Chapter 6.

Performance Testing of Windmill Model

6.1 Testing of the Windmill Model

To find the performance of the windmill model, the performance testing of the windmill was performed by using a large fan set far away from the windmill. The velocity distribution of wind was measured by digital anemometer as shown in Fig.6.1 , at the rotating plane of the windmill to ensure that the wind velocity was nearly uniform before testing was done (wind velocity during test was about 2.4 m/s). Torque was measured by using torque meter which is directly connected with the windmill shaft, and the angular velocity was measured by a digital techometer as shown in Fig.6.2, at one end of the torque meter shaft.

Torque was varied by changing the friction force on one side of the torque meter shaft, the values of torque were recorded by a pen recorder as shown in Fig.6.3. At each stepped value of torque, the angular velocity was measured. Figure 6.4 shows the windmill model at rotating condition.

Fig. 6.1 Digital anemomcter

Fig. 6.2 Tachometer

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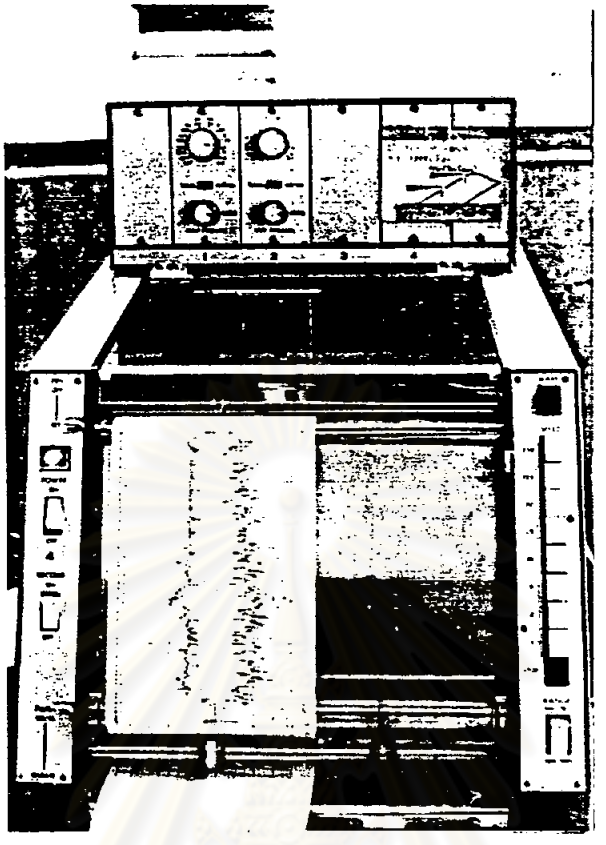

Fig. 6.3 Pen recorder

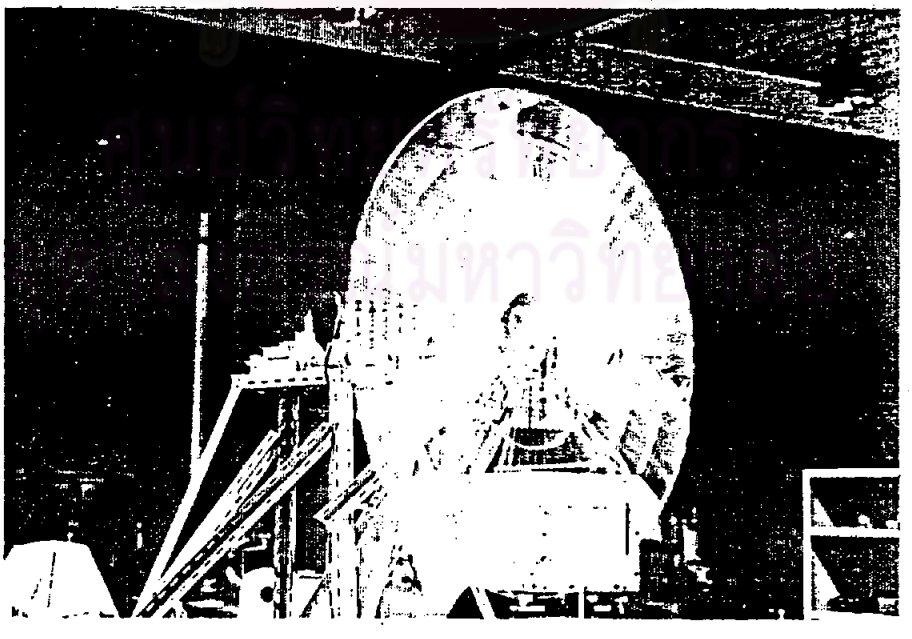

Fig. 6.4 Windmill model at rotating condition

6.2 Performance Testing Results

Tables 6.1 to 6.4 show the results of the experiment. Figures 6.5 to 6.7 show the relation of Cp - λ , CQ - λ characteristics and starting torque - pitch angle of the windmill model.

Figures 6.8 to 6.15 show the theoretical calculation of the attack angle - tip speed ratio, a, b, Cp and CQ at the design condition as the pitch angle varied.

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Table 6.1 Experimental results of windmill model
(Pitch angle = 0.0 °)

U (m/s)	Q (N.m)	n (rpm)	λ	P (W)	P air (W)	C_P	C_Q
2.42	0.231	66	1.78	1.59	10.47	0.152	0.085
2.42	0.229	69	1.86	1.65	10.47	0.158	0.085
2.42	0.219	72	1.94	1.64	10.47	0.157	0.081
2.42	0.208	77	2.09	1.69	10.47	0.161	0.077
2.42	0.205	80	2.16	1.72	10.47	0.164	0.076
2.42	0.184	86	2.32	1.66	10.47	0.158	0.068
2.42	0.177	89	2.40	1.65	10.47	0.158	0.066
2.42	0.170	92	2.49	1.64	10.47	0.156	0.063
2.42	0.166	93	2.51	1.61	10.47	0.154	0.061
2.42	0.156	95	2.57	1.55	10.47	0.148	0.058
2.42	0.135	100	2.70	1.41	10.47	0.135	0.050
2.42	0.121	102	2.76	1.29	10.47	0.123	0.045
2.42	0.114	105	2.84	1.25	10.47	0.119	0.042

