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APPENDICES

Appendix A Yields of Pyrolysis Products

Table A1 Yield of products obtained from pyrolysis

Catalyst	Sample	Yield (wt.%)			
		Gas	Liquid	Solid	Coke
Non-catalyst	Non-catalyst	11.6	46.0	42.4	0.00
Zeolite	HMOR	11.9	43.8	41.6	2.60
	KL	12.2	43.5	41.5	2.79
	HBeta	9.62	43.3	41.6	5.41
	HZSM-5	13.2	43.1	41.7	1.90
Metal loading	5%Co/HMOR	11.4	43.8	41.8	3.01
	5%Co/KL	12.7	41.4	42.5	3.37
	5%Co/HBeta	12.9	40.3	41.6	5.20
	5%Co/HZSM-5	14.2	40.1	41.8	3.95
	5%Fe/HMOR	13.3	42.4	42.4	1.89
	5%Fe/KL	12.3	43.1	42.6	1.98
	5%Fe/HBeta	11.4	43.1	42.1	3.44
	5%Fe/HZSM-5	16.4	38.8	41.9	2.94

Appendix B Gas Products

Table B1 Yield of gas components obtained from waste tire pyrolysis

Catalyst	Methane	Ethylene	Ethane	Propylene	Propane	Mixed-C4	Mixed-C5
Non-catalyst	20.3	9.38	15.9	12.2	9.06	19.6	13.5
HMOR	18.2	4.73	14.9	10.6	16.7	19.4	15.5
KL	19.5	6.70	15.9	12.4	9.13	19.9	16.4
HBeta	14.8	6.31	11.0	11.9	8.98	29.2	17.8
HZSM-5	13.6	5.20	10.7	10.5	19.7	26.5	13.7
5%Co/HMOR	21.0	7.38	16.3	11.5	10.2	19.5	14.2
5%Co/KL	19.3	8.87	15.2	11.8	9.06	19.0	16.8
5%Co/HBeta	16.5	8.08	13.2	12.6	8.52	25.1	16.1
5%Co/HZSM-5	15.8	7.09	12.5	15.5	11.6	24.2	13.4
5%Fe/HMOR	20.7	7.59	16.7	11.3	11.1	18.0	14.5
5%Fe/KL	20.4	9.34	16.1	12.4	9.11	19.1	13.5
5%Fe/HBeta	19.53	9.02	15.2	12.3	8.62	20.1	15.3
5%Fe/HZSM-5	15.17	7.40	12.2	17.4	9.98	24.4	13.4

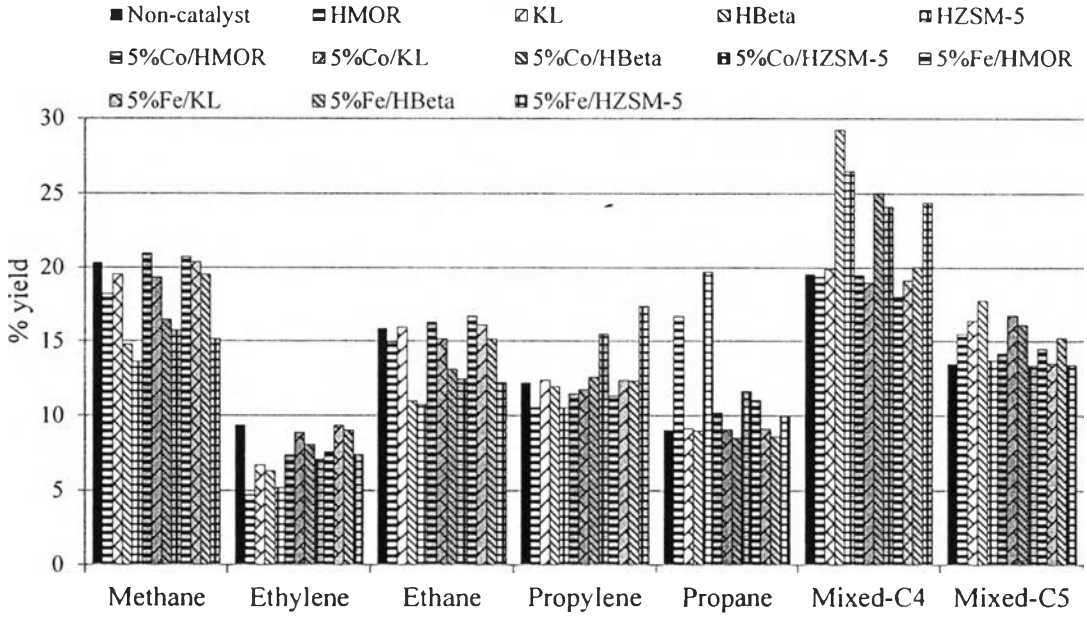

Figure B1 Distribution of gas components obtained from waste tire pyrolysis.

