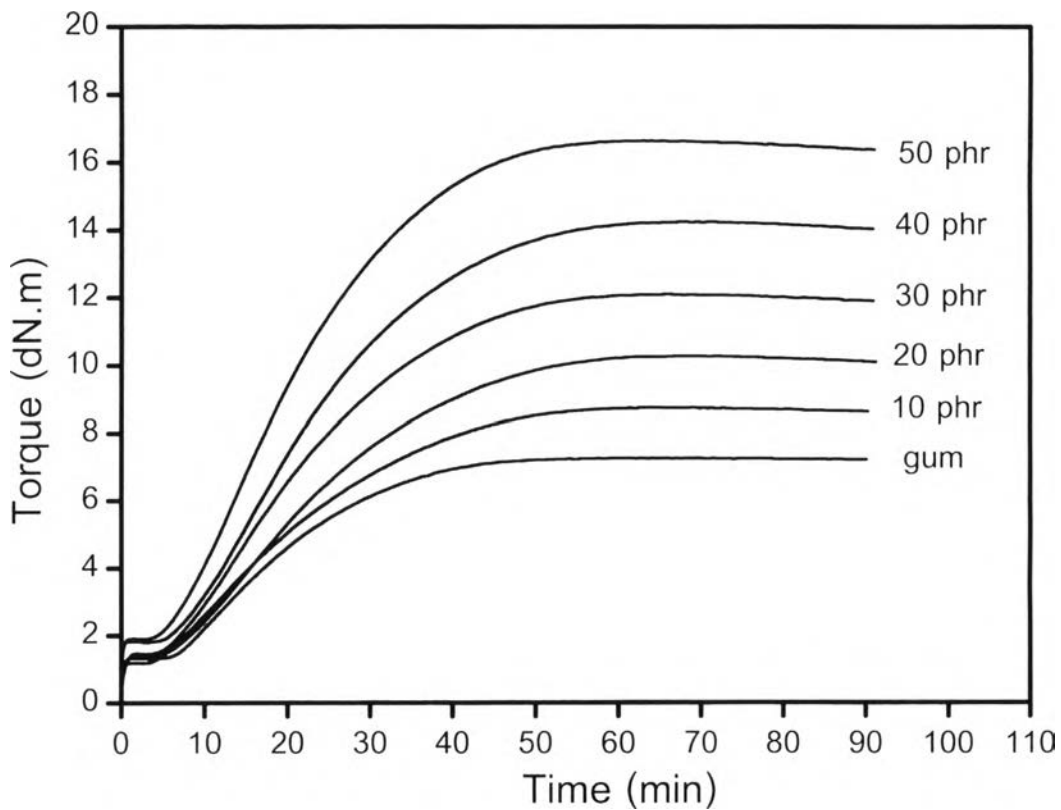


Figure A-27 Cure curve of N776 filled NR compound cured at 130°C with various loading

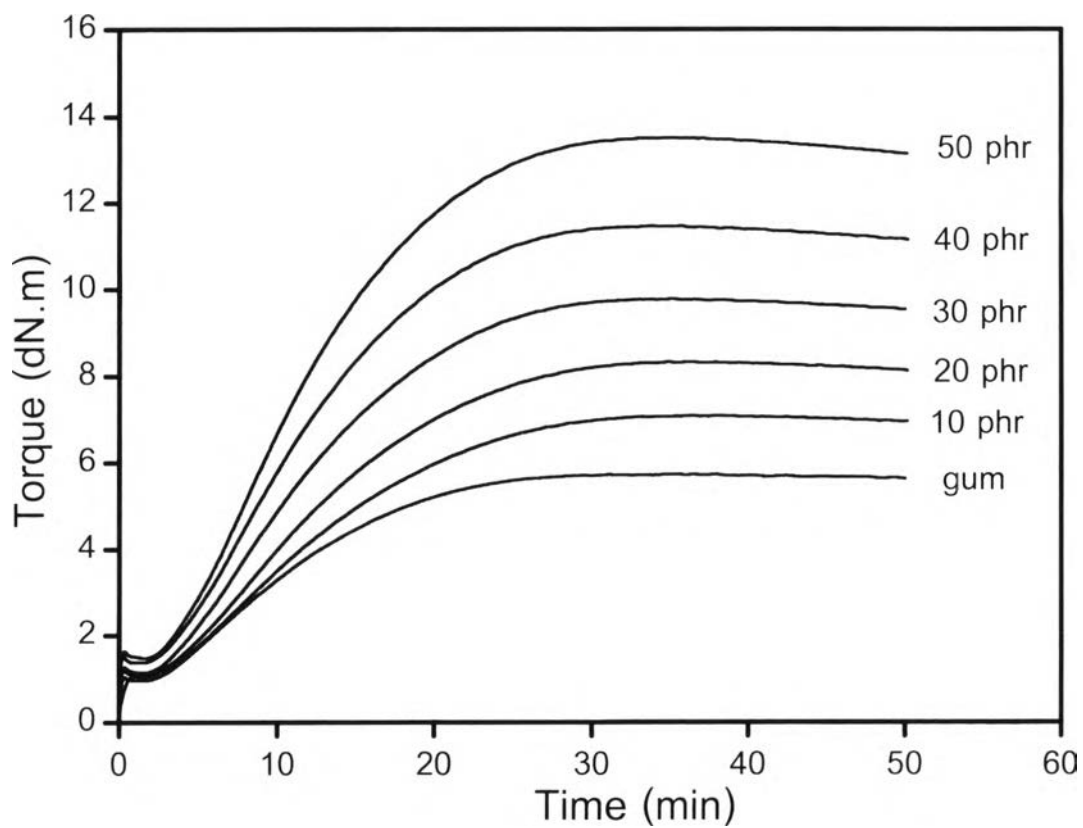


Figure A-28 Cure curve of N776 filled NR compound cured at 140°C with various loading

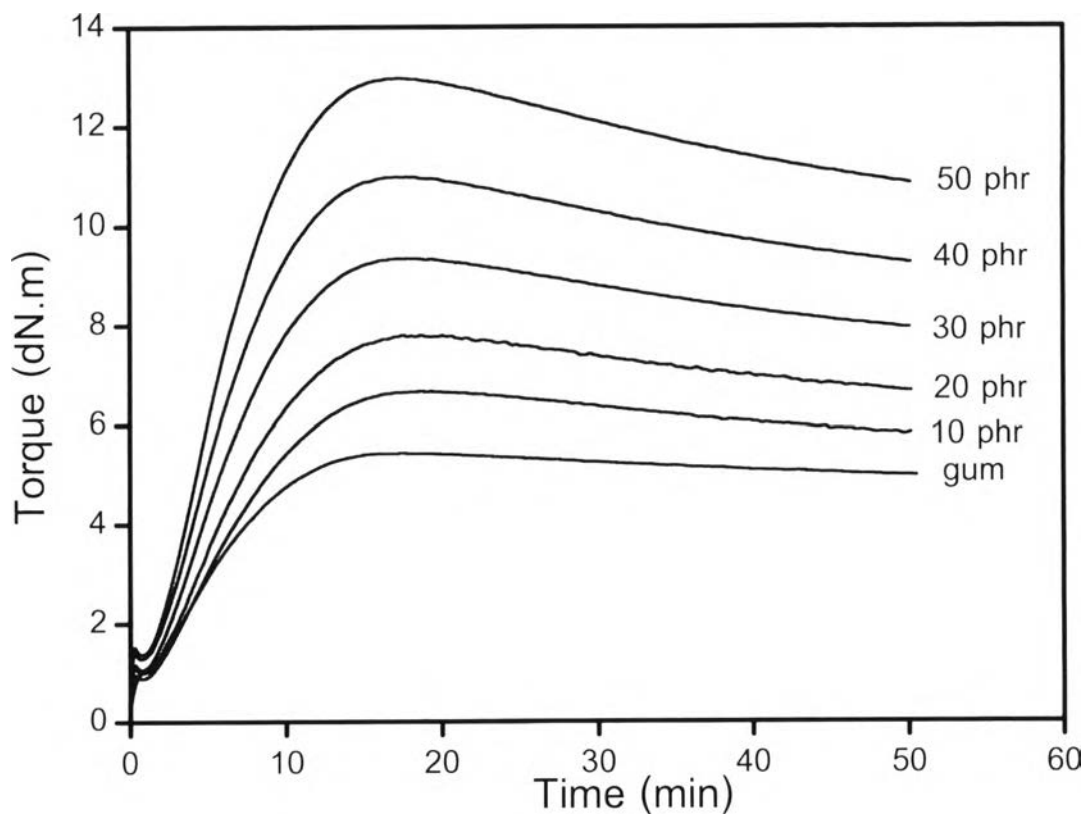


Figure A-29 Cure curve of N776 filled NR compound cured at 150°C with various loading