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Table 6.2 Experimental results of windmill model
(Pitch angle = + 5.0 °)

U (m/s)	Q (N.m)	n (rpm)	λ	P (w)	P air (w)	C_P	C_a
2.42	0.206	56	1.51	1.21	10.47	0.115	0.076
2.42	0.188	62	1.68	1.22	10.47	0.117	0.070
2.42	0.172	65	1.76	1.18	10.47	0.112	0.064
2.42	0.170	66	1.78	1.17	10.47	0.112	0.063
2.42	0.160	67	1.81	1.12	10.47	0.107	0.059
2.42	0.146	70	1.89	1.07	10.47	0.102	0.054
2.42	0.135	70	1.89	0.99	10.47	0.094	0.050
2.42	0.125	76	2.05	0.99	10.47	0.095	0.046
2.42	0.122	76	2.05	0.97	10.47	0.093	0.045
2.42	0.097	81	2.19	0.82	10.47	0.078	0.036

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Table 6.3 Experimental results of windmill model
(Starting torque & Pitch angle , V = 2.4 m/s)

Pitch angle (degree)	Torque (N.m)	C_a
-10	0.0223	0.0086
- 5	0.0346	0.0128
0	0.0403	0.0149
5	0.0473	0.0175
10	0.0614	0.0227

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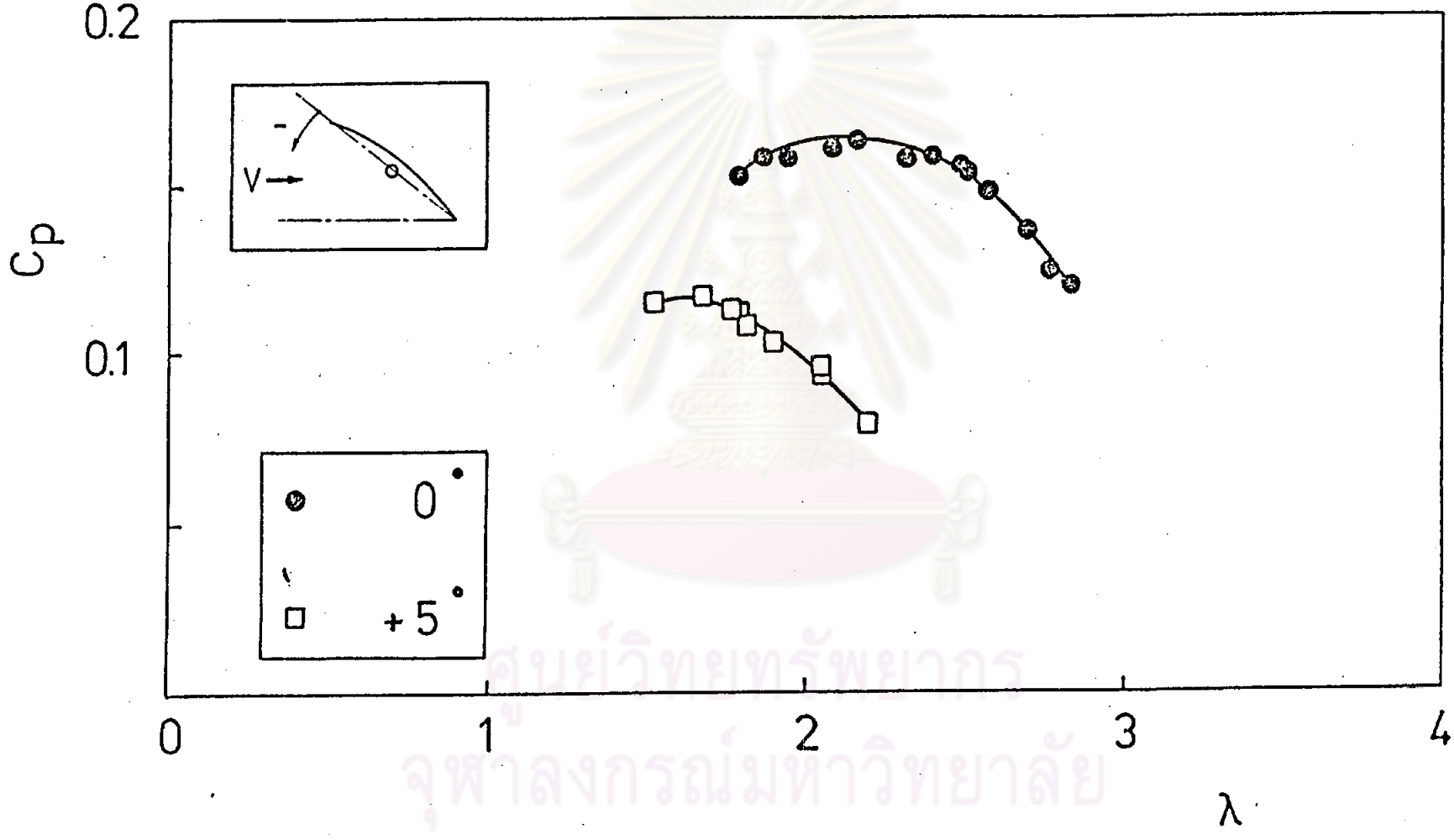

Fig. 6.5 C_p - λ CHARACTERISTICS OF WINDMILL MODEL (EXPERIMENT)

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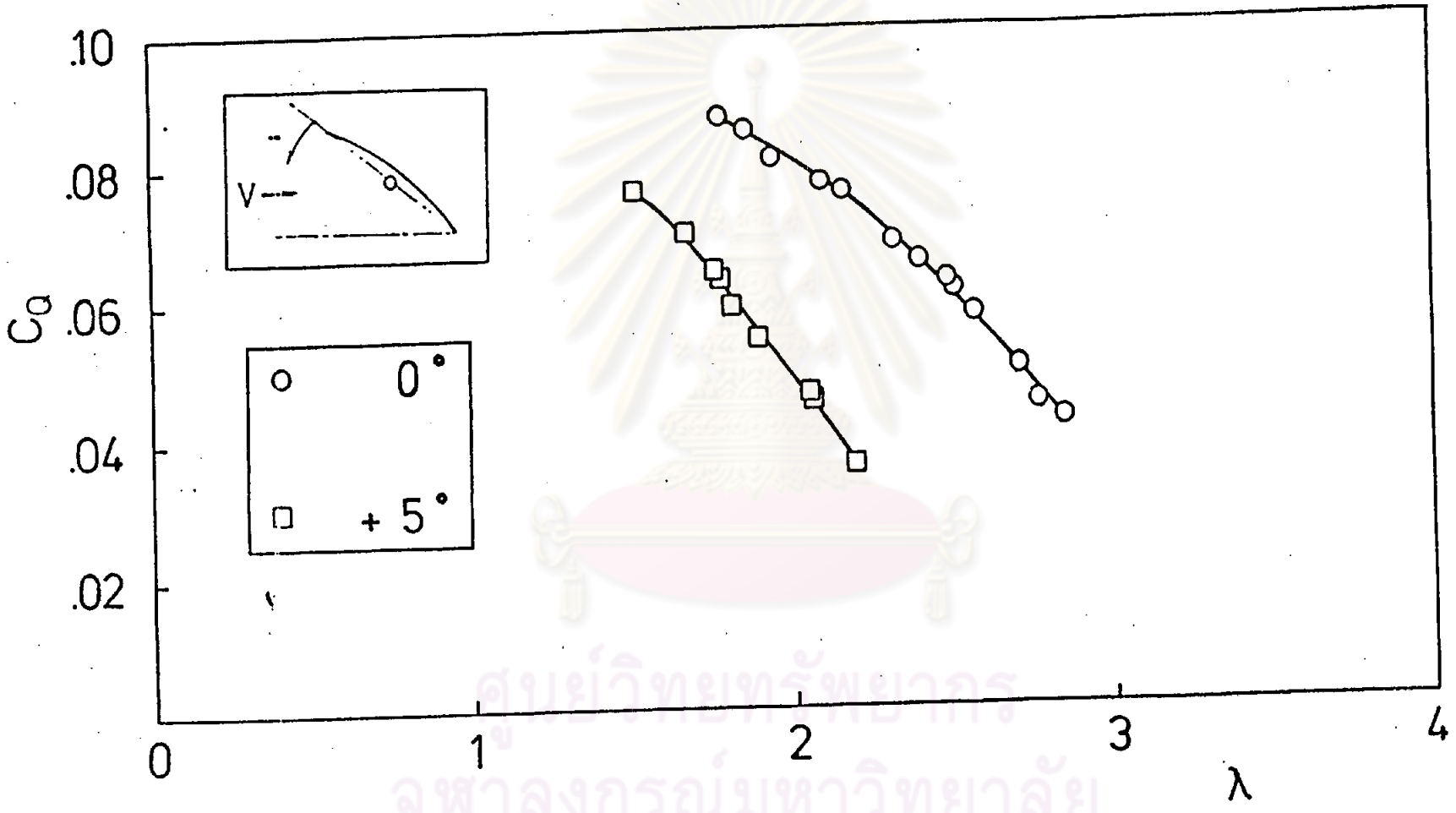

Fig.6.6 $C_a - \lambda$ CHARACTERISTICS OF WINDMILL MODEL (EXPERIMENT)

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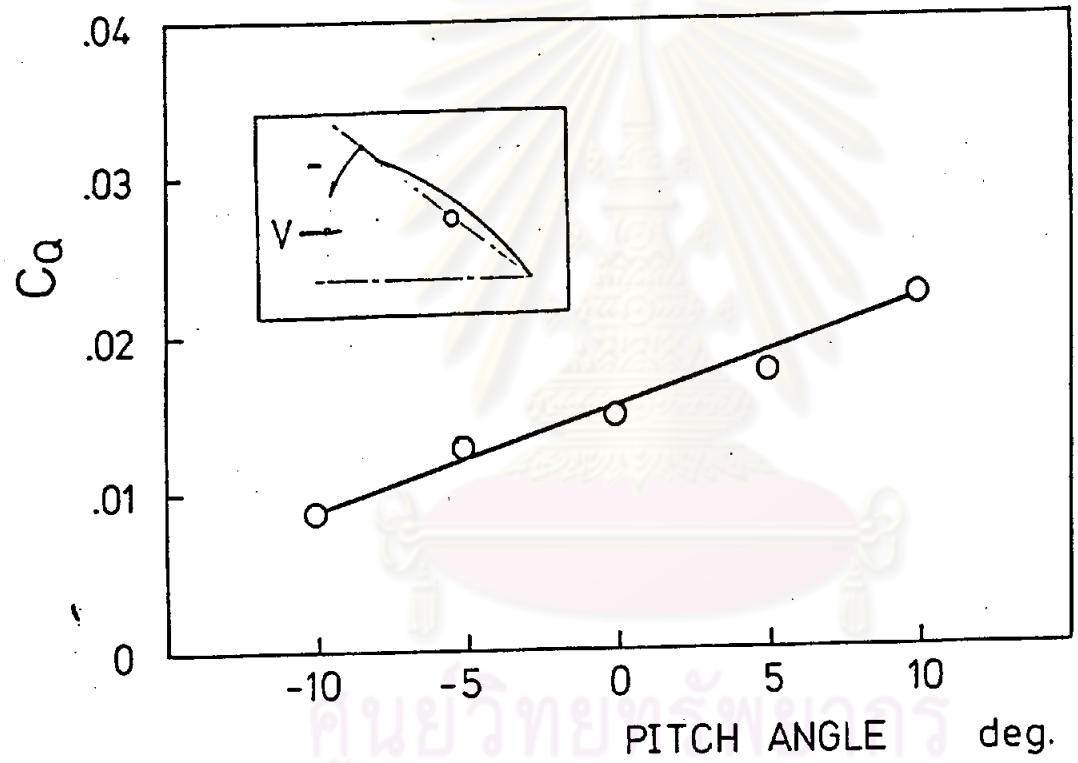

Fig. 6.7 Relation of torque coefficient & pitch angle
(at $\Omega = 0$, $V = 2.4$ m/s)

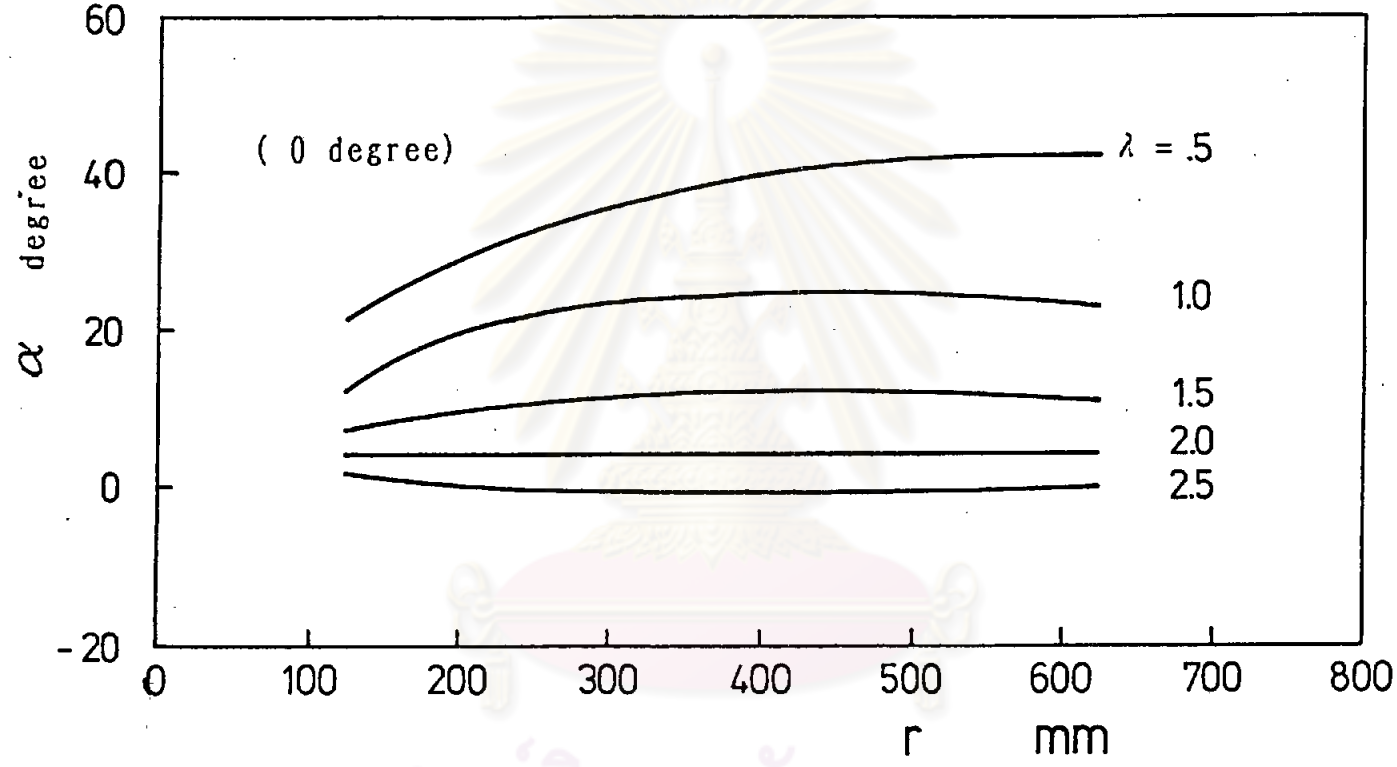

Fig. 6.8 Relation of attack angle & tip speed ratio
(0 degree)

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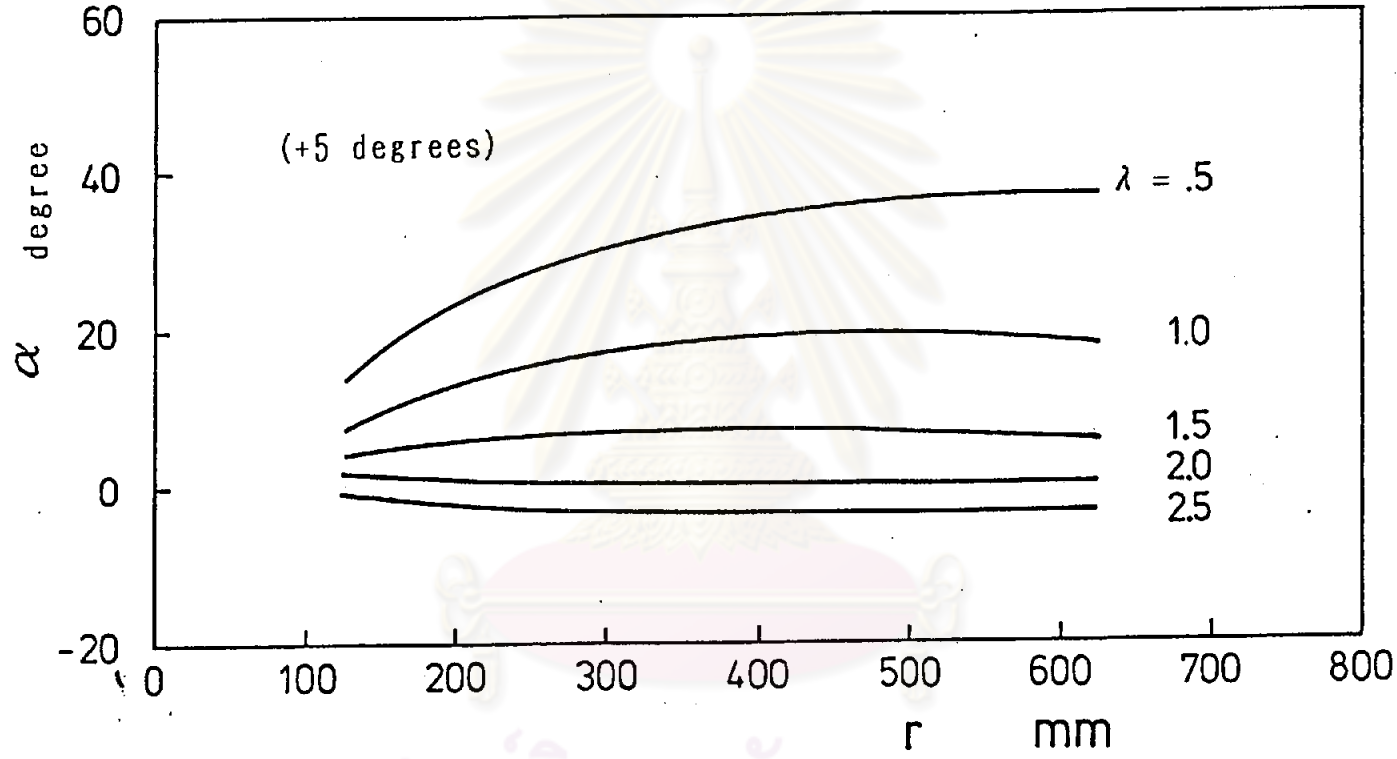