Appendix C Liquid Products

Table C1 Concentration of petroleum fractions in maltenes obtained from waste tire pyrolysis

Catalysts	Fractions (wt.%)				
	Full range naphtha	Kerosene	Light gas oil	Heavy gas oil	Long residue
Non-catalyst	22.1	23.4	20.1	18.3	16.2
HMOR	31.7	21.5	16.9	17.5	12.5
KL	22.1	27.9	19.2	15.4	15.5
HBeta	38.6	22.0	19.1	10.1	10.4
HZSM-5	28.2	21.5	17.3	18.8	14.3
5%Co/HMOR	38.8	20.7	15.5	13.8	11.2
5%Co/KL	44.6	19.5	12.5	11.0	12.3
5%Co/HBeta	29.9	21.8	16.4	15.5	16.5
5%Co/HZSM5	37.5	23.1	16.2	14.1	9.11
5%Fe/HMOR	42.8	19.4	14.3	12.6	10.9
5%Fe/KL	44.7	19.7	13.6	15.6	6.36
5%Fe/HBeta	32.8	20.7	16.5	15.5	14.6
5%Fe/HZSM5	46.4	21.1	12.3	11.1	9.11

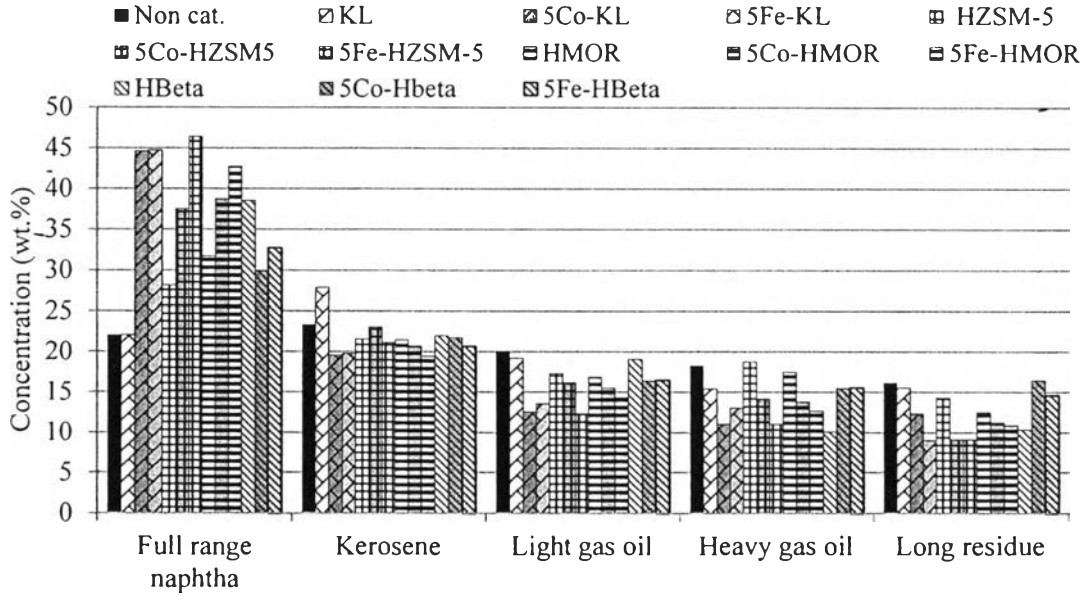

Figure C1 Concentration of petroleum fractions in maltenes obtained from using pure zeolites, 5%Co supported on zeolites, and 5%Fe-promoted catalysts.

Table C2 Concentration of chemical components in maltenes obtained from using pure zeolites (KL, HZSM-5, HMOR, and HBeta), 5%Co- and 5%Fe-promoted catalysts.