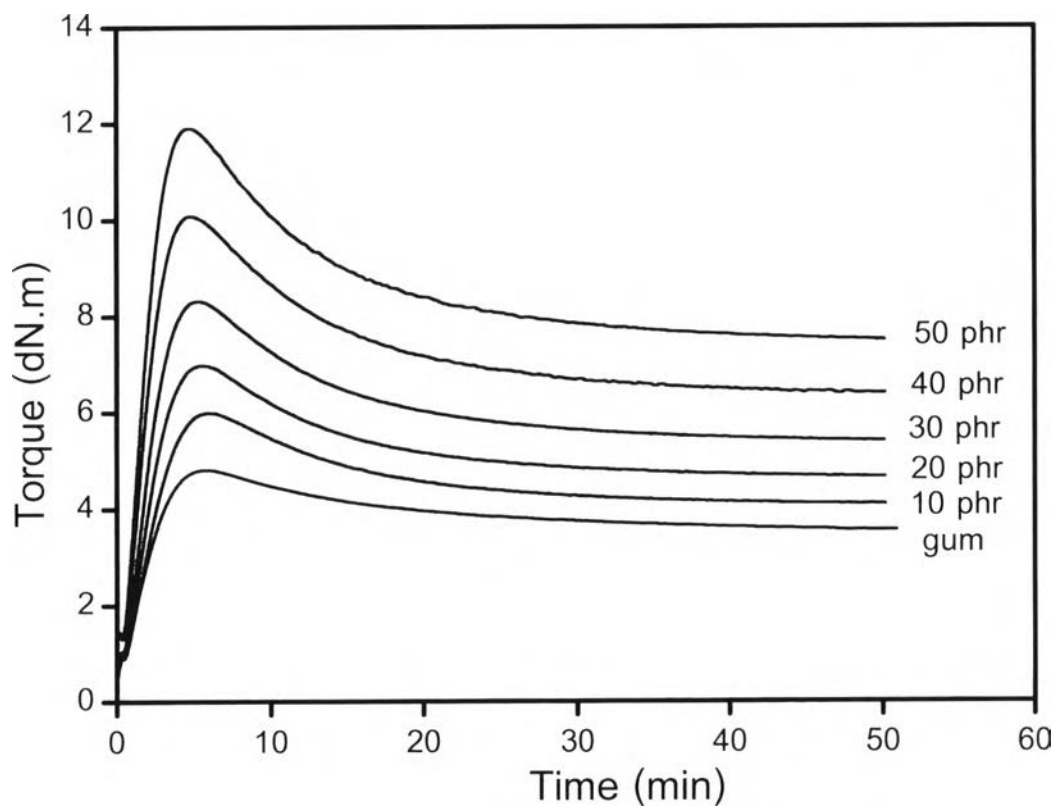


Figure A-30 Cure curve of N776 filled NR compound cured at 170°C with various loading

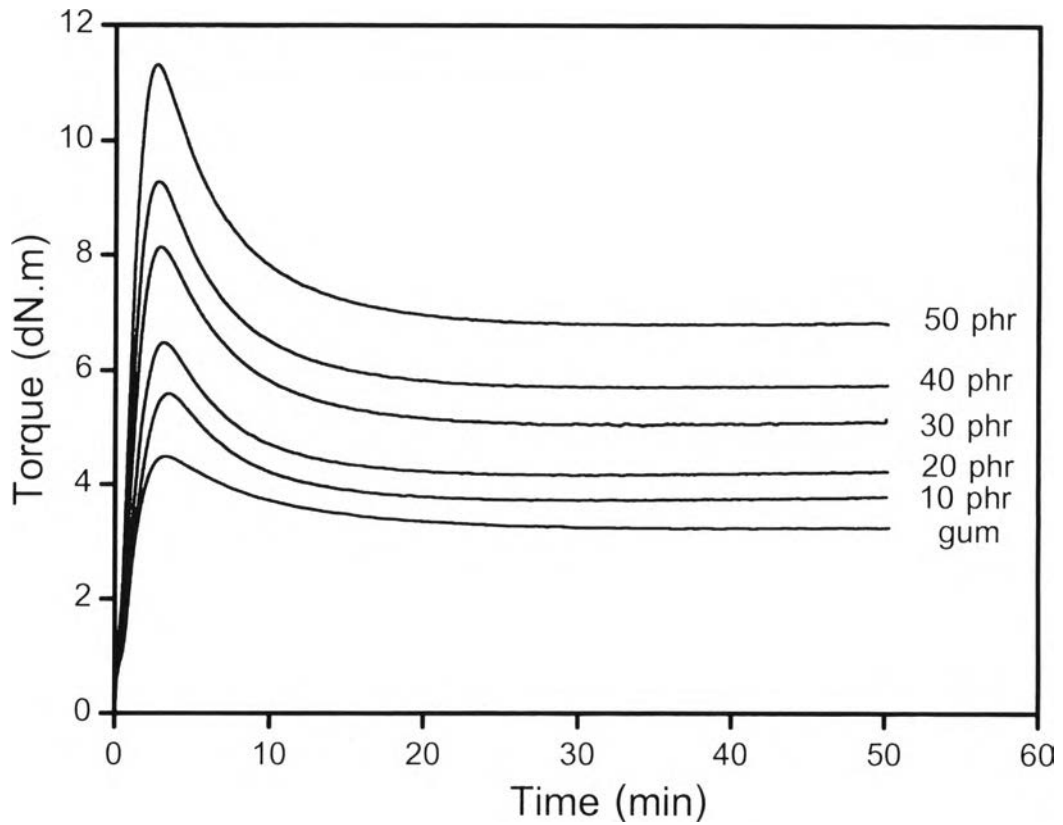


Figure A-31 Cure curve of N776 filled NR compound cured at 180°C with various loading

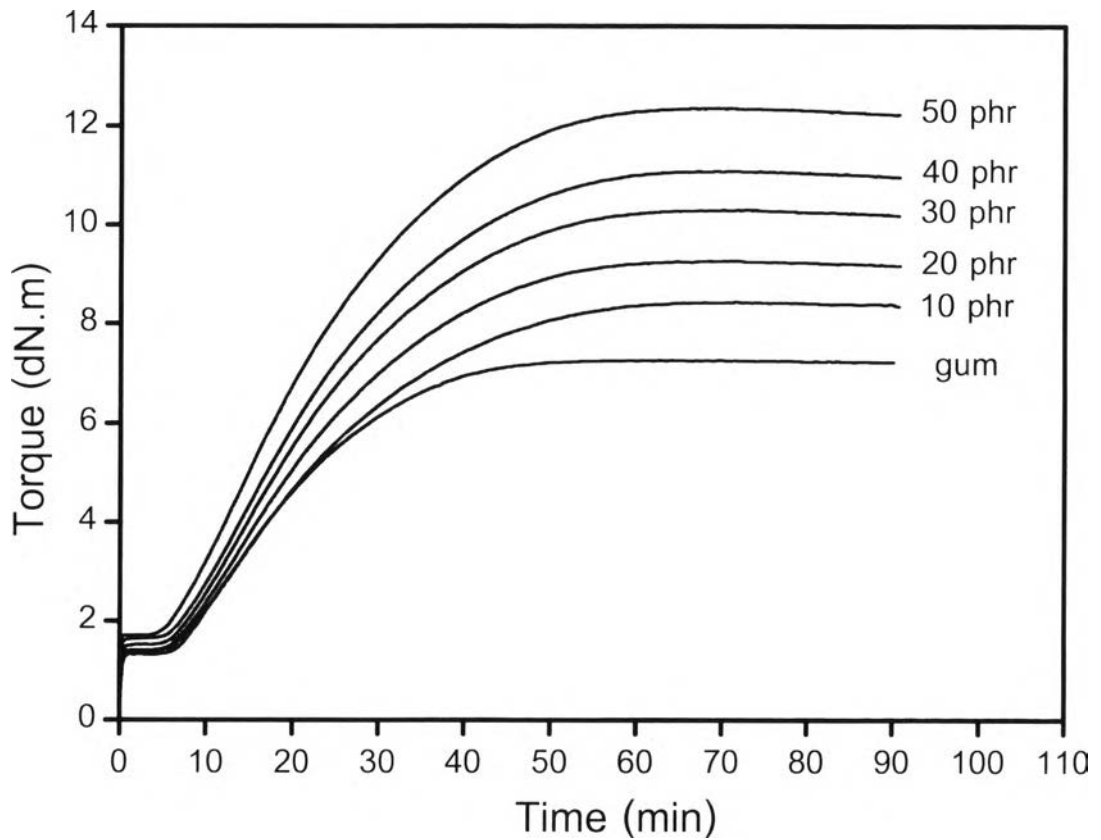


Figure A-32 Cure curve of N990 filled NR compound cured at 130°C with various loading

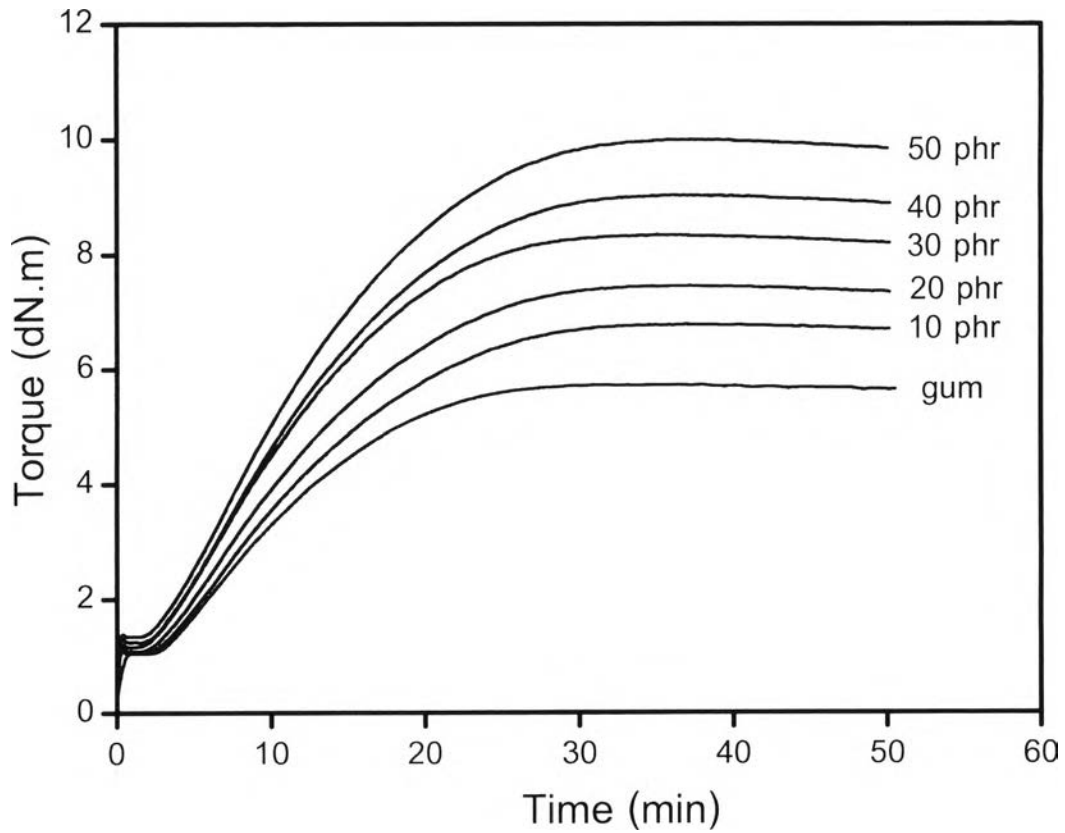


Figure A-33 Cure curve of N990 filled NR compound cured at 140°C with various loading