Fig. 6.9 Relation of attack angle & tip speed ratio (+5 degrees)

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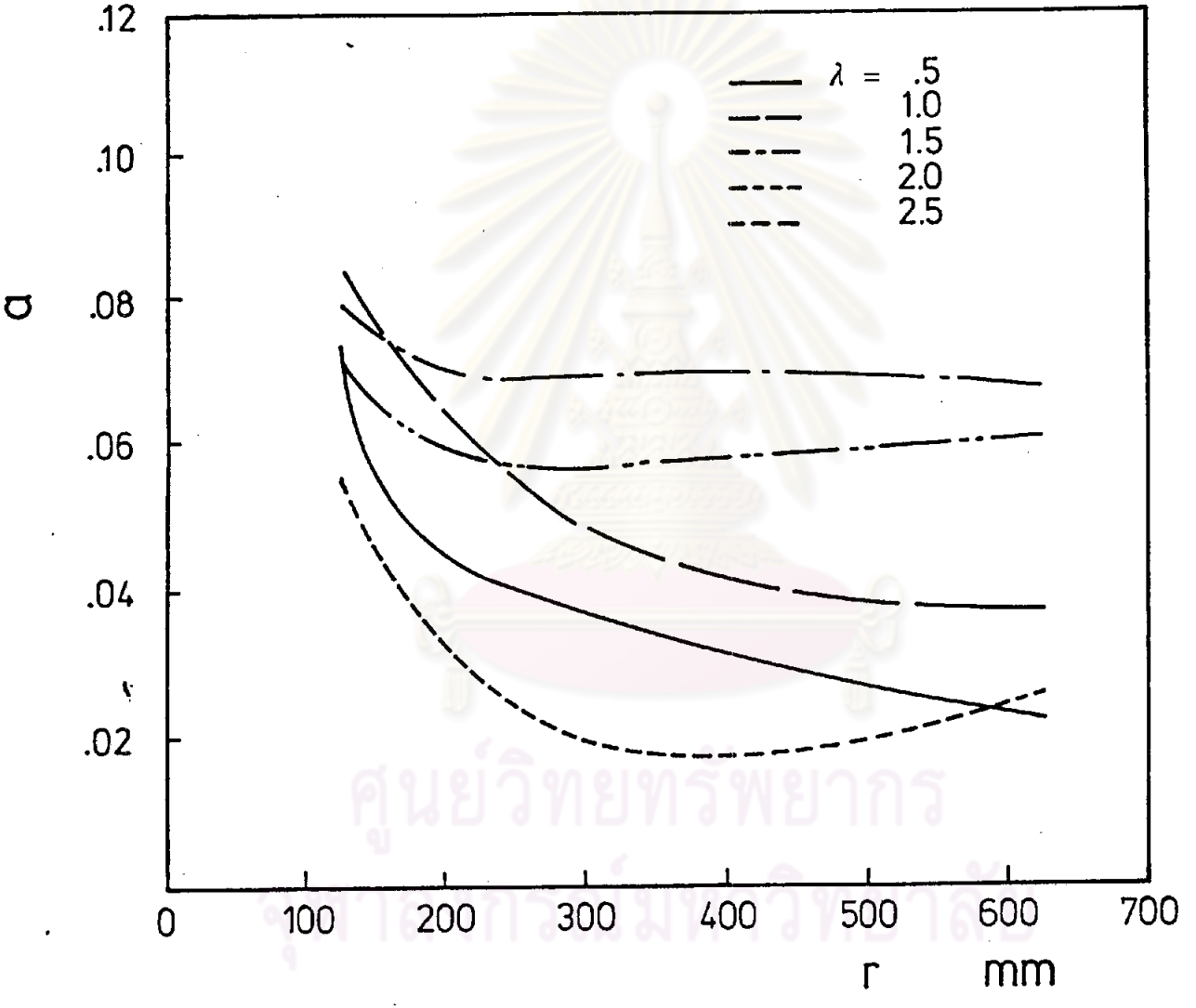

Fig. 6.10 Relation of a & tip speed ratio
(0 degree)

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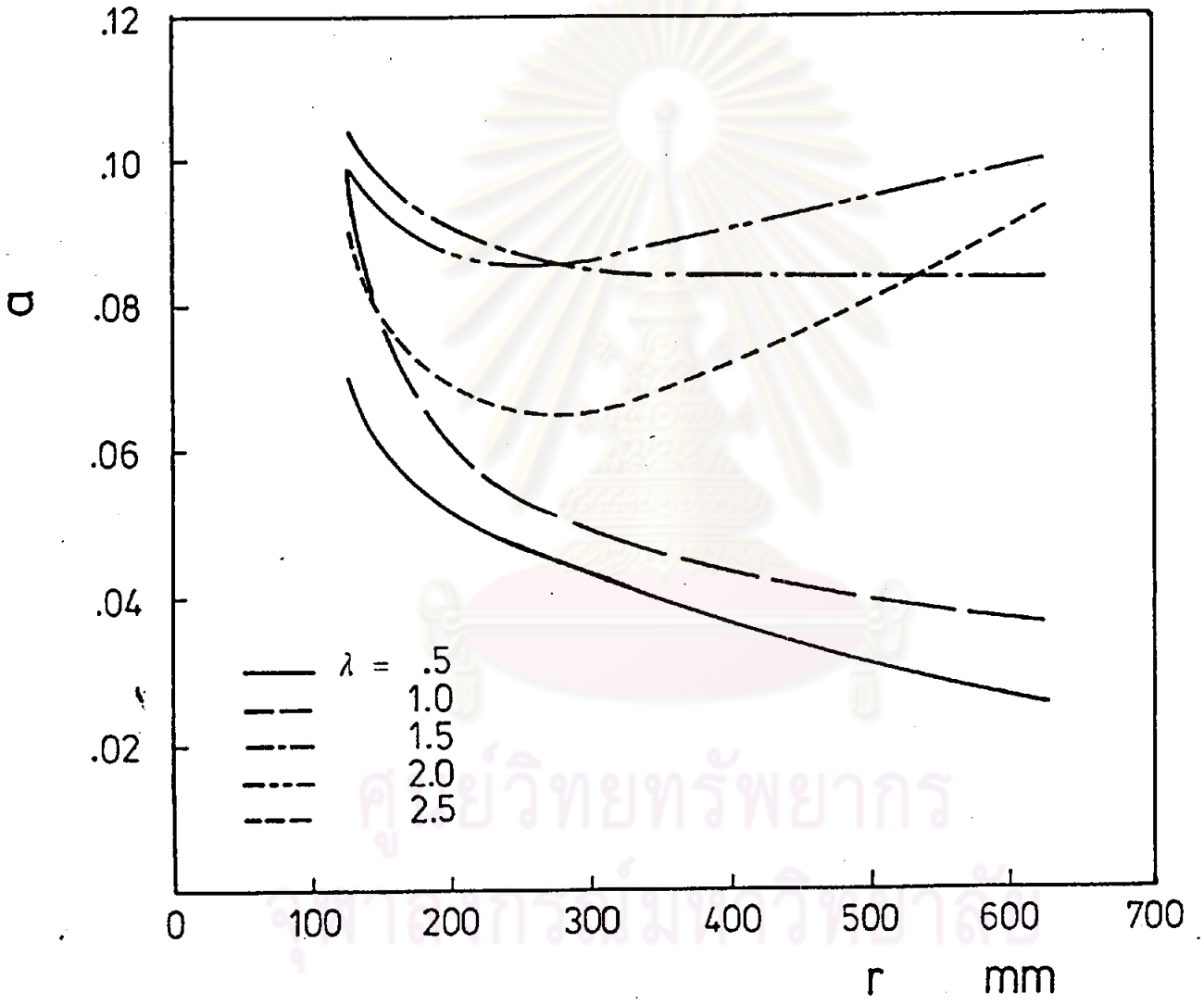

Fig. 6.11 Relation of a & tip speed ratio
(+5 degrees)

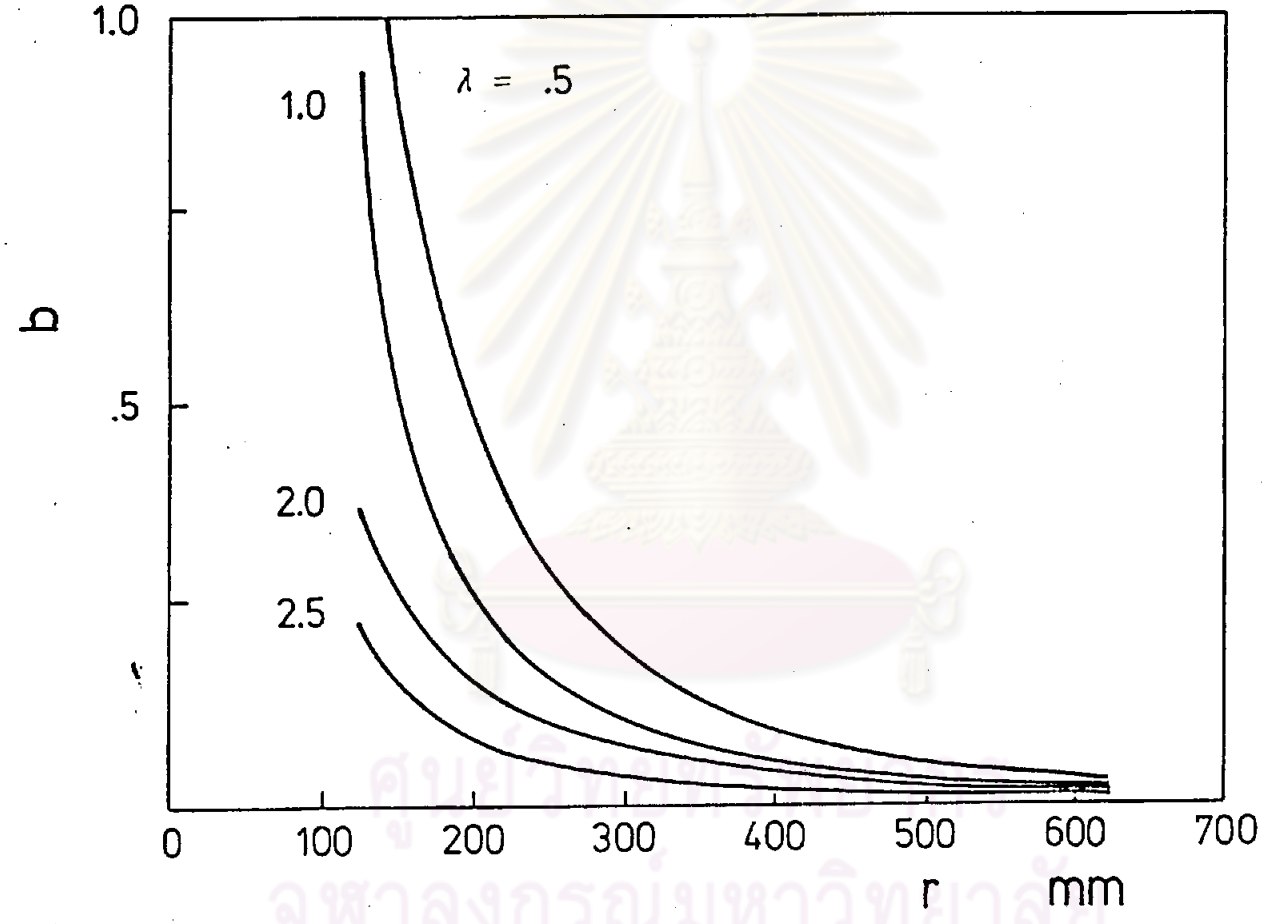

Fig. 6.12 Relation of b & tip speed ratio
(0 degree)