Catalysts	Classification (wt.%)			
	Paraffins	Olefins	Naphthenes	Aromatics
Non-catalyst	3.64	9.22	13.9	73.2
KL	3.81	10.3	11.7	74.2
HZSM-5	1.77	16.9	14.7	66.6
HBeta	1.56	5.00	10.4 -	83.0
HMOR	2.90	8.50	11.7	76.9
5%Co/KL	3.35	7.02	14.3	75.4
5%Co/HZSM-5	2.09	9.38	14.7	73.8
5%Co/HBeta	2.99	9.03	12.0	76.0
5%Co/HMOR	2.89	19.7	12.9	64.4
5%Fe/KL	3.27	7.35	11.5	77.9
5%Fe/HZSM-5	1.69	12.27	14.1	72.0
5%Fe/HBeta	3.66	3.58	8.79	84.0
5%Fe/HMOR	4.53	2.96	12.3	80.2

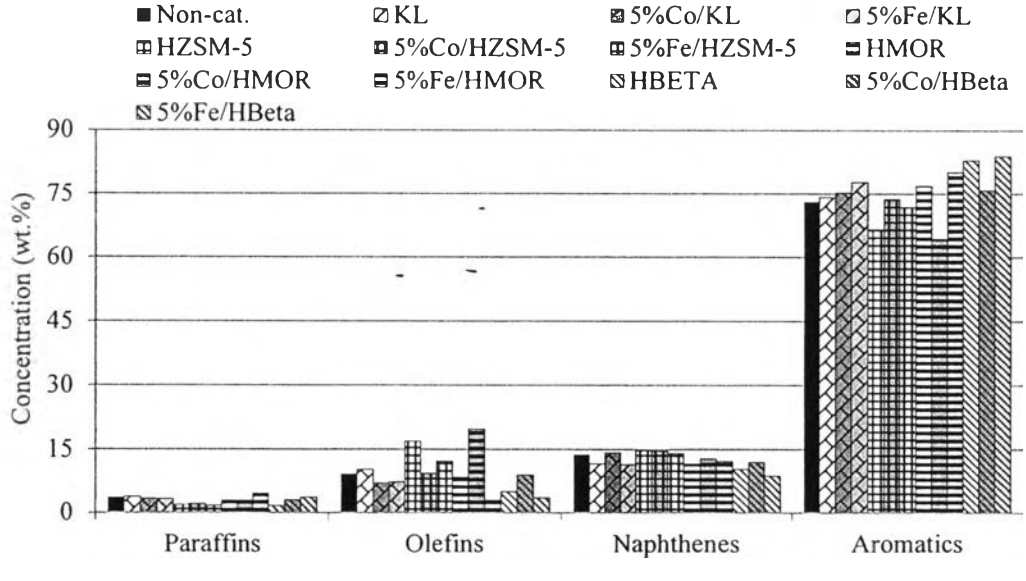

Figure C2 Concentration of chemical components in maltenes obtained from using pure zeolites (KL, HZSM-5, HMOR, and HBeta), 5%Co-, and 5% Fe-promoted catalysts.

Table C3 Concentration of chemical components in maltenes obtained from using pure zeolites, 5%Co- and 5%Fe-promoted catalysts

Catalysts	Classification (wt.%)						
	Paraffins	Olefins	Naphthenes	Mono-ar.	Di-ar.	Poly-ar.	Polar-ar.
Non-cat.	3.64	9.22	13.9	34.9	10.2	15.4	7.74
KL	3.81	10.33	11.7	43.4	10.6	13.7	6.52
HZSM-5	1.77	16.93	14.7	33.1	16.6	11.2	5.71
HBeta	1.56	5.00	10.4	45.2	18.3	12.9	6.53
HMOR	2.90	8.50	11.7	46.1	10.4	11.4	9.08
5%Co/KL	3.35	7.02	14.3	51.8	8.81	8.03	6.70
5%Co/HZSM5	2.09	9.38	14.7	43.5	12.8	10.3	7.23
5%Co/HBeta	2.99	9.03	12.0	42.0	13.3	12.1	8.56
5%Co/HMOR	2.90	19.8	12.9	37.0	10.3	10.4	6.67
5%Fe/KL	3.27	7.35	11.5	52.2	10.1	8.58	6.97
5%Fe/HZSM5	1.69	12.3	14.1	45.4	11.9	8.50	6.22
5%Fe/HBeta	3.66	3.58	8.79	48.3	11.3	15.5	8.92
5%Fe/HMOR	4.53	2.96	12.3	54.7	7.36	10.4	7.76