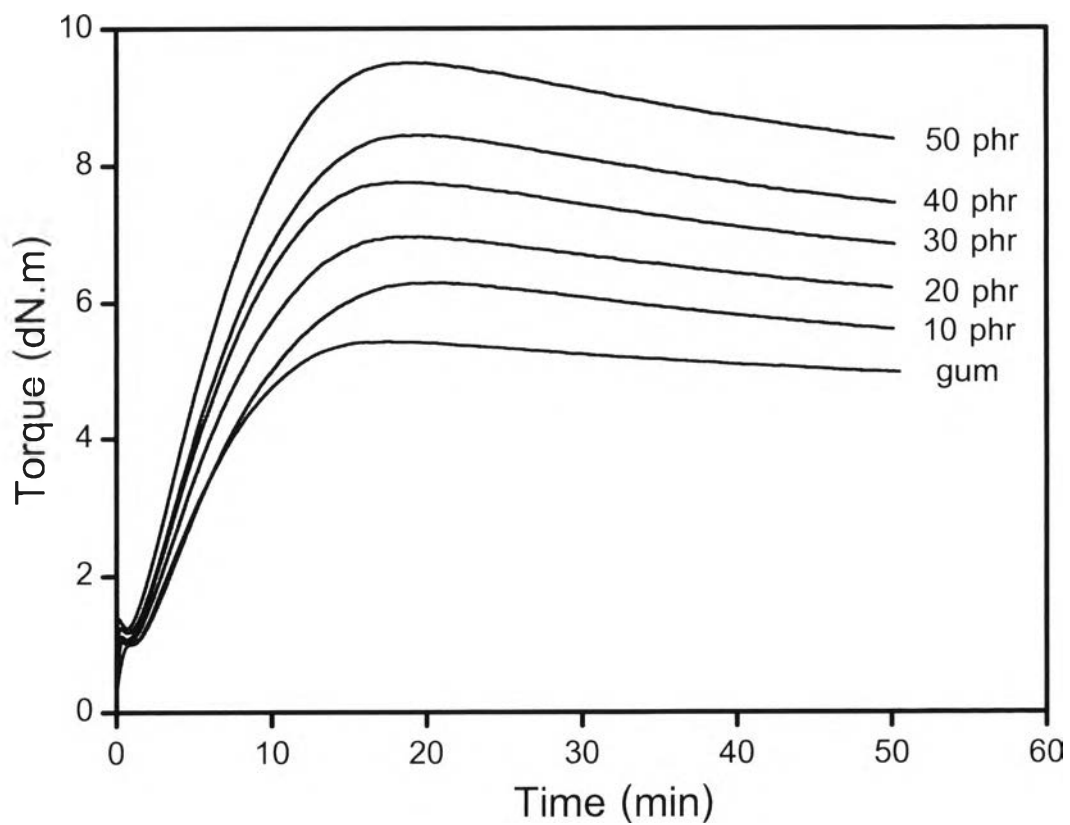


Figure A-34 Cure curve of N990 filled NR compound cured at 150°C with various loading

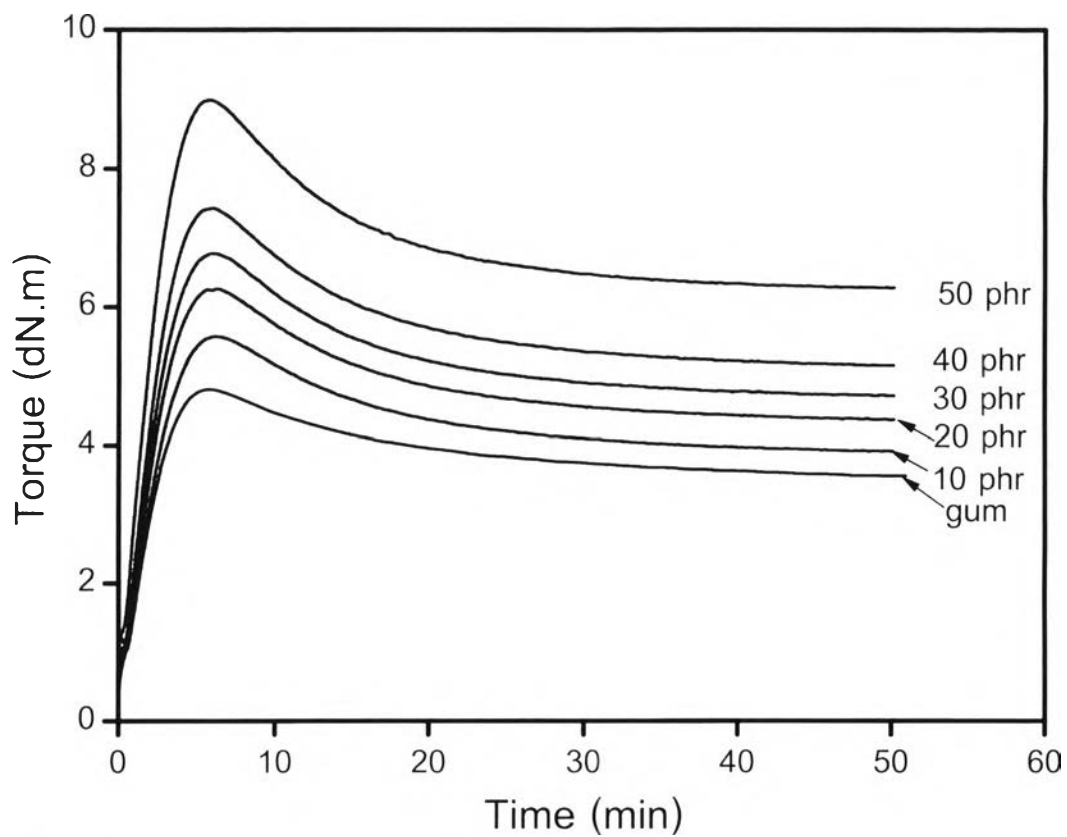


Figure A-35 Cure curve of N990 filled NR compound cured at 170°C with various loading

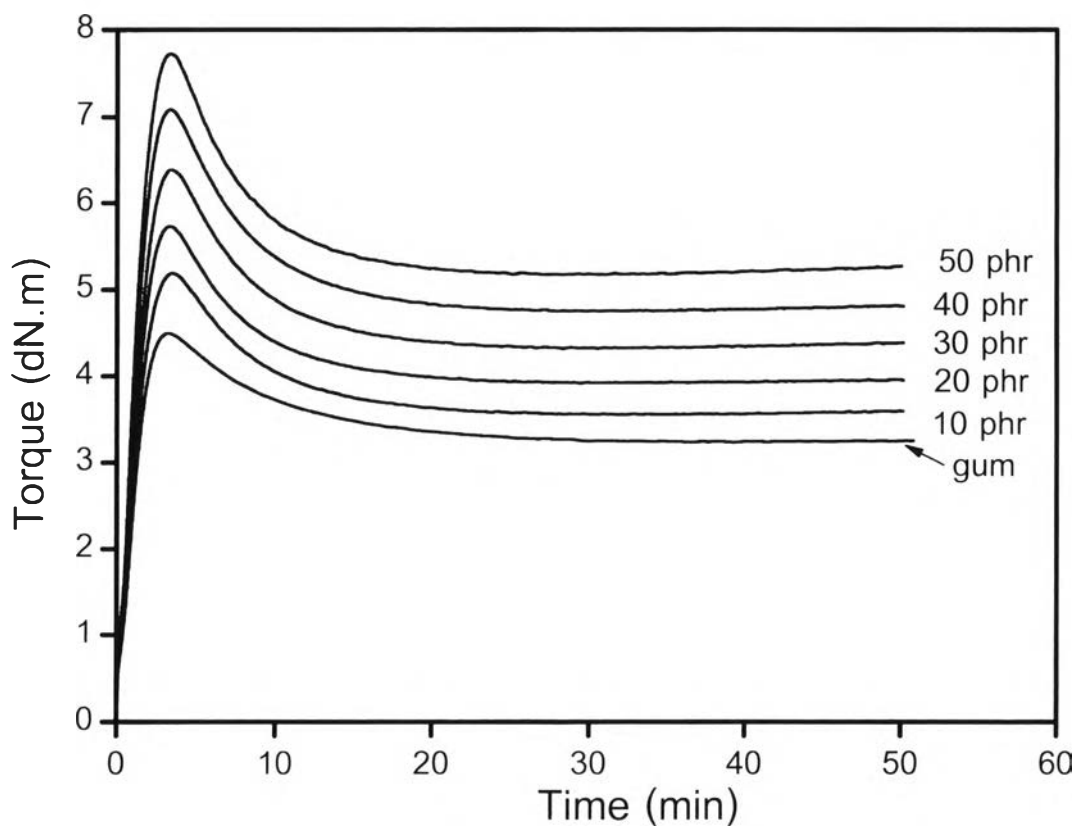


Figure A-36 Cure curve of N990 filled NR compound cured at 180°C with various loading

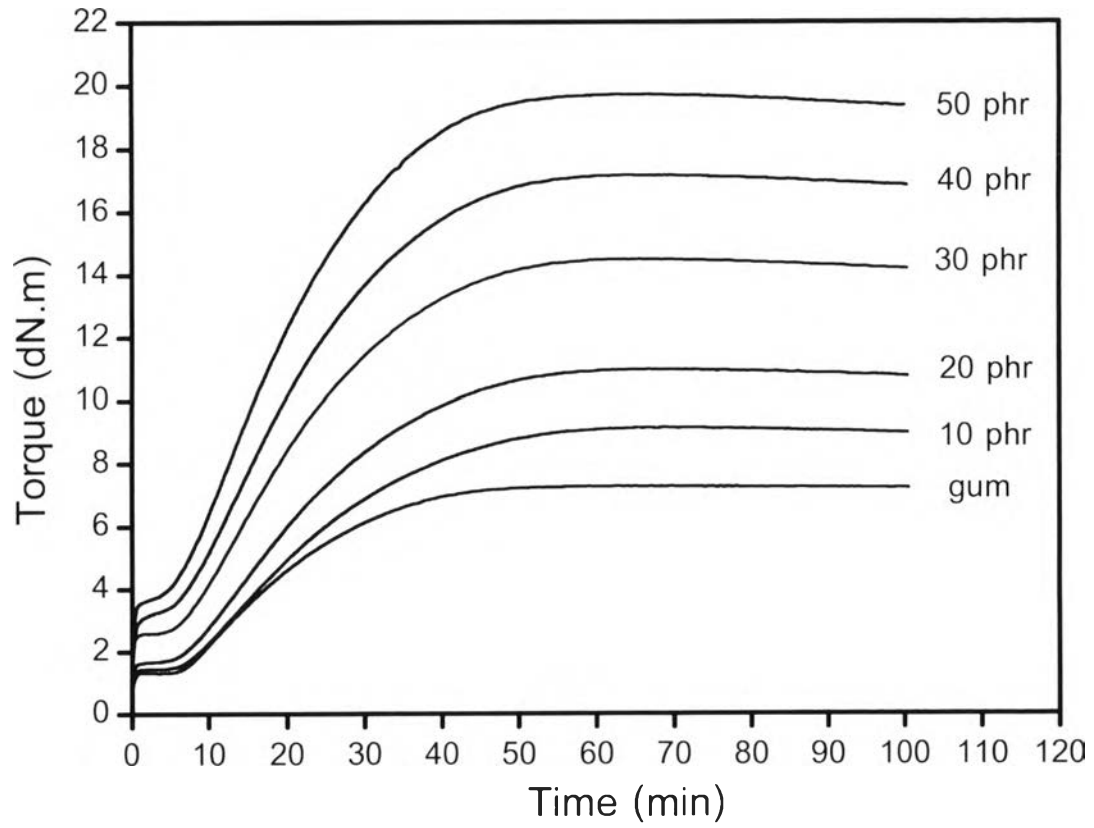


Figure A-37 Cure curve of gN330 filled NR compound cured at 130°C with various loading

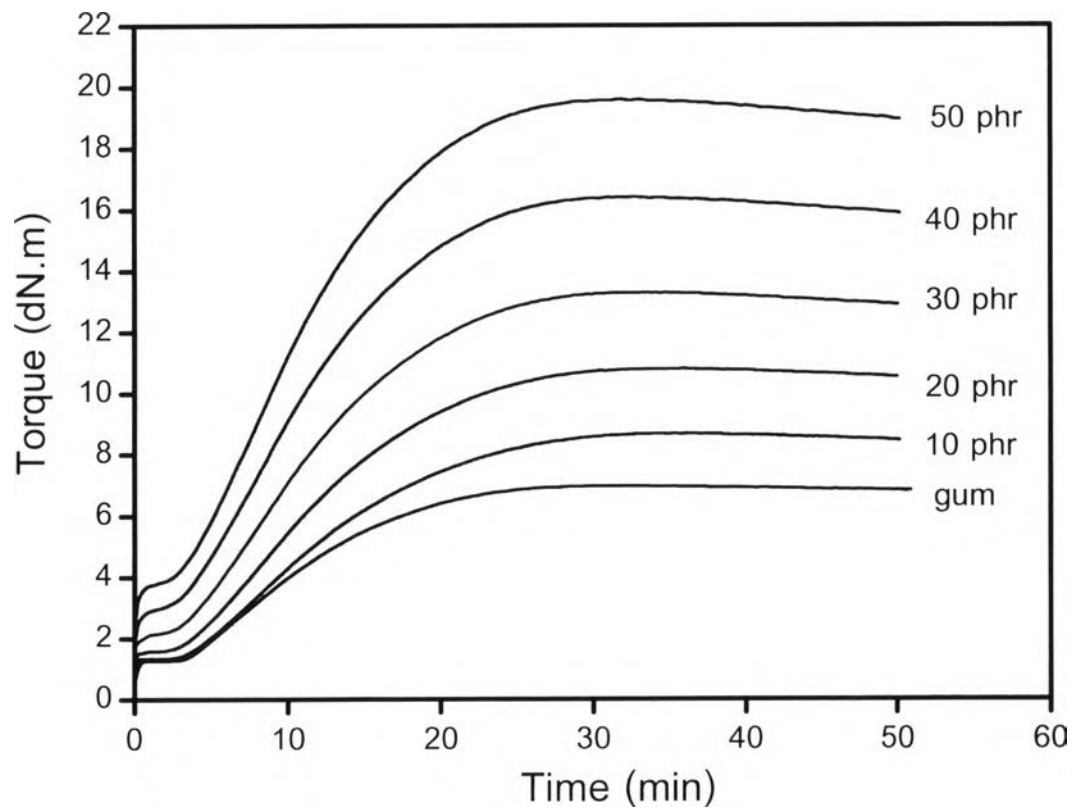


Figure A-38 Cure curve of gN330 filled NR compound cured at 140°C with various loading

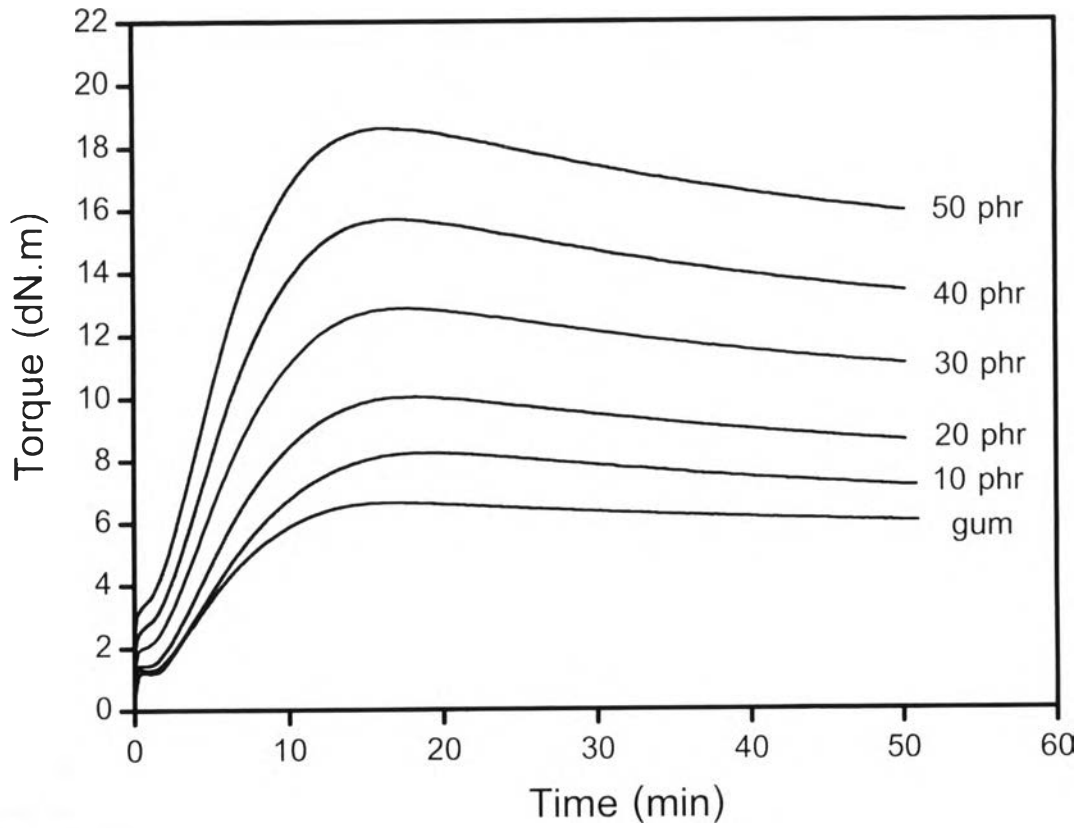


Figure A-39 Cure curve of gN330 filled NR compound cured at 150°C with various loading

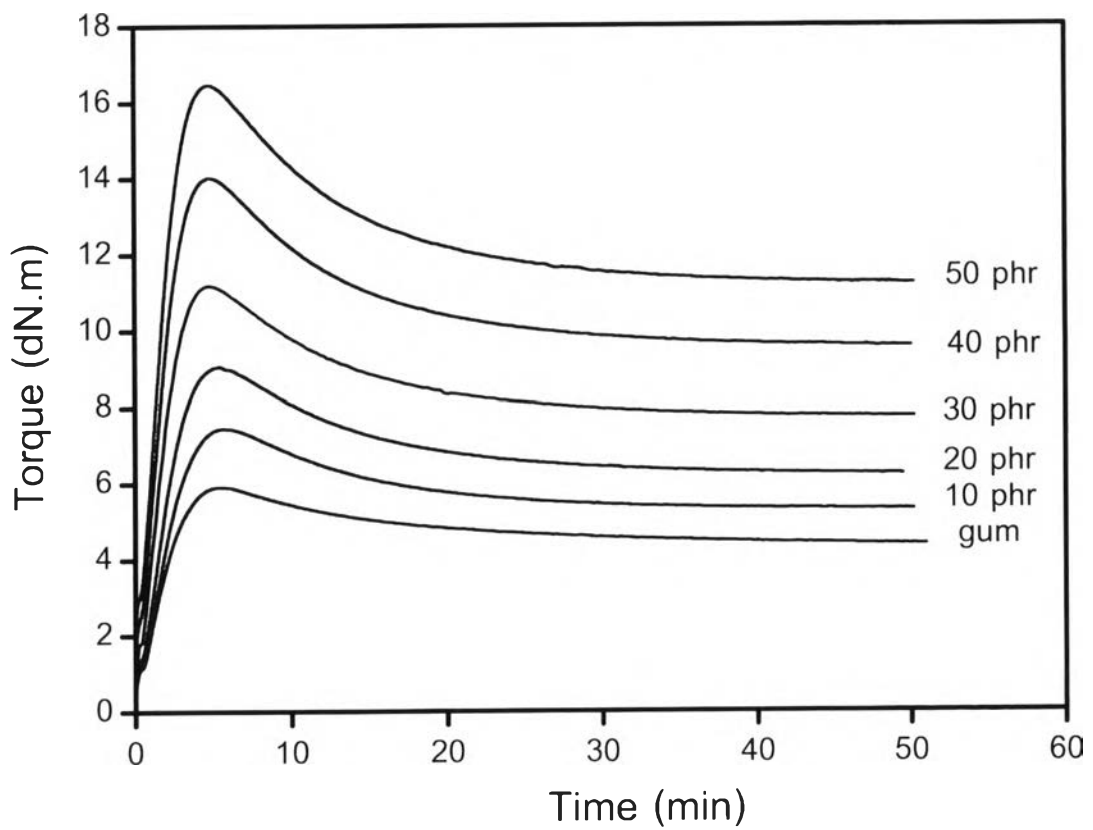


Figure A-40 Cure curve of gN330 filled NR compound cured at 170°C with various loading

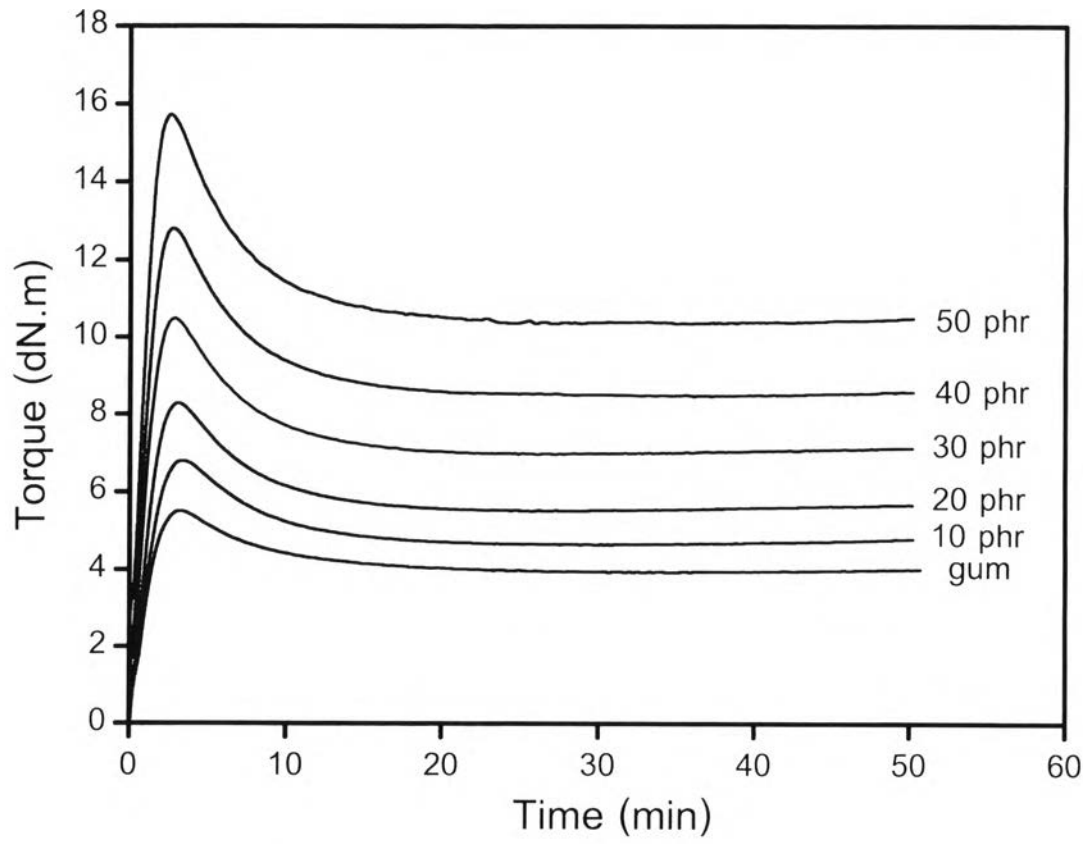


Figure A-41 Cure curve of gN330 filled NR compound cured at 180°C with various loading

APPENDIX B

CROSSLINK DENSITIES OF NR COMPOUNDS

Table B-1 Crosslink densities of gum NR vulcanizates

Sample	Crosslink density (mol/m ³)		
	tc ₉₀	tc ₁₀₀	tc _{100+20min}
1	79.9	66.8	48.5
2	79.1	65.2	49.2
3	80.8	67.7	49.3
Mean	80.0	66.5	66.5
SD	0.86	1.26	1.26

Table B-2 Crosslink densities of N330 filled NR vulcanizates at tc₉₀

Sample	Crosslink density (mol/m ³)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	67.6	92.5	117	114	182
2	67.5	94.1	116	123	184
3	66.9	92.5	120	140	186
Mean	67.3	93.0	117	126	184
SD	0.36	0.91	0.96	5.81	2.15

Table B-3 Crosslink densities of N330 filled NR vulcanizates at tc₁₀₀

Sample	Crosslink density (mol/m ³)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	68.9	91.0	123	133	186
2	68.9	91.1	121	135	196
3	68.5	91.6	200	135	186
Mean	68.7	91.2	122	135	189
SD	0.23	0.34	1.59	1.10	5.40

Table B-4 Crosslink densities of N330 filled NR vulcanizates at $t_{c_{100+20 \text{ min}}}$

Sample	Crosslink density (mol/m ³)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	50.8	66.8	81.8	113	146
2	51.1	67.8	82.6	112	156
3	47.9	70.2	85.7	113	146
Mean	68.8	91.2	122	134	189
SD	0.23	0.34	1.59	1.10	5.40

Table B-5 Crosslink densities of N550 filled NR vulcanizates at $t_{c_{90}}$

Sample	Crosslink density (mol/m ³)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	67.3	85.5	112	137	164
2	65.6	85.7	113	139	170
3	65.9	85.8	112	142	169
Mean	66.3	85.7	112	139	167
SD	0.90	0.18	0.43	3.33	4.02

Table B-6 Crosslink densities of N550 filled NR vulcanizates at $t_{c_{100}}$

Sample	Crosslink density (mol/m ³)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	61.8	89.7	112	145	168
2	60.4	89.5	110	142	172
3	61.9	88.8	109	136	168
Mean	61.4	89.4	110	141	170
SD	0.85	0.47	1.14	6.05	3.39

Table B-7 Crosslink densities of N550 filled NR vulcanizates at $t_{c_{100+20 \text{ min}}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	44.5	62.9	82.2	103	134
2	44.5	63.1	82.7	100	128
3	43.8	63.0	82.5	104	128
Mean	44.3	63.0	82.5	102	131
SD	0.41	0.10	0.29	0.54	4.26

Table B-8 Crosslink densities of N776 filled NR vulcanizates at $t_{c_{90}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	64.6	86.9	98.8	123	142
2	66.9	84.6	100	120	147
3	63.7	83.7	97.2	120	146
Mean	65.1	85.0	98.7	121	145
SD	1.62	1.66	0.95	2.00	2.76

Table B-9 Crosslink densities of N776 filled NR vulcanizates at $t_{c_{100}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	62.5	74.3	94.3	117	146
2	62.4	72.1	93.9	116	150
3	62.1	72.8	94.3	117	150
Mean	62.4	73.1	94.1	117	148
SD	0.21	1.14	0.32	0.57	1.95

Table B-10 Crosslink densities of N776 filled NR vulcanizates at $t_{c_{100+20min}}$

Sample	Crosslink density (mol/m ³)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	49.6	55.7	68.3	85.2	112
2	48.5	55.6	69.6	88.5	111
3	48.6	55.6	69.5	83.7	111
Mean	48.9	55.6	69.1	85.8	111
SD	0.61	0.06	0.72	2.47	0.67

Table B-11 Crosslink densities of N990 filled NR vulcanizates at $t_{c_{90}}$

Sample	Crosslink density (mol/m ³)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	55.1	64.2	74.2	85.4	102
2	56.4	63.6	74.6	84.3	101
3	55.0	63.5	75.1	83.3	105
Mean	55.5	63.8	74.6	84.3	103
SD	0.75	0.36	0.26	0.75	1.85

Table B-12 Crosslink densities of N990 filled NR vulcanizates at $t_{c_{100}}$

Sample	Crosslink density (mol/m ³)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	56.2	67.6	80.1	83.9	103
2	56.6	68.0	77.3	85.6	107
3	56.7	67.3	227	85.2	101
Mean	56.5	67.6	78.7	84.9	104
SD	0.29	0.36	2.03	0.91	3.15

Table B-13 Crosslink densities of N990 filled NR vulcanizates at $t_{c_{100+20 \text{ min}}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	42.5	50.1	57.4	65.7	79.6
2	43.4	49.7	57.5	65.1	77.1
3	43.2	50.2	57.1	65.6	75.9
Mean	43.0	50.0	57.3	65.5	77.5
SD	0.50	0.26	0.24	0.32	2.57

Table B-14 Crosslink densities of gN330 filled NR vulcanizates at $t_{c_{90}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	57.2	64.8	74.7	83.2	98.7
2	57.1	67.3	74.5	85.3	98.7
3	57.1	64.8	74.9	84.1	97.3
Mean	57.2	65.7	74.7	84.2	98.2
SD	0.09	1.43	0.08	1.48	0.80

Table B-15 Crosslink densities of gN330 filled NR vulcanizates at $t_{c_{100}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	58.7	66.0	74.2	87.9	96.5
2	59.8	67.1	76.3	86.1	97.6
3	56.9	67.2	76.0	85.9	97.7
Mean	58.4	66.8	75.2	86.6	97.3
SD	1.46	0.70	1.44	1.12	0.64

Table B-16 Crosslink densities of gN330 filled NR vulcanizates at $tc_{100+20\text{ min}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	43.5	49.9	56.1	62.0	73.6
2	42.4	48.9	56.9	62.7	71.0
3	40.3	48.7	55.9	63.8	69.5
Mean	42.1	49.2	56.3	62.8	71.3
SD	1.63	0.68	0.52	0.92	2.88

Table B-17 Crosslink densities of gum NR vulcanizates with thermal aging at tc_{90}

Sample	Crosslink density (mol/m^3)		
	tc_{90}	tc_{100}	$tc_{100+20\text{min}}$
1	83.6	83.6	60.3
2	83.5	83.5	60.8
3	83.6	70.7	62.3
Mean	83.6	79.27	61.1
SD	0.06	0.06	1.03

Table B-18 Crosslink densities of N330 filled NR vulcanizates with thermal aging at tc_{90}

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	84.0	121	160	207	262
2	86.6	122	163	191	250
3	87.2	120	160	214	235
Mean	85.9	121	161	204	249
SD	1.68	1.23	1.84	4.77	8.06

Table B-19 Crosslink densities of N330 filled NR vulcanizates with thermal aging at $t_{c_{100}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	93.2	126	173	197	267
2	93.7	125	173	194	269
3	93.2	127	173	197	266
Mean	93.4	126	173	196	267
SD	0.27	0.55	0.02	1.47	1.28

Table B-20 Crosslink densities of N550 filled NR vulcanizates with thermal aging at $t_{c_{90}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	90.4	121	161	203	248
2	88.4	121	163	206	254
3	87.2	120	161	202	253
Mean	88.7	121	162	204	251
SD	1.61	0.81	1.01	0.69	4.14

Table B-21 Crosslink densities of N550 filled NR vulcanizates with thermal aging at $t_{c_{100}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	83.7	119	158	212	254
2	81.1	116	156	213	244
3	84.0	121	158	209	246
Mean	82.9	119	157	211	249
SD	1.58	2.57	0.85	2.13	7.04

Table B-22 Crosslink densities of N776 filled NR vulcanizates with thermal aging at $t_{c_{90}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	85.1	113	140	174	217
2	86.4	111	140	146	225
3	86.1	113	142	172	226
Mean	85.9	112	141	164	223
SD	0.68	0.97	1.28	0.97	5.87

Table B-23 Crosslink densities of N776 filled NR vulcanizates with thermal aging at $t_{c_{100}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	84.1	102	138	172	216
2	83.8	103	134	174	216
3	81.2	108	137	178	214
Mean	83.0	104	136	175	215
SD	1.58	3.65	2.42	3.14	0.94

Table B-24 Crosslink densities of N990 filled NR vulcanizates at with thermal aging $t_{c_{90}}$

Sample	Crosslink density (mol/m^3)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	73.0	86.2	101	114	145
2	74.1	84.0	101	115	146
3	73.9	85.8	104	117	145
Mean	73.7	85.3	102	115	145
SD	0.58	1.17	1.67	1.65	0.46

Table B-25 Crosslink densities of N990 filled NR vulcanizates with thermal aging at $t_{c_{100}}$

Sample	Crosslink density (mol/m ³)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	73.1	91.6	109	120	146
2	76.5	90.6	109	120	142
3	74.4	90.6	107	120	145
Mean	74.7	90.9	109	120	145
SD	1.70	0.55	0.38	0.38	2.21

Table B-26 Crosslink densities of gN330 filled NR vulcanizates with thermal aging at $t_{c_{90}}$

Sample	Crosslink density (mol/m ³)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	73.8	92.4	106	122	143
2	76.1	94.3	105	125	142
3	75.3	91.6	108	122	145
Mean	75.1	92.8	106	123	143
SD	1.16	1.35	1.29	0.10	0.81

Table B-27 Crosslink densities of gN330 filled NR vulcanizates with thermal aging at $t_{c_{100}}$

Sample	Crosslink density (mol/m ³)				
	10 phr	20 phr	30 phr	40 phr	50 phr
1	74.8	91.3	107	123	143
2	76.3	93.0	107	122	140
3	75.8	92.7	106	126	143
Mean	75.59	92.3	107	124	142
SD	0.76	0.93	0.33	2.26	1.66

APPENDIX C

TENSILE PROPERTIES OF NR COMPOUNDS

Table C-1 Tensile properties of gum NR vulcanizates at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	0.68	1.10	1.65	21.0	740	25.2
2	0.72	1.15	1.66	20.3	712	26.5
3	0.75	1.17	1.55	20.6	724	25.4
4	0.73	1.16	1.68	21.0	740	26.2
5	0.71	1.14	1.64	20.7	728	23.9
Mean	0.72	1.14	1.63	20.7	729	25.4
SD	0.03	0.02	0.05	0.29	11.8	1.00

Table C-2 Tensile properties of N330 filled NR vulcanizates with 10 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	0.80	1.37	2.30	18.5	640	24.2
2	0.90	1.54	2.47	19.5	680	25.6
3	0.78	1.42	2.35	19.0	660	23.5
4	0.90	1.54	2.47	18.3	632	25.0
5	0.79	1.45	2.30	18.7	648	26.1
Mean	0.83	1.47	2.38	18.8	652	24.9
SD	0.06	0.07	0.08	0.47	18.8	1.06

Table C-3 Tensile properties of N330 filled NR vulcanizates with 20 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.15	2.28	4.11	18.5	640	27.7
2	1.10	2.27	4.14	18.5	640	29.7
3	1.13	2.27	3.86	18.8	652	29.1
4	1.04	1.91	3.29	18.0	620	28.7
5	1.11	1.89	3.49	16.0	540	21.6
Mean	1.11	2.12	3.78	18.0	618	27.4
SD	0.04	0.20	0.38	1.13	45.3	3.31

Table C-4 Tensile properties of N330 filled NR vulcanizates with 30 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.48	2.92	5.22	17.0	580	28.5
2	1.40	3.00	5.32	17.5	600	29.3
3	1.44	2.86	5.20	17.0	580	29.4
4	1.63	3.15	5.65	18.0	620	30.1
5	1.63	3.07	5.46	17.5	600	29.3
Mean	1.52	3.00	5.37	17.4	596	29.3
SD	0.11	0.12	0.19	0.42	16.7	0.56

Table C-5 Tensile properties of N330 filled NR vulcanizates with 40 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.78	4.52	8.16	16.0	540	30.8
2	1.99	4.45	8.68	14.5	480	31.4
3	1.76	3.97	7.75	16.0	540	29.1
4	1.94	4.30	8.32	16.0	540	30.3
5	2.01	4.99	8.76	15.5	520	30.2
Mean	1.89	4.45	8.33	15.6	524	30.4
SD	0.12	0.37	0.41	0.65	26.1	0.84

Table C-6 Tensile properties of N330 filled NR vulcanizates with 50 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	2.56	6.23	11.0	13.0	420	28.2
2	2.33	5.38	9.74	14.0	460	28.3
3	3.28	6.70	11.5	13.5	440	28.6
4	3.52	6.21	14.1	14.0	460	28.8
5	2.77	5.94	11.4	13.5	440	28.6
Mean	2.89	6.09	11.6	13.6	444	28.5
SD	0.50	0.48	1.61	0.42	16.7	0.25

Table C-7 Tensile properties of N550 filled NR vulcanizates with 10 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.52	3.88	8.37	12.5	400	13.9
2	1.72	3.89	8.14	12.0	380	8.49
3	1.42	3.14	7.20	13.0	420	12.1
4	1.47	3.41	6.94	12.0	380	9.03
5	1.48	3.46	7.05	13.0	420	12.7
Mean	1.52	3.56	7.54	12.5	400	11.3
SD	0.11	0.32	0.66	0.50	20.0	2.37

Table C-8 Tensile properties of N550 filled NR vulcanizates with 20 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	2.26	5.98	12.3	11.0	340	12.8
2	2.36	6.54	12.0	10.5	320	12.5
3	2.12	6.12	N/A	9.50	280	9.60
4	2.40	6.59	12.0	10.5	320	12.6
5	2.05	5.96	N/A	9.50	280	11.3
Mean	1.34	2.99	6.31	18.5	642	27.0
SD	0.20	0.20	0.24	0.51	20.5	0.76

Table C-9 Tensile properties of N550 filled NR vulcanizates with 30 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.63	4.39	9.48	16.7	568	25.8
2	1.82	4.63	9.89	16.3	552	26.4
3	1.96	5.10	9.24	16.6	564	25.8
4	2.11	6.79	10.9	16.7	568	26.0
5	1.99	4.98	10.1	16.4	556	25.9
Mean	1.90	5.18	9.92	16.5	562	26.0
SD	0.18	0.94	0.63	0.18	7.27	0.24

Table C-10 Tensile properties of N550 filled NR vulcanizates with 40 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	2.65	7.28	13.7	14.2	468	26.2
2	2.44	7.87	13.4	15.1	504	25.6
3	3.09	7.41	13.5	14.9	496	25.7
4	2.88	7.31	14.2	14.9	496	25.6
5	2.88	6.95	13.2	15.3	512	25.9
Mean	2.79	7.36	13.6	14.9	495	25.8
SD	0.25	0.33	0.36	0.41	16.6	0.23

Table C-11 Tensile properties of N550 filled NR vulcanizates with 50 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	4.04	11.3	17.9	12.8	412	24.2
2	3.72	9.82	16.8	14.3	472	25.5
3	3.87	9.66	17.7	13.1	424	23.9
4	3.78	10.4	17.2	14.1	464	25.5
5	3.75	9.76	16.4	13.6	444	23.9
Mean	3.83	10.2	17.2	13.6	443	24.6
SD	0.13	0.67	0.64	0.64	25.5	0.86

Table C-12 Tensile properties of N776 filled NR vulcanizates with 10 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	0.95	2.01	3.02	18.2	628	18.7
2	1.01	2.07	3.24	18.9	656	24.5
3	1.01	2.01	3.29	20.2	708	27.6
4	0.99	2.00	3.32	20.0	700	25.8
5	-	-	-	-	-	-
Mean	0.99	2.02	3.22	19.3	673	24.1
SD	0.03	0.03	0.14	0.94	37.7	3.85

Table C-13 Tensile properties of N776 filled NR vulcanizates with 20 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.25	2.30	5.07	18.8	652	26.5
2	1.38	2.72	4.70	18.6	644	26.2
3	1.32	2.51	4.78	18.3	632	25.0
4	1.36	2.43	4.69	18.2	628	23.3
5	1.21	2.36	4.82	17.9	616	23.4
Mean	1.30	2.46	4.81	18.4	634	24.9
SD	0.07	0.16	0.15	0.35	14.0	1.50

Table C-14 Tensile properties of N776 filled NR vulcanizates with 30 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.67	3.42	7.70	16.8	572	25.5
2	1.78	3.61	7.68	17.0	580	24.9
3	1.69	3.76	8.02	16.0	540	22.4
4	1.96	3.58	8.05	17.3	592	25.8
5	1.64	3.99	7.02	16.2	548	22.6
Mean	1.75	3.67	7.69	16.7	566	24.2
SD	0.13	0.22	0.41	0.55	21.8	1.61

Table C-15 Tensile properties of N776 filled NR vulcanizates with 40 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.98	4.41	10.3	16.8	572	26.6
2	1.98	5.50	10.6	16.9	576	27.2
3	1.98	5.22	10.8	16.6	564	26.1
4	2.05	5.40	10.7	16.1	544	25.1
5	1.86	4.29	8.00	17.1	584	25.4
Mean	1.97	4.96	10.1	16.7	568	26.1
SD	0.07	0.57	1.17	0.38	15.2	0.84

Table C-16 Tensile properties of N776 filled NR vulcanizates with 50 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	2.31	6.72	13.3	14.5	480	23.8
2	2.54	5.87	12.4	14.4	476	22.8
3	2.82	6.96	12.5	15.2	508	23.8
4	2.34	7.20	13.0	14.3	472	22.7
5	2.68	7.77	13.7	14.9	496	24.2
Mean	2.54	6.90	13.0	14.7	486	23.5
SD	0.22	0.70	0.55	0.38	15.1	0.69

Table C-17 Tensile properties of N990 filled NR vulcanizates with 10 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.00	1.63	2.60	20.5	720	25.2
2	0.87	1.58	2.46	20.6	724	25.9
3	0.96	1.57	2.58	21.3	752	26.9
4	0.72	1.35	2.33	20.5	720	25.3
5	1.01	1.81	2.61	21.1	744	28.3
Mean	0.91	1.59	2.52	20.8	732	26.3
SD	0.12	0.17	0.12	0.37	15.0	1.29

Table C-18 Tensile properties of N990 filled NR vulcanizates with 20 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	0.88	1.87	3.29	19.8	692	26.5
2	1.06	1.93	3.38	19.7	688	27.1
3	0.88	1.83	3.01	20.6	724	26.9
4	0.93	1.73	2.97	20.3	712	25.6
5	1.05	1.75	3.21	20.2	708	26.9
Mean	0.96	1.82	3.17	20.1	705	26.6
SD	0.09	0.08	0.18	0.37	14.8	0.62

Table C-19 Tensile properties of N990 filled NR vulcanizates with 30 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.10	2.13	3.89	18.7	648	25.4
2	1.19	2.14	3.94	18.6	644	26.8
3	1.13	1.93	3.91	19.1	664	26.6
4	1.03	2.01	3.87	18.3	632	25.0
5	1.05	2.00	3.79	19.0	660	25.3
Mean	1.10	2.04	3.88	18.7	650	25.8
SD	0.06	0.09	0.06	0.32	12.8	0.82

Table C-20 Tensile properties of N990 filled NR vulcanizates with 40 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.13	2.34	4.79	18.4	636	22.6
2	1.31	2.62	4.43	18.5	640	24.3
3	1.22	2.27	4.58	17.9	616	22.7
4	1.31	2.46	4.63	18.5	640	24.9
5	1.25	2.39	4.81	18.1	624	23.2
Mean	1.24	2.42	4.65	18.3	631	23.5
SD	0.07	0.13	0.15	0.27	10.7	1.04

Table C-21 Tensile properties of N990 filled NR vulcanizates with 50 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.37	2.91	5.86	18.3	632	22.8
2	1.34	2.94	6.22	17.7	608	22.2
3	1.35	2.93	5.79	17.3	592	22.0
4	1.46	2.84	5.64	17.7	608	23.6
5	1.53	2.95	6.17	17.3	592	22.4
Mean	1.41	2.91	5.94	17.7	606	22.6
SD	0.08	0.04	0.25	0.41	16.4	0.62

Table C-22 Tensile properties of gN330 filled NR vulcanizates with 10 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	0.73	1.39	2.19	20.5	720	25.2
2	0.83	1.41	2.36	21.5	760	25.6
3	0.80	1.38	2.10	22.0	780	24.0
4	0.83	1.37	2.00	22.5	800	27.2
5	0.82	1.41	2.08	21.5	760	24.2
Mean	0.80	1.39	2.15	21.6	764	25.2
SD	0.04	0.02	0.14	0.74	29.7	1.28

Table C-23 Tensile properties of gN330 filled NR vulcanizates with 20 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	0.93	1.55	2.41	25.0	900	28.7
2	1.02	1.73	2.48	22.0	780	28.2
3	1.08	1.68	2.46	23.0	820	28.0
4	0.99	1.53	2.49	21.0	740	27.1
5	-	-	-	-	-	-
Mean	1.01	1.62	2.46	22.8	810	28.0
SD	0.06	0.10	0.04	1.71	68.3	0.69

Table C-24 Tensile properties of gN330 filled NR vulcanizates with 30 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.07	1.98	2.96	20.5	720	25.2
2	1.27	2.11	3.38	21.0	740	28.5
3	1.03	1.81	2.72	22.0	780	28.5
4	1.23	1.94	3.02	19.0	660	26.6
5	1.24	2.02	2.89	19.5	680	29.7
Mean	1.17	1.97	3.00	20.4	716	27.7
SD	0.11	0.11	0.24	1.19	47.8	1.80

Table C-25 Tensile properties of gN330 filled NR vulcanizates with 40 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.42	2.36	3.54	21.0	740	25.4
2	1.37	2.30	3.76	21.0	740	25.7
3	1.33	2.14	3.10	21.0	740	26.1
4	1.26	2.27	3.81	21.0	740	26.9
5	1.47	2.45	3.76	20.0	700	26.2
Mean	1.37	2.31	3.60	20.8	732	26.1
SD	0.08	0.11	0.30	0.45	17.9	0.58

Table C-26 Tensile properties of gN330 filled NR vulcanizates with 50 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.71	2.70	4.29	20.0	700	24.8
2	1.62	2.64	3.83	20.0	700	25.3
3	1.73	3.02	4.27	20.0	700	25.1
4	1.73	2.74	4.18	20.0	700	25.9
5	1.65	2.51	3.81	19.5	680	25.2
Mean	1.69	2.72	4.07	19.9	696	25.2
SD	0.05	0.19	0.24	0.22	8.94	0.40

APPENDIX D

THERMAL AGING PROPERTIES OF NR COMPOUNDS

Table D-1 Thermal aging properties of gum NR vulcanizates at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.71	4.33	N/A	8.50	240	10.7
2	1.57	3.64	N/A	12.5	400	10.5
3	1.69	3.90	N/A	10.0	300	12.1
4	1.76	3.97	N/A	9.50	280	11.8
5	-	-	-	-	-	-
Mean	1.68	3.96	N/A	10.1	305	11.3
SD	0.08	0.28	N/A	1.70	68.1	0.80

Table D-2 Thermal aging properties of N330 filled NR vulcanizates with 10 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.71	4.33	N/A	8.50	240	5.37
2	1.57	3.64	N/A	12.5	400	9.74
3	1.69	3.90	N/A	10.0	300	9.33
4	1.76	3.97	N/A	9.50	280	7.66
5	1.80	4.41	N/A	6.00	140	5.04
Mean	1.71	4.05	N/A	9.30	272	7.43
SD	0.09	0.32	N/A	2.36	94.5	2.18

Table D-3 Thermal aging properties of N330 filled NR vulcanizates with 20 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	2.13	6.44	N/A	10.0	300	10.6
2	2.26	6.53	N/A	8.50	240	8.66
3	2.43	6.56	N/A	8.00	220	7.53
4	2.61	6.50	N/A	9.00	260	11.9
5	-	-	-	-	-	-
Mean	2.36	6.51	N/A	8.88	255	9.67
SD	0.21	0.05	N/A	0.85	34.2	1.96

Table D-4 Thermal aging properties of N330 filled NR vulcanizates with 30 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	4.27	11.5	N/A	9.00	260	15.8
2	3.72	9.87	N/A	8.50	240	12.5
3	4.31	11.5	N/A	7.50	200	12.1
4	3.95	10.2	N/A	8.50	240	14.0
5	-	-	-	-	-	-
Mean	4.06	10.7	N/A	8.38	235	13.6
SD	0.28	0.85	N/A	0.63	25.2	1.70

Table D-5 Thermal aging properties of N330 filled NR vulcanizates with 40 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	4.87	N/A	N/A	8.50	240	15.9
2	5.49	N/A	N/A	7.50	200	15.7
3	5.20	N/A	N/A	8.50	240	18.5
4	5.01	N/A	N/A	9.00	260	18.3
5	-	-	-	-	-	-
Mean	5.14	N/A	N/A	8.38	235	17.1
SD	0.27	N/A	N/A	0.63	25.2	1.50

Table D-6 Thermal aging properties of N330 filled NR vulcanizates with 50 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	7.37	17.2	N/A	8.00	220	18.9
2	7.15	15.0	N/A	6.50	160	15.5
3	7.02	16.4	N/A	7.00	180	16.9
4	6.51	N/A	N/A	6.00	140	13.9
5	7.31	15.7	N/A	7.50	200	16.3
Mean	7.07	16.1	N/A	7.00	180	16.3
SD	0.34	0.97	N/A	0.79	31.6	1.83

Table D-7 Thermal aging properties of N550 filled NR vulcanizates with 10 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.56	2.99	7.41	17.5	600	13.5
2	1.30	3.43	7.11	13.0	420	12.5
3	1.39	3.40	6.48	14.0	460	18.3
4	1.50	3.51	6.90	14.0	460	19.4
5	-	-	-	-	-	-
Mean	1.44	3.33	6.97	14.6	485	15.9
SD	0.12	0.23	0.39	1.97	79.0	3.40

Table D-8 Thermal aging properties of N550 filled NR vulcanizates with 20 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	2.38	6.40	12.4	10.5	320	15.5
2	2.39	6.37	11.9	12.0	380	14.6
3	2.39	5.91	12.8	12.5	400	18.1
4	2.36	6.61	12.5	12.5	400	19.7
5	2.46	6.83	12.2	12.0	380	16.0
Mean	2.40	6.42	12.4	11.9	376	16.8
SD	0.04	0.34	0.36	0.82	32.9	2.09

Table D-9 Thermal aging properties of N550 filled NR vulcanizates with 30 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	3.09	10.5	17.7	11.0	340	19.3
2	3.74	9.53	16.4	9.50	280	17.5
3	3.60	10.7	18.5	11.0	340	20.6
4	3.35	10.3	N/A	9.50	280	16.4
5	3.99	9.10	16.8	11.0	340	19.5
Mean	3.56	10.0	17.3	10.4	316	18.7
SD	0.35	0.67	0.93	0.82	32.9	1.70

Table D-10 Thermal aging properties of N550 filled NR vulcanizates with 40 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	4.82	12.9	N/A	9.50	280	20.0
2	4.74	12.3	19.4	10.0	300	20.0
3	4.58	12.9	20.0	10.0	300	20.7
4	3.73	11.6	N/A	9.50	280	19.1
5	5.02	14.6	N/A	9.00	260	23.2
Mean	4.58	12.8	19.7	9.60	284	20.6
SD	0.50	1.09	0.40	0.42	16.7	1.58

Table D-11 Thermal aging properties of N550 filled NR vulcanizates with 50 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	7.58	18.3	N/A	7.50	200	18.6
2	7.34	16.4	N/A	8.50	240	19.1
3	6.77	15.7	N/A	9.00	260	20.7
4	8.35	17.4	N/A	8.50	240	19.8
5	7.67	16.8	N/A	9.00	260	19.7
Mean	7.54	16.9	N/A	8.50	240	19.6
SD	0.57	0.98	N/A	0.61	24.5	0.82

Table D-12 Thermal aging properties of N776 filled NR vulcanizates with 10 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.44	3.23	6.12	16.2	548	21.9
2	1.53	3.42	5.83	15.5	520	16.4
3	1.35	2.78	5.39	14.9	496	16.5
4	1.47	3.07	5.55	15.2	508	16.3
5	1.48	2.96	4.88	16.7	568	20.7
Mean	1.45	3.09	5.55	15.7	528	18.4
SD	0.07	0.25	0.47	0.74	29.5	2.72

Table D-13 Thermal aging properties of N776 filled NR vulcanizates with 20 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.80	3.87	8.76	14.2	468	19.2
2	1.91	4.42	8.86	15.2	508	22.3
3	1.72	4.83	8.56	14.3	472	23.2
4	1.67	4.31	9.79	14.5	480	20.1
5	1.87	4.32	8.51	14.8	492	19.9
Mean	1.79	4.35	8.90	14.6	484	20.9
SD	0.10	0.34	0.52	0.41	16.3	1.72

Table D-14 Thermal aging properties of N776 filled NR vulcanizates with 30 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	2.55	5.62	11.5	12.0	380	16.5
2	2.33	5.92	12.6	13.7	448	21.7
3	2.88	6.36	12.3	13.5	440	20.7
4	2.77	5.68	11.3	13.8	452	21.0
5	2.53	5.89	12.5	13.7	448	22.9
Mean	2.61	5.89	12.0	13.3	434	20.6
SD	0.22	0.29	0.58	0.76	30.3	2.45

Table D-15 Thermal aging properties of N776 filled NR vulcanizates with 40 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	3.59	8.72	15.4	11.6	364	19.1
2	3.09	8.81	16.0	11.4	356	18.3
3	3.28	7.66	15.3	12.4	396	21.1
4	3.07	8.88	16.2	12.2	388	20.1
5	2.46	9.18	16.6	11.8	372	20.2
Mean	3.10	8.65	15.9	11.9	375	19.8
SD	0.41	0.58	0.55	0.41	16.6	1.09

Table D-16 Thermal aging properties of N776 filled NR vulcanizates with 50 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	3.59	11.5	N/A	8.30	232	14.0
2	3.61	11.3	N/A	8.60	244	13.0
3	4.44	12.1	18.1	10.0	300	18.4
4	3.79	11.3	20.1	10.4	316	20.3
5	3.53	10.9	N/A	8.10	224	15.8
Mean	3.79	11.4	19.1	9.08	263	16.3
SD	0.38	0.41	1.41	1.05	41.9	3.04

Table D-17 Thermal aging properties of N990 filled NR vulcanizates with 10 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.41	2.30	4.06	15.0	500	19.3
2	1.21	2.31	4.21	14.5	480	18.7
3	1.17	2.48	4.32	15.0	500	19.5
4	1.24	2.52	4.72	16.0	540	17.8
5	1.22	2.33	4.51	14.5	480	15.3
Mean	1.25	2.39	4.35	15.0	500	18.1
SD	0.09	0.10	0.27	0.61	24.5	1.69

Table D-18 Thermal aging properties of N990 filled NR vulcanizates with 20 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.49	3.00	6.34	16.0	540	21.3
2	1.30	2.60	6.00	16.4	556	23.8
3	1.47	2.83	5.68	16.9	576	26.7
4	1.32	2.75	6.08	16.8	572	24.7
5	1.32	2.68	5.79	16.2	548	24.9
Mean	1.38	2.77	5.98	16.5	558	24.3
SD	0.10	0.15	0.26	0.38	15.4	1.96

Table D-19 Thermal aging properties of N990 filled NR vulcanizates with 30 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	-	-	-	-	-	-
2	1.59	3.21	7.14	14.9	496	22.0
3	1.38	3.57	6.94	16.5	560	22.7
4	1.46	3.51	6.98	16.0	540	20.0
5	1.59	3.51	7.21	15.9	536	23.9
Mean	1.50	3.45	7.07	15.8	533	22.2
SD	0.10	0.16	0.13	0.67	26.8	1.63

Table D-20 Thermal aging properties of N990 filled NR vulcanizates with 40 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.80	4.78	9.17	15.9	536	23.8
2	1.84	4.06	8.97	14.5	480	20.3
3	1.77	4.35	9.39	15.3	512	22.6
4	1.86	4.13	8.71	14.7	488	20.4
5	1.94	4.38	8.70	16.4	556	23.6
Mean	1.84	4.34	8.99	15.4	514	22.1
SD	0.07	0.28	0.30	0.80	32.0	1.71

Table D-21 Thermal aging properties of N990 filled NR vulcanizates with 50 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	2.26	5.25	10.4	14.2	468	19.5
2	2.53	5.04	10.1	14.6	484	19.3
3	2.17	5.40	10.8	14.1	464	18.6
4	2.42	5.44	10.7	14.5	480	19.3
5	2.02	4.78	11.0	13.2	428	17.2
Mean	2.28	5.18	10.6	14.1	465	18.8
SD	0.20	0.28	0.36	0.55	22.2	0.95

Table D-22 Thermal aging properties of gN330 filled NR vulcanizates with 10 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.04	1.88	2.94	19.0	660	22.9
2	1.16	1.89	2.84	18.5	640	22.6
3	0.92	1.84	2.70	18.5	640	24.2
4	1.06	1.90	3.41	19.0	660	23.3
5	1.15	1.91	2.87	19.0	660	24.8
Mean	1.07	1.88	2.95	18.8	652	23.6
SD	0.10	0.03	0.27	0.27	11.0	0.92

Table D-23 Thermal aging properties of gN330 filled NR vulcanizates with 20 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.27	2.20	4.09	14.5	480	17.6
2	1.22	2.43	3.87	16.0	540	20.7
3	1.27	2.32	3.71	17.5	600	26.0
4	1.14	2.23	3.65	19.0	660	24.9
5	1.42	2.36	3.82	18.5	640	23.9
Mean	1.26	2.31	3.82	17.1	584	22.6
SD	0.11	0.09	0.17	1.85	74.0	3.44

Table D-24 Thermal aging properties of gN330 filled NR vulcanizates with 30 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.50	2.91	5.05	17.5	600	23.5
2	1.79	3.11	5.13	18.0	620	27.8
3	1.49	3.10	5.20	17.5	600	23.3
4	1.53	2.97	5.20	14.0	460	15.5
5	1.66	3.05	4.95	17.0	580	25.4
Mean	1.59	3.03	5.10	16.8	572	23.1
SD	0.13	0.08	0.11	1.60	64.2	4.63

Table D-25 Thermal aging properties of gN330 filled NR vulcanizates with 40 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	1.86	3.26	5.84	16.0	540	22.2
2	2.21	3.94	6.68	16.0	540	20.7
3	1.79	3.24	5.42	16.0	540	20.2
4	1.89	4.13	6.84	15.0	500	21.7
5	1.88	3.77	7.29	17.0	580	24.3
Mean	1.93	3.66	6.41	16.0	540	21.8
SD	0.16	0.40	0.77	0.71	28.3	1.60

Table D-26 Thermal aging properties of gN330 filled NR vulcanizates with 50 phr at $t_{c_{90}}$

Sample	100% Modulus (MPa)	200% Modulus (MPa)	300% Modulus (MPa)	Elongation at break (cm)	% Elongation	Tensile strength (MPa)
1	2.05	4.09	6.96	16.5	560	19.8
2	2.21	4.07	6.69	16.0	540	20.7
3	2.45	4.96	7.95	16.0	540	18.8
4	2.36	4.38	6.88	16.0	540	19.0
5	2.55	4.72	7.39	16.0	540	21.2
Mean	2.32	4.44	7.17	16.1	544	19.9
SD	0.20	0.39	0.50	0.22	8.94	1.04

BIOGRAPHY

Miss. Wisullaya Phasook was born in Lopburi, Thailand on May 28, 1985. She received the Degree of the Bachelor of Engineering Program in Petrochemical and Ploymeric Materials, Slipakorn University in 2008. Then, she continued her post graduate study in Applied Polymer Science and Textile Technology Major at the Department of Materials Science, Faculty of Science, Chulalongkorn University and ultimately completed the Degree of the Master of Science in Applied Polymer Science and Textile Technology in October 2010.