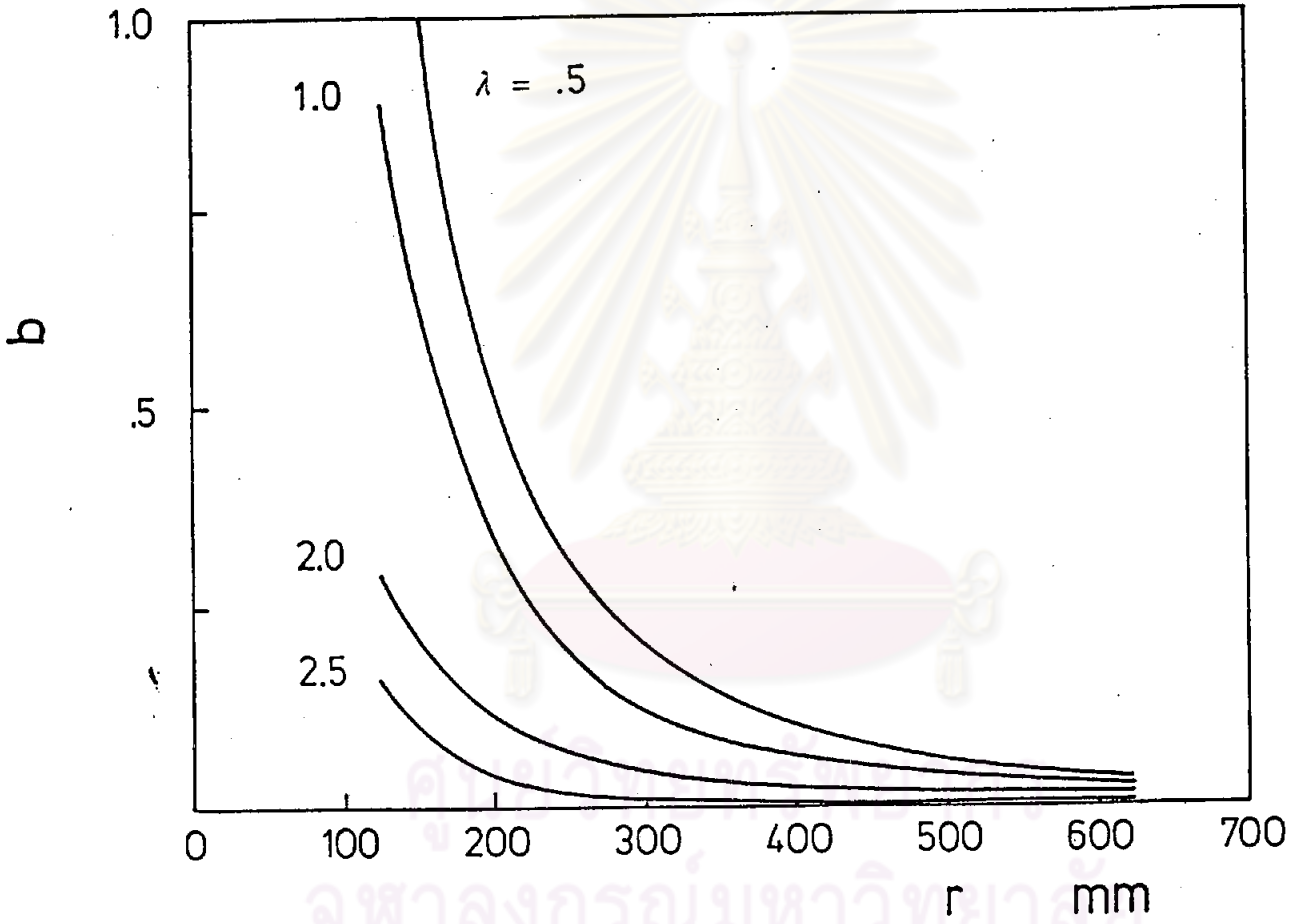

Fig. 6. 13 Relation of b & tip speed ratio
(+5 degrees)

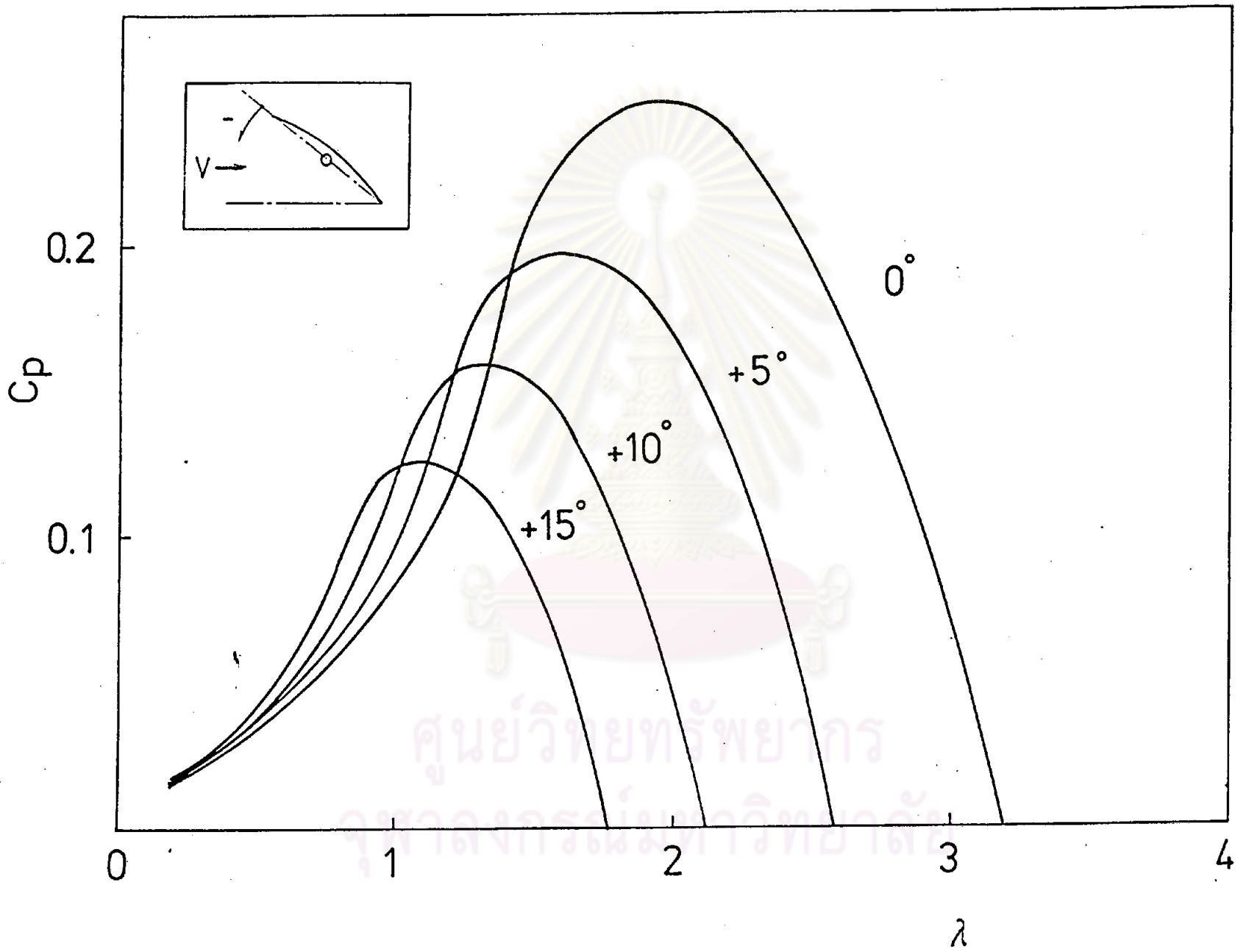

Fig. 6.14 C_P - λ characteristics of windmill model (Theory)

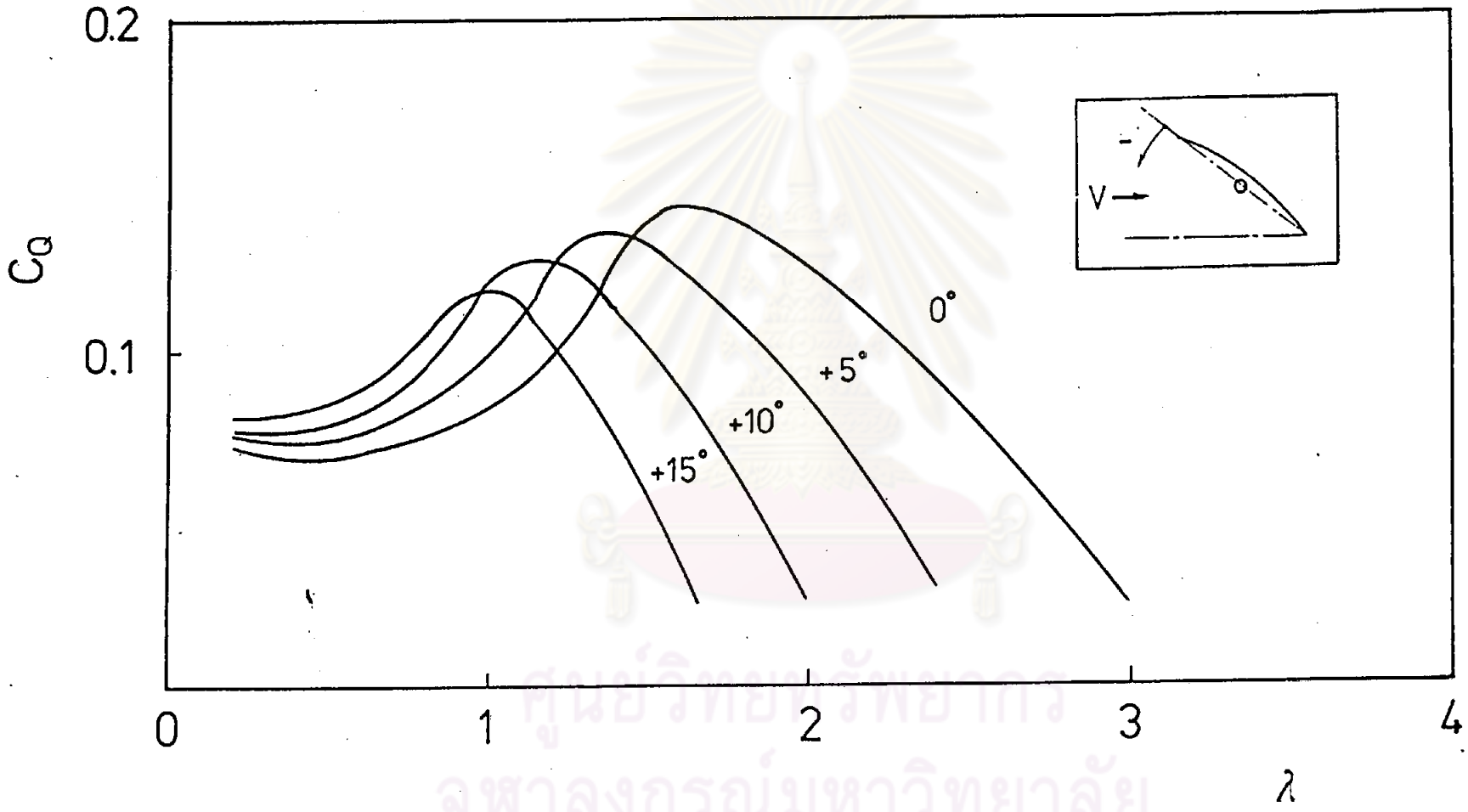

Fig. 6.15 $C_Q - \lambda$ characteristics of windmill model (Theory)

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