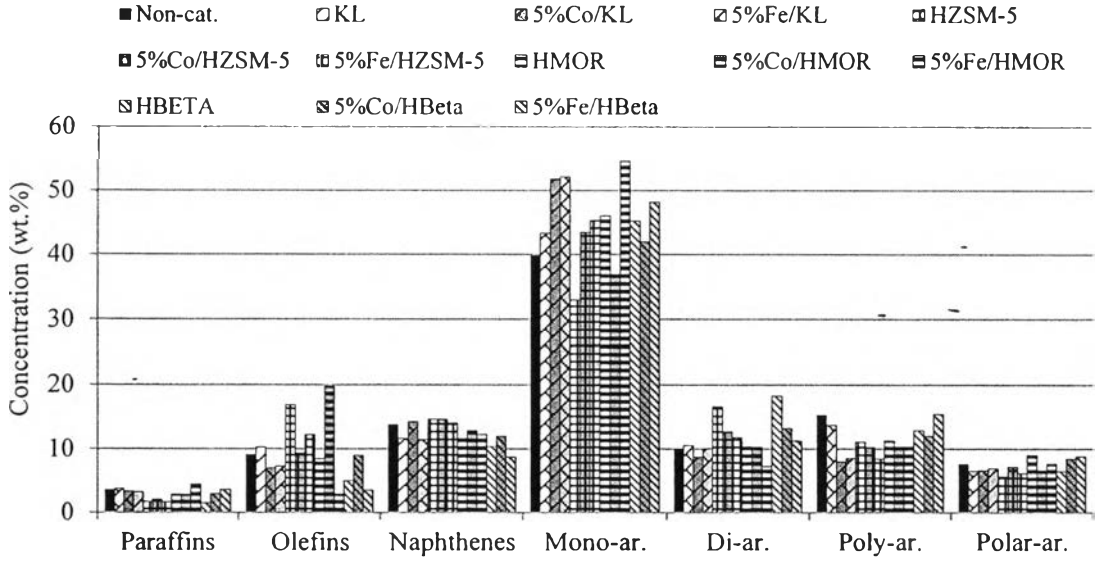

Figure C3 Concentration of chemical components in maltenes obtained from using pure zeolites, 5%Co-, and 5%Fe-promoted catalysts.

Table C3 Yield of chemical components in maltenes obtained from waste tire pyrolysis

Catalysts	wt.% in maltenes								
	Benzene	Toluene	Ethyl-benzene	*m*-xylene	*o*-xylene	*p*-xylene	Styrene	Cyclo-hexane	Cumene
Non-catalyst	0.430	0.0274	0.833	-	-	-	0.189	0.0239	0.0660
HMOR	0.124	0.184	0.408	0.185	-	-	1.31	-	0.105
HBeta	4.81	0.917	3.31	-	0.161	0.129	0.320	1.05	0.0771
HZSM-5	-	0.196	0.258	0.0981	-	0.0304	0.207	3.46	0.035
KL	0.265	0.00497	0.102	-	-	-	0.125	-	0.0827
5%Co/HMOR	-	0.197	0.280	-	-	0.0831	0.396	3.78	0.280
5%Co/HBeta	0.284	0.00540	0.00352	-	-	-	-	0.0394	-
5%Co/HZSM5	4.21	0.108	0.132	-	0.123	0.451	0.313	0.972	0.144
5%Co/KL	9.99	3.79	0.311	0.994	-	-	0.891	2.43	0.717
5%Fe/HMOR	14.0	0.053	0.833	-	-	0.284	-	7.17	0.882
5%Fe/HBeta	-	0.0945	0.867	-	0.234	0.253	0.464	4.12	0.506
5%Fe/HZSM5	3.41	0.652	0.403	0.835	0.0105	0.044	0.602	4.11	1.09
5%Fe/KL	12.7	1.19	-	0.392	-	0.210	0.464	3.28	0.682

Appendix D Sulfur Contents in Pyrolysis Products

	Sulfur in oil (wt.%)			
	Spent catalyst	Char	Oil	Gas
Non-catalyst	-	45.4	23.9	30.7
KL	2.77	46.8.	19.7	30.7
HZSM-5	2.99	46.4	20.7	29.9
HBeta	4.55	45.0	21.2	29.3
HMOR	2.00	42.0	21.0	35.0
5%Co/KL	8.13	43.8	15.7	32.3
5%Co/HZSM-5	12.3	42.9	15.3	29.5
5%Co/HBeta	11.3	42.5	15.6	30.6
5%Co/HMOR	8.16	43.1	19.3	29.5
5%Fe/KL	10.3	43.0	17.6	29.2
5%Fe/HZSM-5	13.7	44.5	12.5	29.3
5%Fe/HBeta	11.03	46.1	19.0	23.9
5%Fe/HMOR	10.6	43.2	17.1	29.1

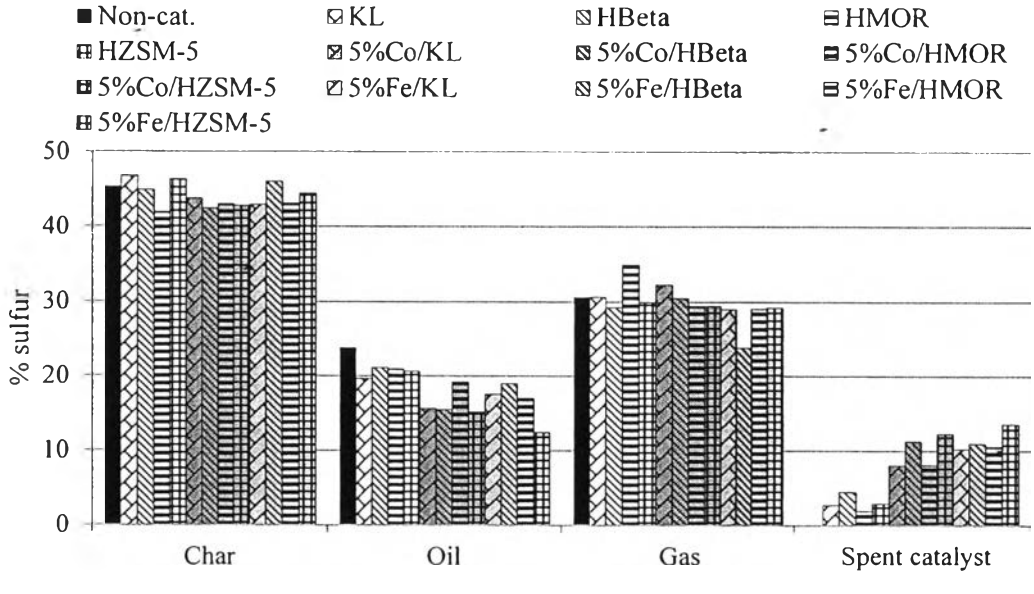

Figure D1 Distribution of sulfur in pyrolysis products obtained from using, pure zeolites (KL, HZSM-5, HMOR, and HBeta), 5%Co-, and 5%Fe-promoted catalysts.

Appendix E Surface Area and Pore Volume of Catalysts

Table E1 Catalyst properties obtained from surface area analyzer

Catalyst	Surface area (m^2/g)	Pore volume (cm^3/g)	Maximum pore width (Å)	Median pore width (Å)
HBeta	539.3	0.2570	8.148	8.351
HMOR	394.3	0.1990	8.392	8.422
HZSM-5	366.3	0.1780	7.774	7.443
KL	218.0	0.1130	6.954	7.078
5%Co/HBeta	434.2	0.2422	7.137	7.277
5%Co/HMOR	361.8	0.1821	7.553	7.421
5%Co/HZSM-5	310.3	0.2245	5.907	6.188
5%Co/KL	114.1	0.0570	6.426	6.275
5%Fe/HBeta	405.8	0.2339	6.589	8.112
5%Fe/HMOR	351.7	0.1764	6.498	6.942
5%Fe/HZSM-5	265.0	0.1309	6.815	6.956
5%Fe/KL	98.82	0.04700	6.618	7.006

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Proceedings:

1. Muenpol, S.; and Jitkarnka, S. Effect of Zeolitic Support Properties on Sulfur Species and Distribution in Tire-derived Products. Proceedings of The 5th Research Symposium on Petroleum, Petrochemicals, and Advanced Materials and the 20th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand.
2. Muenpol S.; and Jitkarnka S. (2014, August 23 - 27) Impact of Zeolite Channel Structure on Structure of Hydrocarbon Compounds and Petrochemicals in Waste Tyre-derived Oils. The 17th Conference Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction (PRES 2014), Prague, Czech Republic.

Presentation:

1. Muenpol, S.; and Jitkarnka, S. (2014, April 22) Effect of Zeolitic Support Properties on Sulfur Species and Distribution in Tire-derived Products. Paper presented at The 5th Research Symposium on Petroleum, Petrochemicals, and Advanced Materials and the 20th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand.