CHAPTER 4

RESULTS AND DISCUSSION

4.1 Carrier Dependency

The toner namely KT-05b was mixed with each type of the carriers, A-3, F-200, and Iron Shot, by a rotating roller unit. The sizes of carrier in a decreasing order are as follows: Iron Shot > F-200 > A-3. The toner-to-carrier wt% ratios were five to ninety-five. The toner was charged by friction with the carriers. The surface areas of the toner-to-carrier ratio in a decreasing order are as follows: A-3 > F-200 > Iron Shot. The number of toner per carrier particle was the reversed order of the above one. The charge to mass ratios (q/m) of KT-05b and three types of carrier from a blow off measurement unit are shown in Figure 4-1. The q/m values at the equilibrium state are as follows: A-3 > F-200 > Iron Shot. This can be explained by a model, which is shown in Figure 4-2; the small size carrier has a smaller number of toner particles per carrier than does large size carrier. The toner particles have more chances to select the effective charging sites of the carrier and less opportunity to attach together; therefore, the q/m values are the highest. It is in accordance with the literature that the level of contact charging increases when the area of contact increases.[32] This can be concluded that the charge characteristics of a toner in a two-component developer depend on the size of carrier and the number of toner particles per carrier particle.

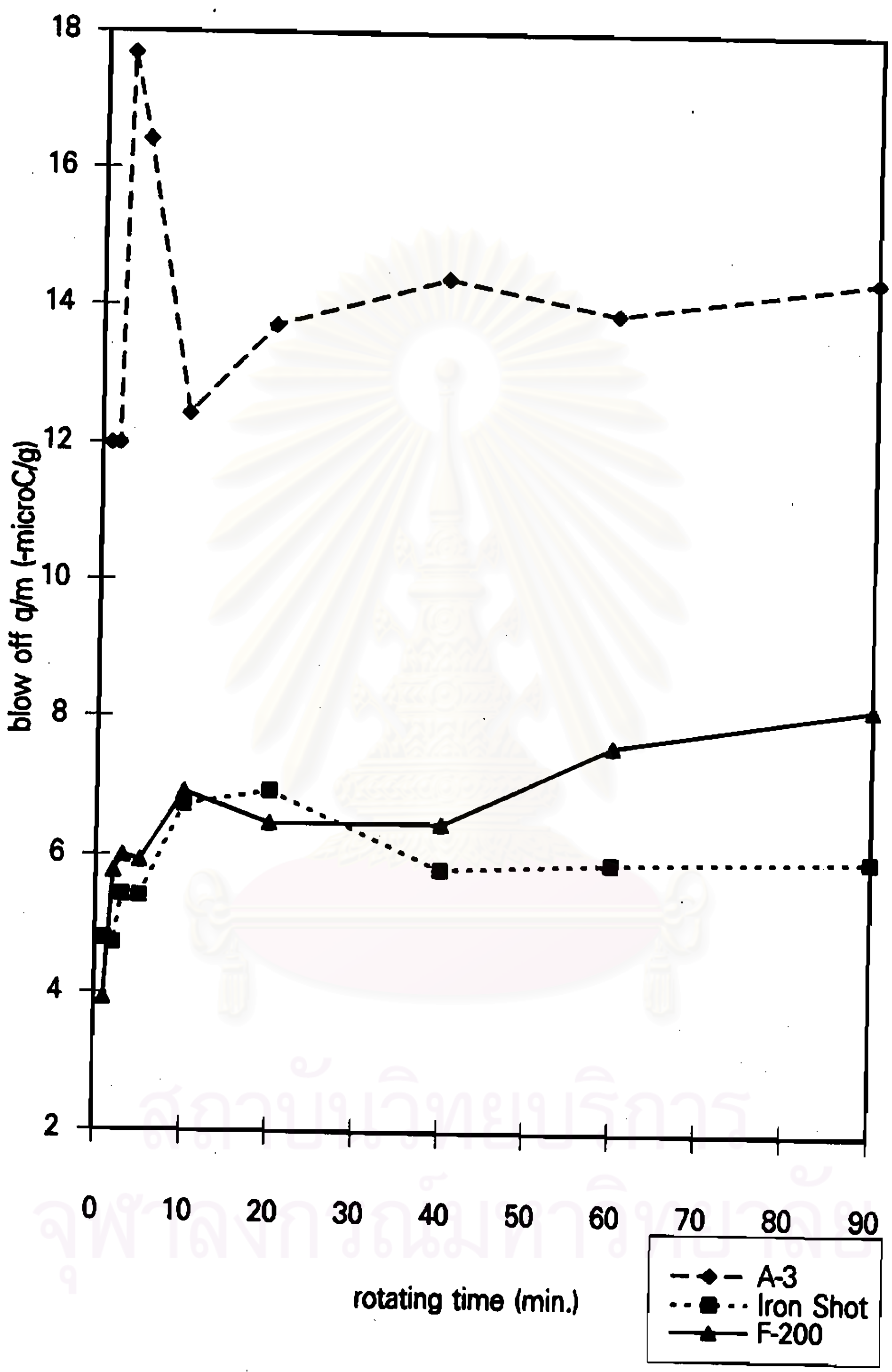


Figure 4-1 Dependence of q/m (blow off) of various carriers on rotating time

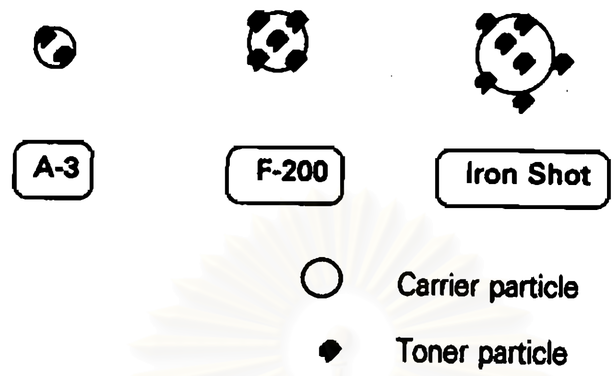


Figure 4-2 A model of toner and various carrier sizes at the same T/C wt% ratio

4.2 CCA Dependency

The toner without CCA, KT-04b, and the toners with CCA amounts, KT-05b, KT-06b, and KT-07b, were mixed with three types of carrier, A-3, F-200, and Iron Shot, by a rotating roller. The toner charge was measured by a blow off measurement unit. The relations between the rotating time and the q/m values are shown in Figures 4-3 to 4-7. The charge of the toner with CCA is higher than the toner without CCA because CCA helps increase more effective charging sites on toner, therefore, the charge of the toner with CCA is increased up to an equilibrium state within a shorter time. This is conformed to the literature that the time constants for a saturation value decrease with an increase of CCA wt%.[31]

4.2.1 *CCA wt% dependency*

All toners, which were of various CCA amounts, KT-05 to KT-15b (except KT-10b), and CCA types A and B were mixed with F-200 carrier by a rotating roller.

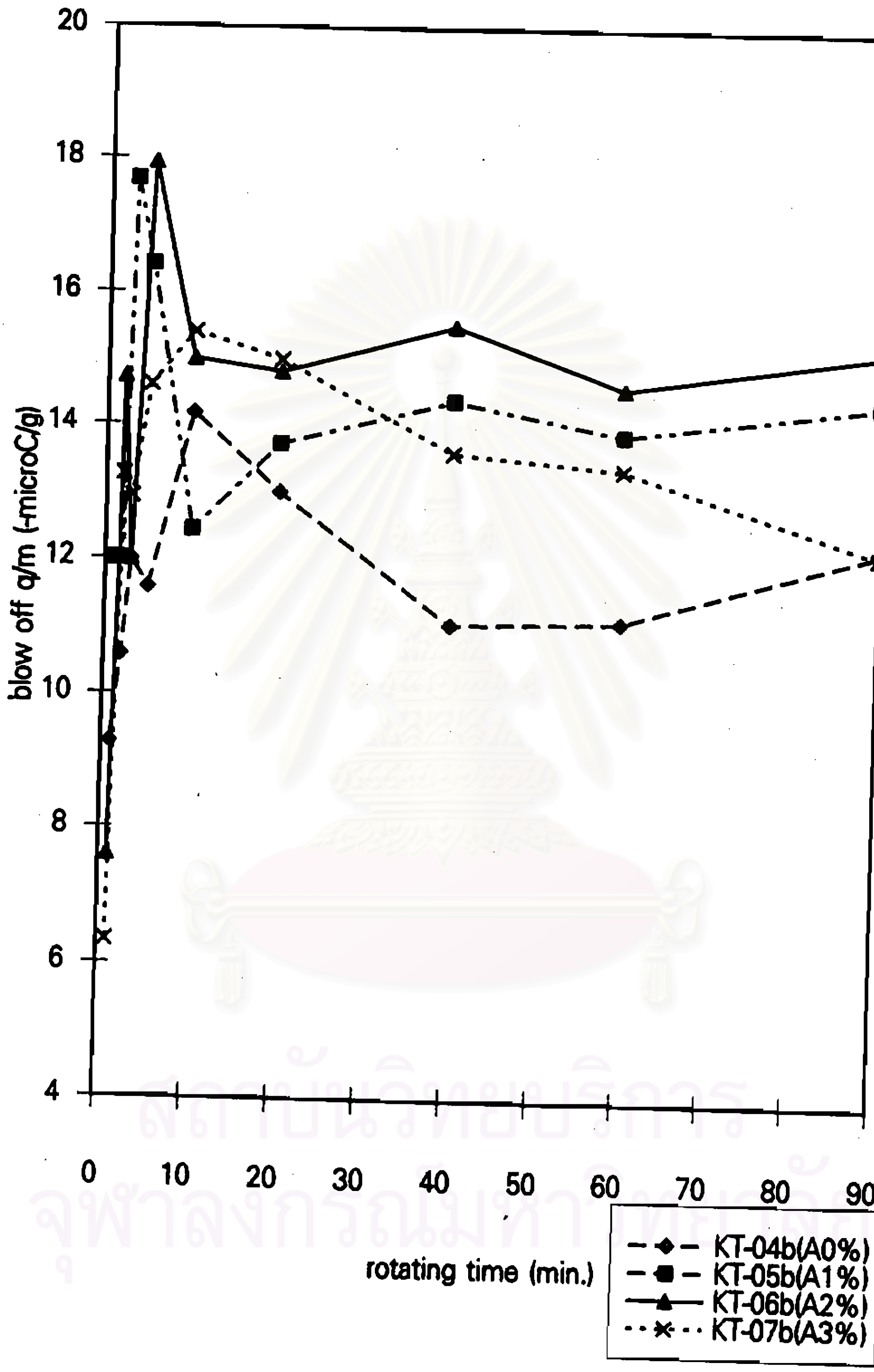


Figure 4-3 Dependence of q/m (blow off) on rotating time with many CCA amounts of A-3 carrier

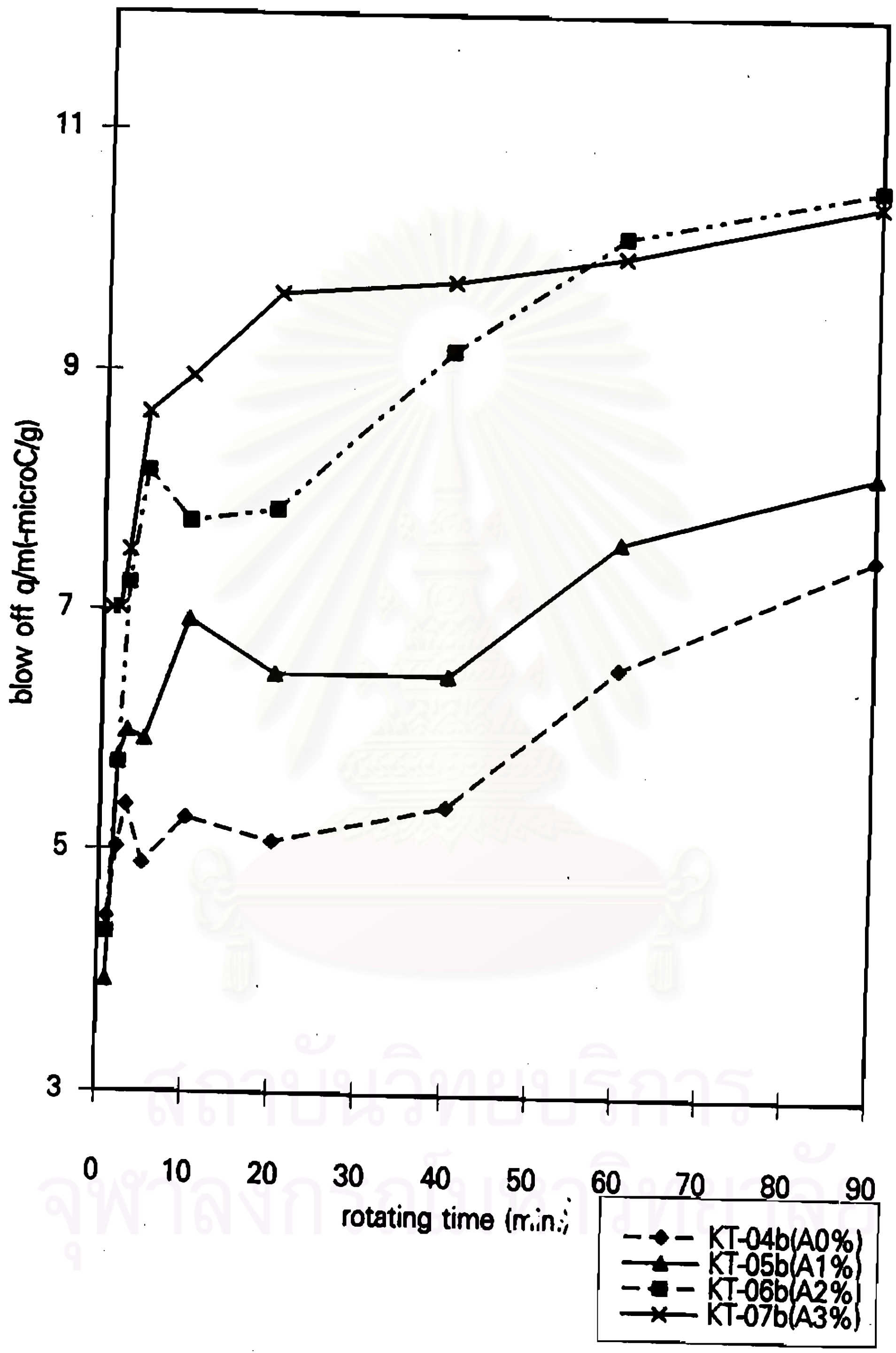


Figure 4-4 Dependence of q/m (blow off) on rotating time with many CCA amounts of F-200 carrier

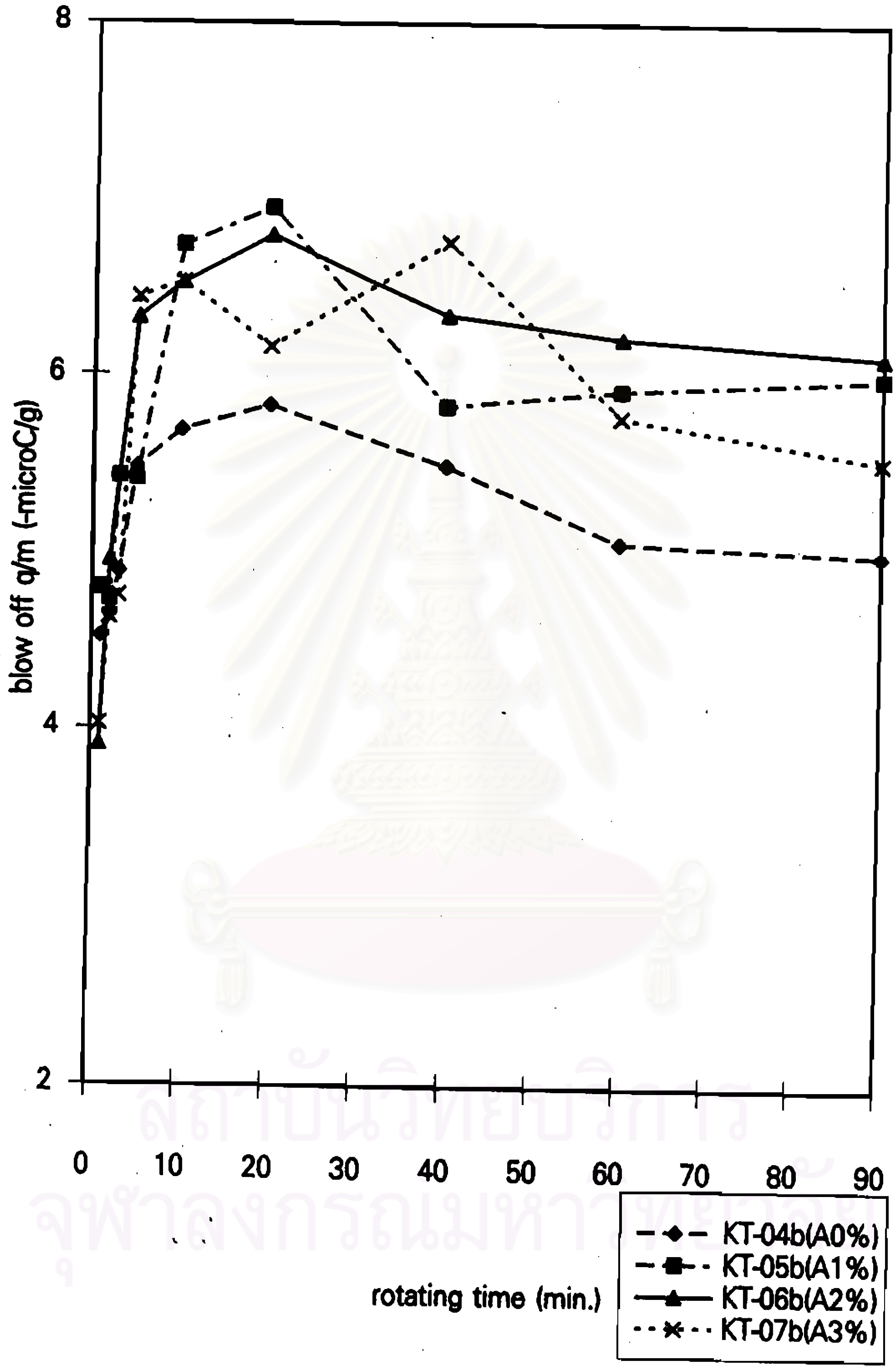


Figure 4-5 Dependence of q/m (blow off) on rotating time with many CCA amounts of Iron Shot carrier

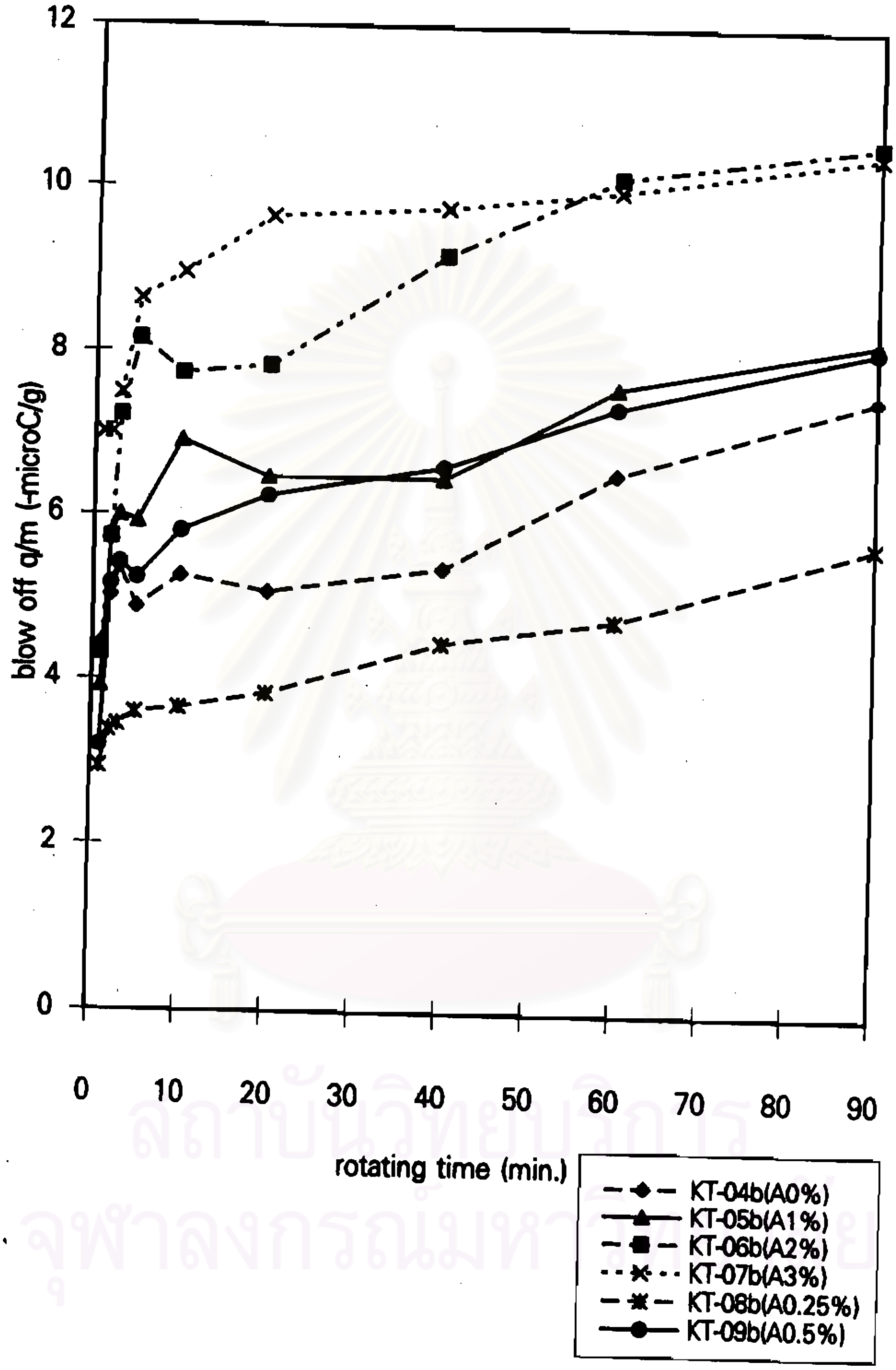


Figure 4-6 Dependence of q/m (blow off) on rotating time at various amounts of CCA type A with F-200 carrier

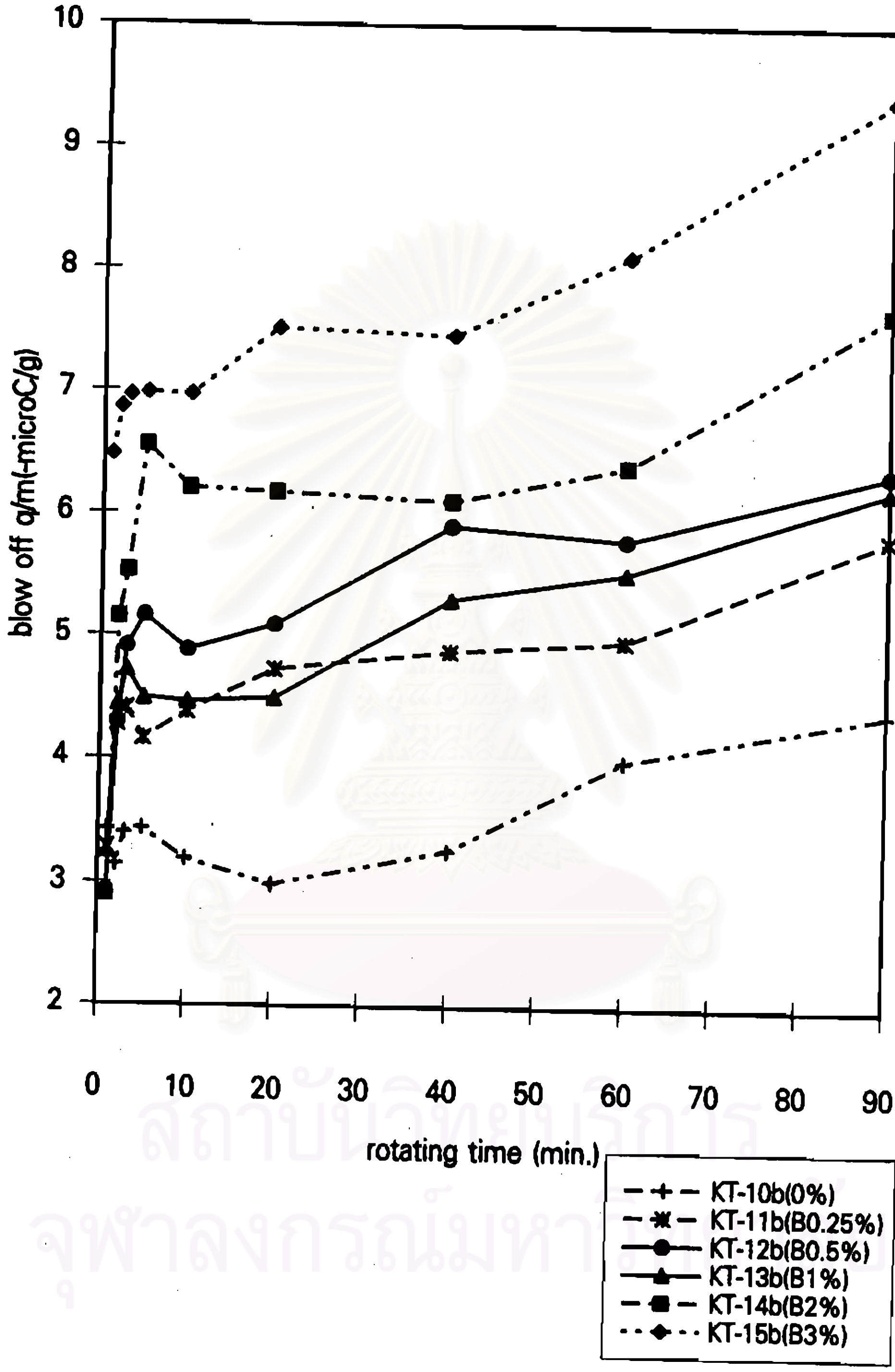


Figure 4-7 Dependence of q/m (blow off) on rotating time at various amounts of CCA type B with F-200 carrier

The toner charge was measured by a blow off measurement unit. From both Figures 4-6 and 4-7, almost all the q/m values are increased by increasing CCA amounts. It may be explained by a model shown in Figure 4-8 that the function of CCA is to increase the stronger effective charging sites of the toner. When the CCA amount is increased, the number of effective charging sites of the toner is increased accordingly resulting in a reduction in the charging time for a saturated charge to develop and increase values of q/m.

In the case of KT-07b, the trend of q/m values, when increasing rotating time, is lower than that of KT-06b. It may be explained that too much a CCA amount may fall off from the toner surface to the carrier while rubbing with the carrier for a long period. This is the so called "carrier contamination with CCA" shown in Figure 4-9. The charges cannot be exchanged when the CCA rubbed together, therefore, q/m values of this case are lower.

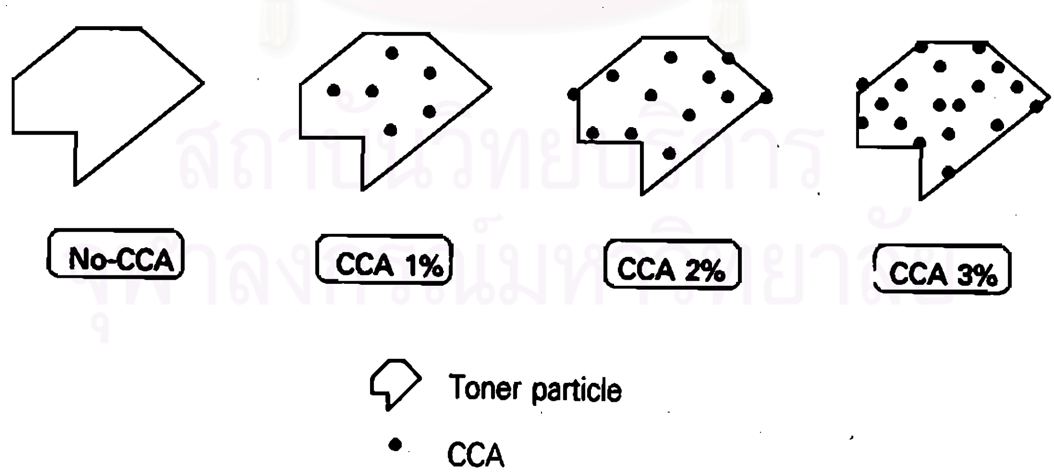


Figure 4-8 A model of CCA amount on toner particle

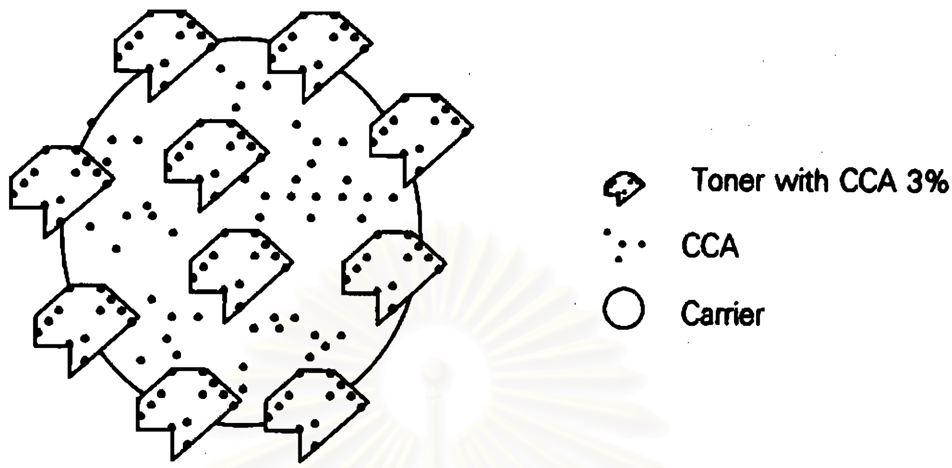


Figure 4-9 A model of carrier contamination with CCA

4.2.2 CCA type dependency

The toners with CCA and F-200 carrier were mixed by a rotating roller. The toner charge was measured by a blow off measurement unit. The main structure of CCA is the same but some positions of functional groups are different as shown in Figure 4-10. The symbol Y represents an alkyl-amine functional group. For CCA type A, the positions 2 and 4 are the chlorine functionality, for CCA type B, only the position 2 or 4 is the Cl functional group, while the CCA type C, the positions 2 and 4 are the NO_2 groups. The affinity for electron exchange of CCA types in a decreasing order is as follows: C > A > B in the same magnitude as the q/m values as shown in Figure 4-11.

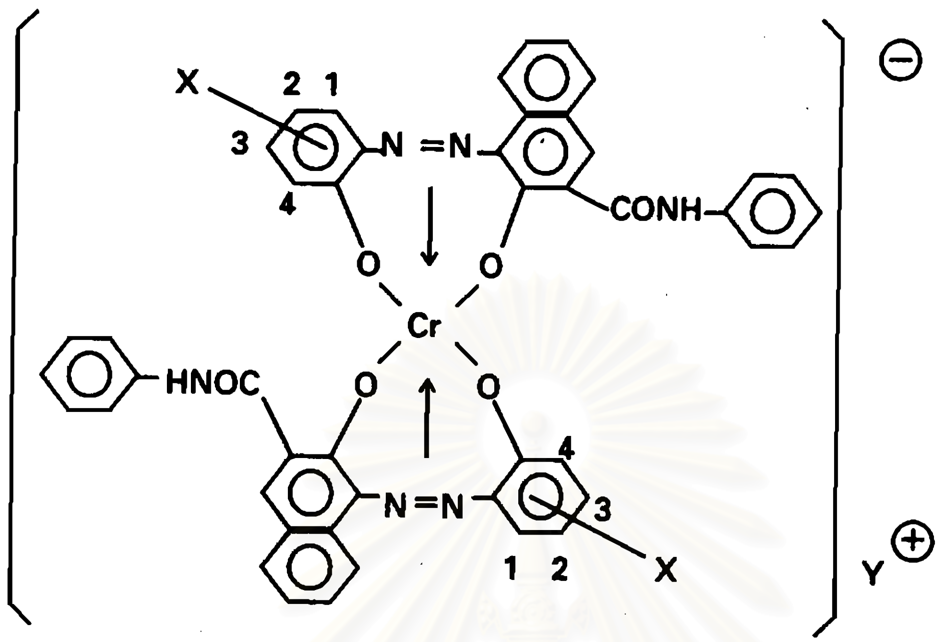


Figure 4-10 Molecular structure of CCA

4.3 Charging Mechanism

All toners and F-200 carrier were mixed by a rotating roller and a hand shaking. The toners were charged by the friction with the carrier to produce a two-component developer. For a printing-charging mechanism, only toners were charged in a developing unit of the printer. When comparing with the rotation-charging mechanism, the hand shaking charging imposes a stronger force, so the q/m values are higher and reach a saturation within a shoner time as Figures 4-12 to 4-13. The q/m values of various CCA amounts by the hand shaking charging mechanism scatter upwards and downwards, which may due to that the hand shaking intensity is not so consistent and the opportunity of carrier contamination with CCA may occur.

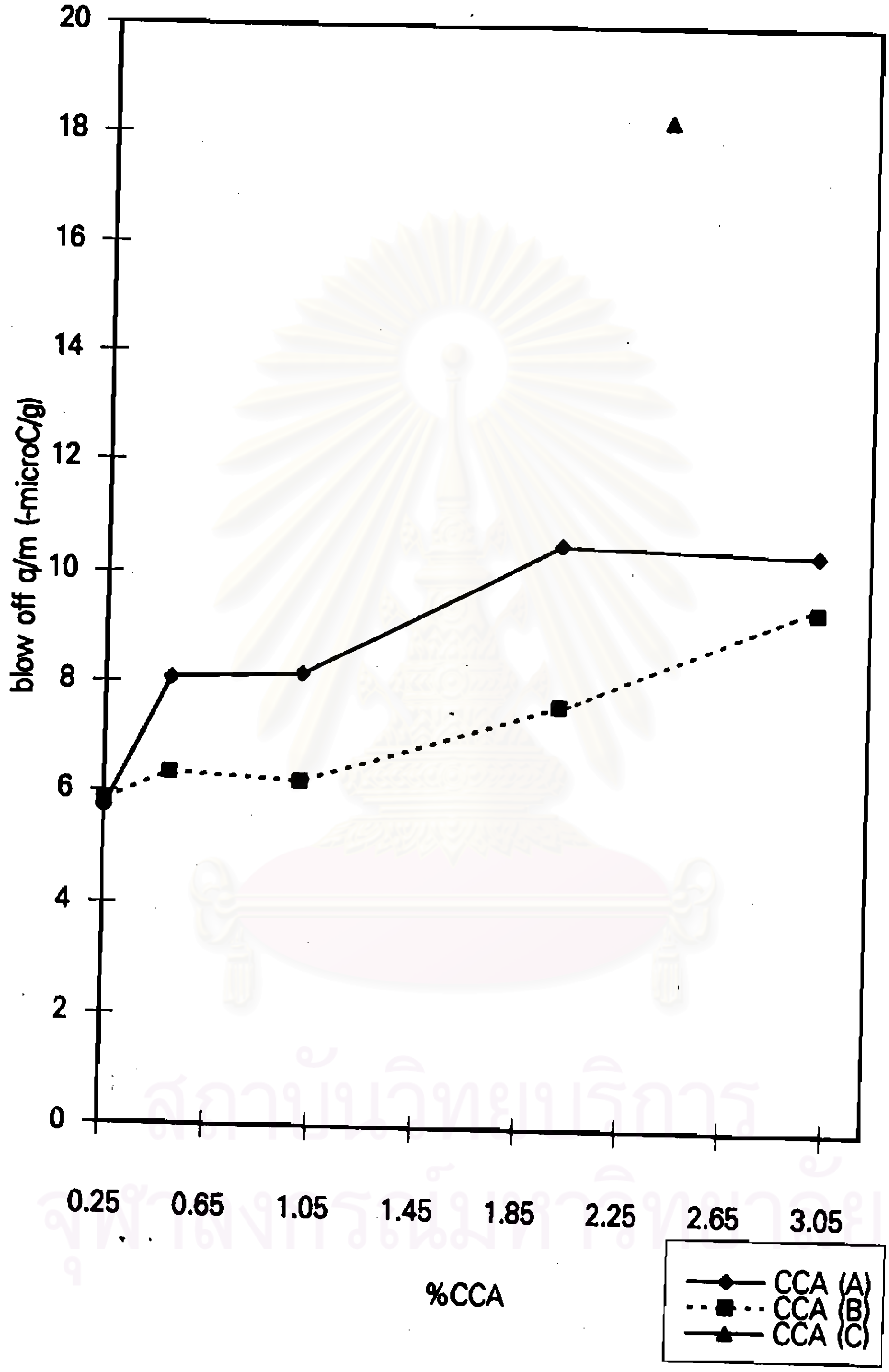


Figure 4-11 Dependence of q/m (blow off) on CCA amounts at various CCA types

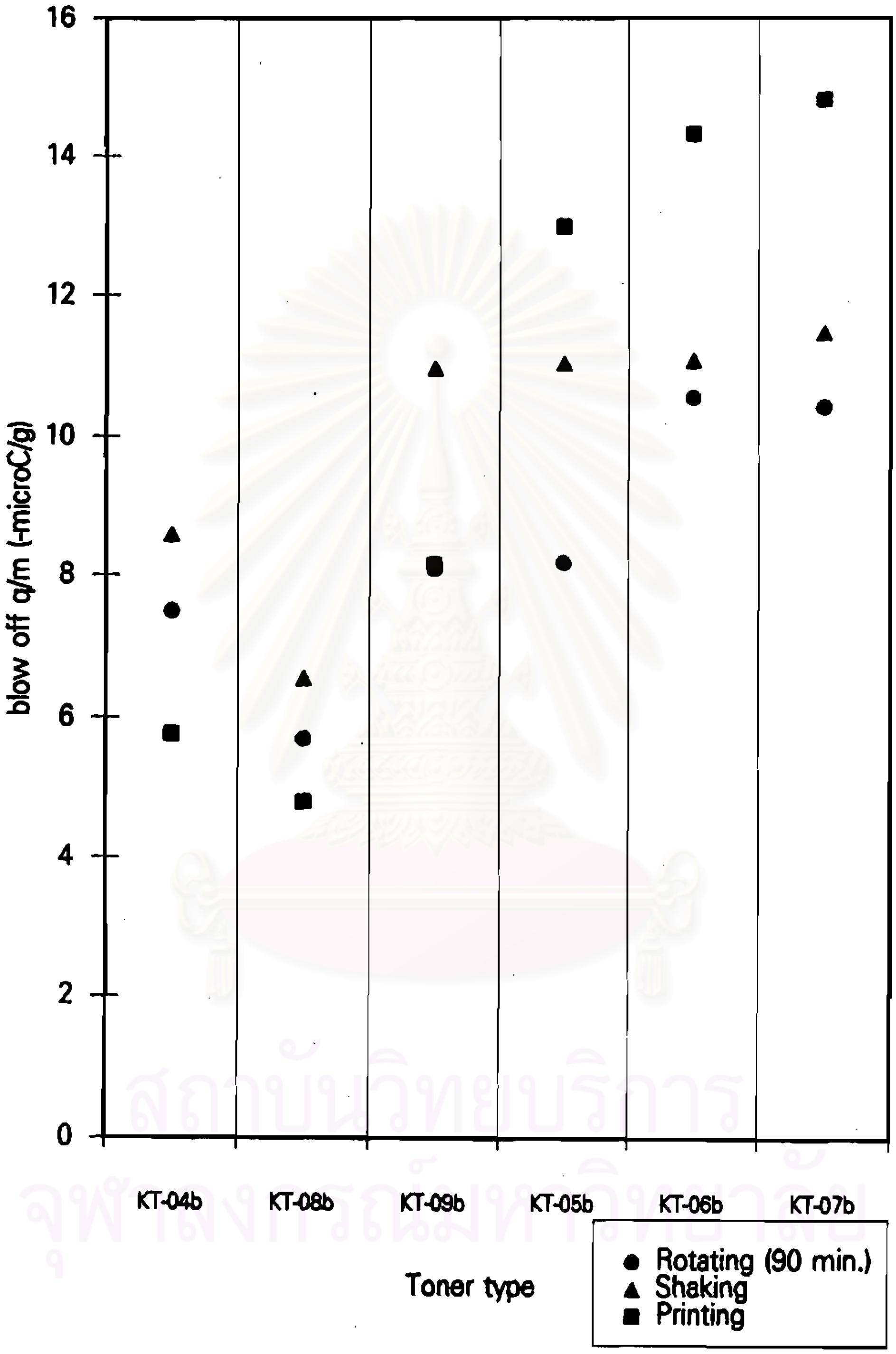


Figure 4-12 Dependence of q/m (blow off) on various toners with CCA type A amount at various charging mechanisms

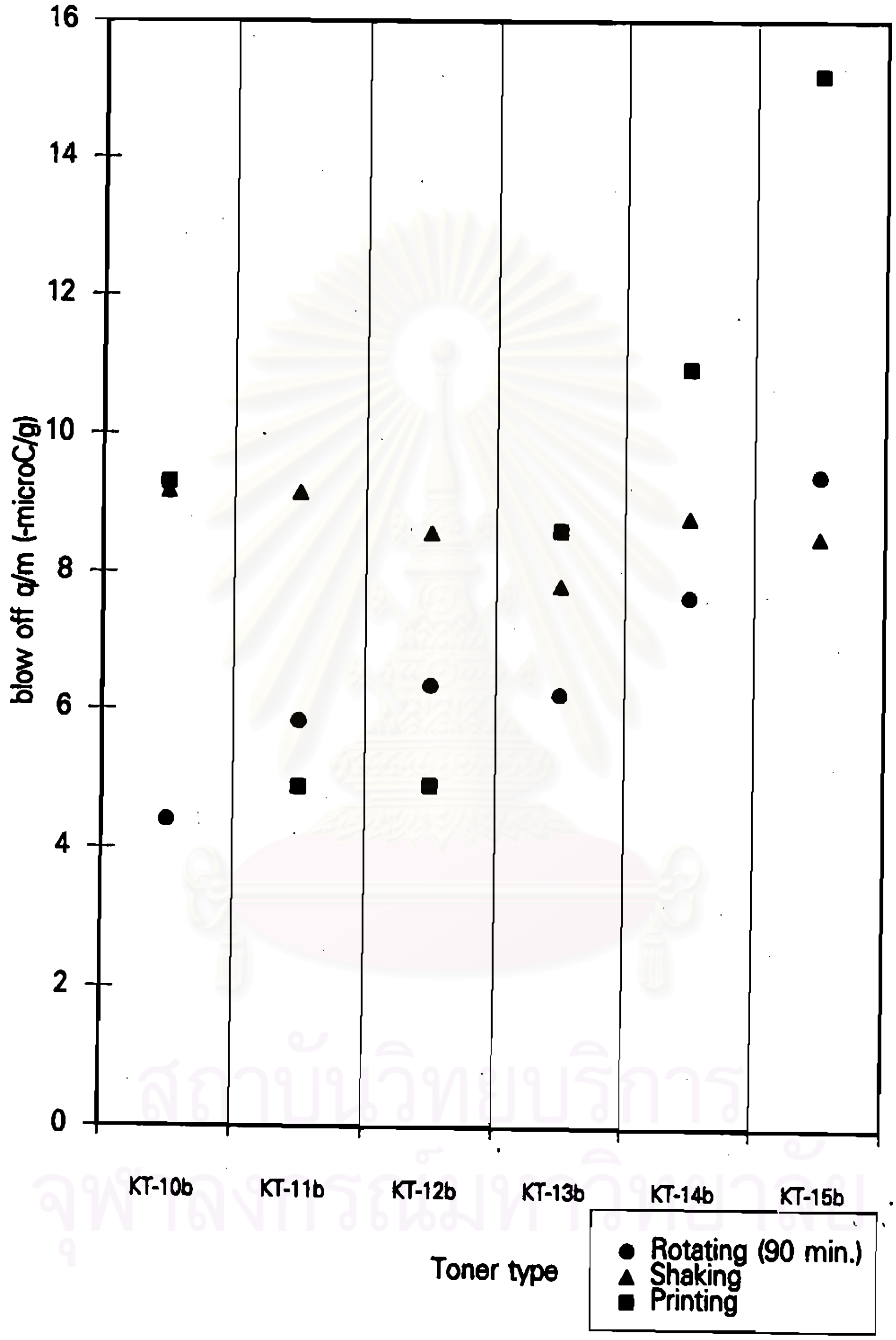


Figure 4-13 Dependence of q/m (blow off) on various toners with CCA type B amount at varicus charging mechanisms

When comparing with another mechanism, the q/m values by the printing-charging mechanism of the toners without CCA and the toners with CCA amounts less than 1% are the lowest; on the contrary, that of the toners with CCA amounts from 1% are the highest.

The dependence of q/m values on charging mechanisms and CCA types is shown in Figure 4-14. For the CCA amount of 0.25%, q/m values by the hand shaking charging mechanism of CCA type A are lower than that of type B, whereas q/m values by the rotating and the printing charging mechanisms are nearly the same. The CCA amounts of 0.5%, 1%, and 2%, q/m values by three charging mechanisms of CCA type A are higher than that of type B. In the CCA amounts of 3%, q/m values by the hand shaking and the rotating charging mechanism of CCA type A are also higher than those of type B; in contrast, q/m values by the printing charging mechanism are opposite. It can be concluded that a small amounts of different CCA types do not affect q/m values so much. The excessive amount of CCA lowers the q/m values, since the CCA particles may drop off when they are charged, resulting in a CCA contamination on charging blade of the printer.

4.4 Toner Shape Dependency

The spherical-shaped toner, N-09S, and the irregularly-shaped toner, N-09C, were mixed with F-200 carrier by a rotating roller. The toner charge was measured by a blow off measurement unit. The effect of various rotating times on q/m values is shown in Figure 4-15. The q/m values of N-09C increased to the highest values within a shorter time and decrease steadily after three minutes. The q/m value of N-09S increased to the highest value in five minutes and then decreased, but its

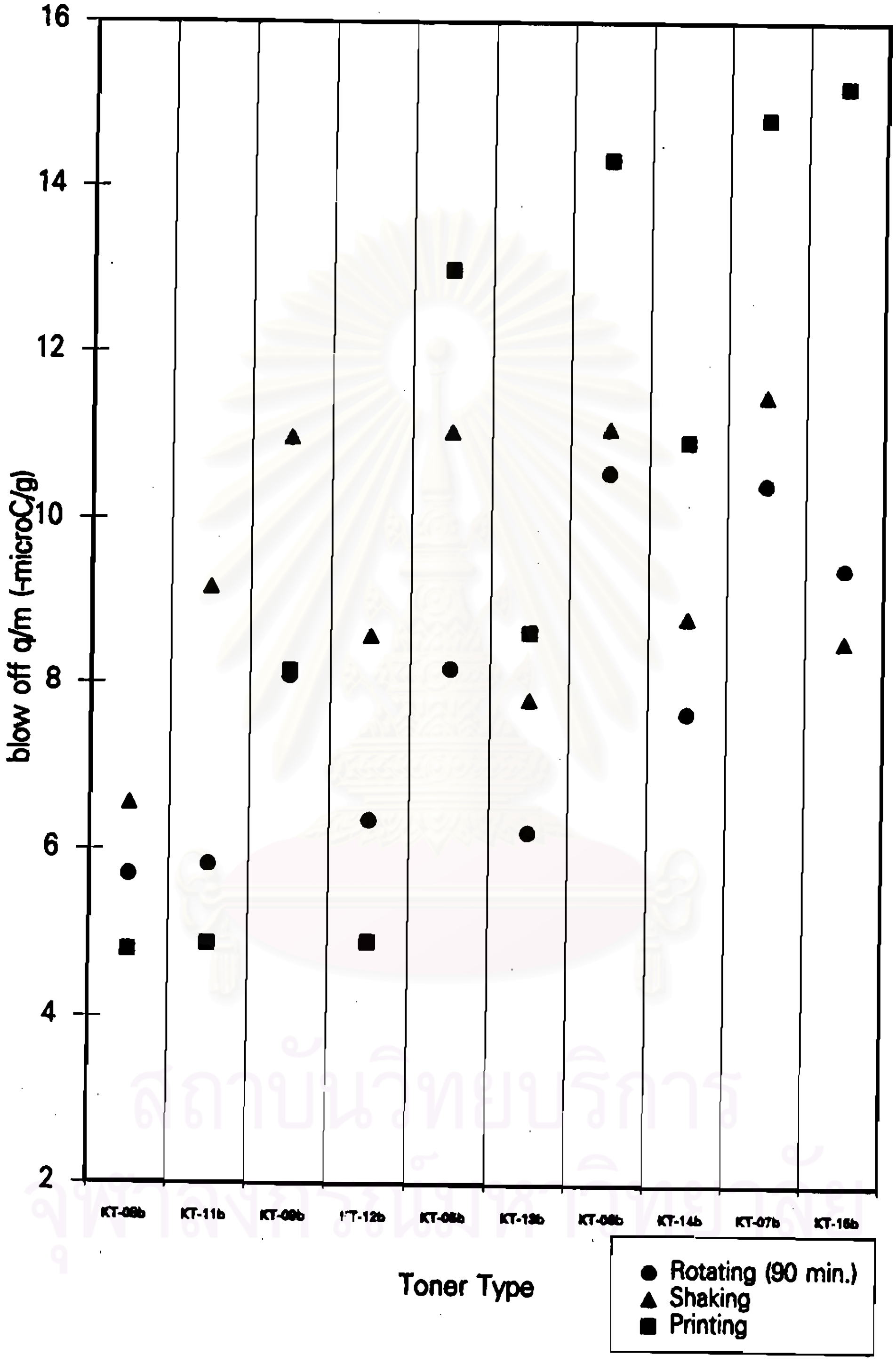


Figure 4-14 Dependence of q/m (blow off) on various toners with CCA types A and B amounts at various charging mechanisms

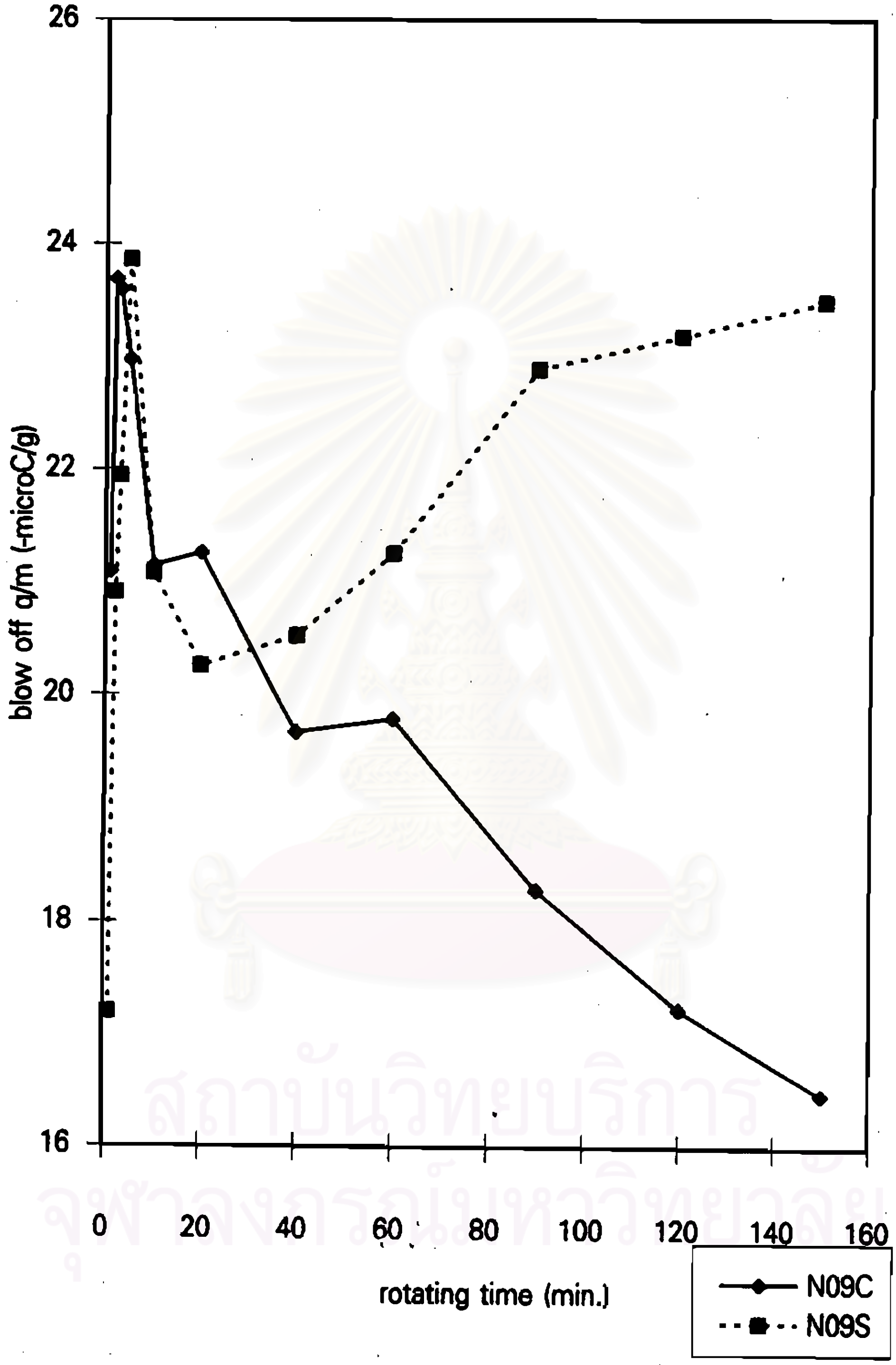


Figure 4-15 Dependence of q/m (blow off) on rotating time at various toner shapes

values increased gradually and reached a relatively stable value after ninety minutes as shown in Table A-2 (see Appendix A). It can be explained that the q/m values of both toners are not stable for a short rotating time because some effective charging sites of the toner cannot be charged. The q/m values of N-09C after a rotating time of three minutes decreased possibly due to the CCA contamination on the carrier surface, since the irregular shape of the toner may have some protruded sharp sites to expel and fall off the CCA particles from the toner surface while it is rubbing. In case of N-09S, the spherical toner has smooth surface,[29] i.e., it does not have protruded sharp sites to fall off the CCA particles.

The extent of q/m values resulting from various charging mechanisms and toner shape is shown in Figure 4-16. In case of N-09C, the q/m values by the printing- charging mechanism are the highest because of sufficient CCA concentration. While that of the hand shaking charging mechanism are relatively lower because of CCA contamination on the carrier surface by strong force. Likewise, the toner N-09S, the q/m values by the hand shaking charging mechanism are the highest because of the high intensity of shaking and the absence of the CCA contamination effect. For the rotation-charging mechanism, the q/m values of both toner shapes are consistently lower than those mechanisms because they could be charged by the low and constant force. When comparing with N-09C, q/m values by any charging mechanism of N-09S are higher because of its spherical shape that can be rolled easier while it is charging, therefore, almost all the surface area can be charged effectively.

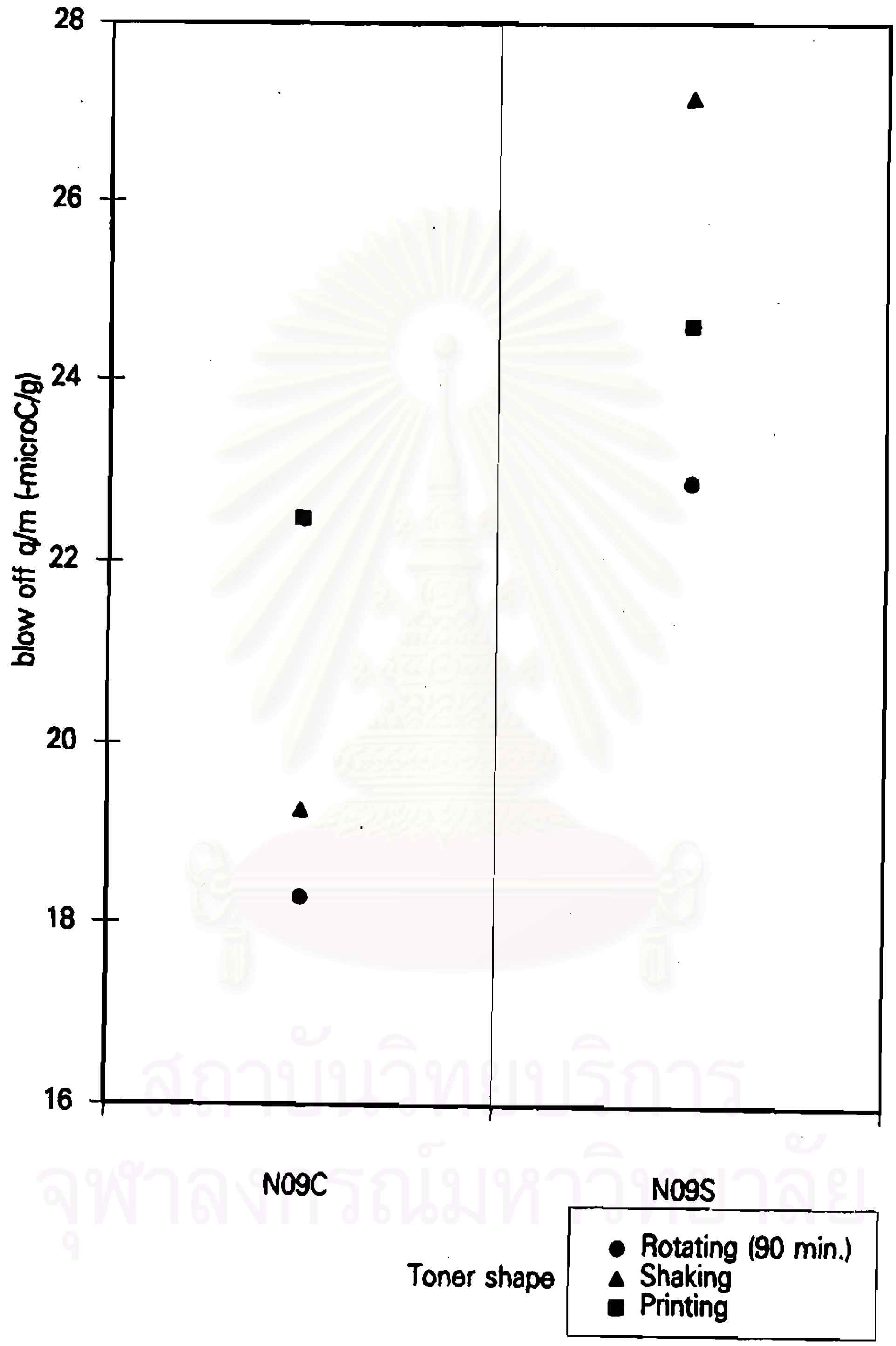


Figure 4-16 Dependence of q/m (blow off) on various toner shapes at various charging mechanisms

4.5 Print Quality Evaluation

All toners were evaluated for their print qualities by OKI LED printer; they were printed with a test form on five pieces of plain paper. The density and dot gain percentage were measured by a reflection densitometer. The solid density of print-outs by various toners is shown in Figure 4-17. The toners without CCA give the lowest density. The solid density increased when increasing the CCA amounts. For the same CCA amount, the solid densities of print-out by the toners with CCA type A are higher than those of type B.

The background densities of print-outs by various toners without CCA are higher than toners with CCA as shown in Figure 4-18. The increasing CCA amounts of the CCA type B is not significantly effective to decrease the background density. For the CCA type A, when increasing CCA amounts, the background density is decreased and is vanished at %CCA of 0.5 wt%. The background density by using the toner with CCA type A is lower than that of the CCA type B because CCA type A has a higher affinity for electron exchange than does the CCA type B leading to the higher q/m values. Therefore, the toners are attached only the positions of the latent image, resulting in less background densities.

The dot gain percentage, when comparing between original dot areas produced by digital data and dot area reproduction of print-outs, is shown in Figures 4-19 to 4-20. The dot gain percentage at highlight areas is increased slightly, while the dot gain increased mostly to reach the highest values at midtone areas before decreasing at shadow areas. For solid areas, some toners produce the lower density than the calibrated maximum density resulting in minus values of dot gain percentage.

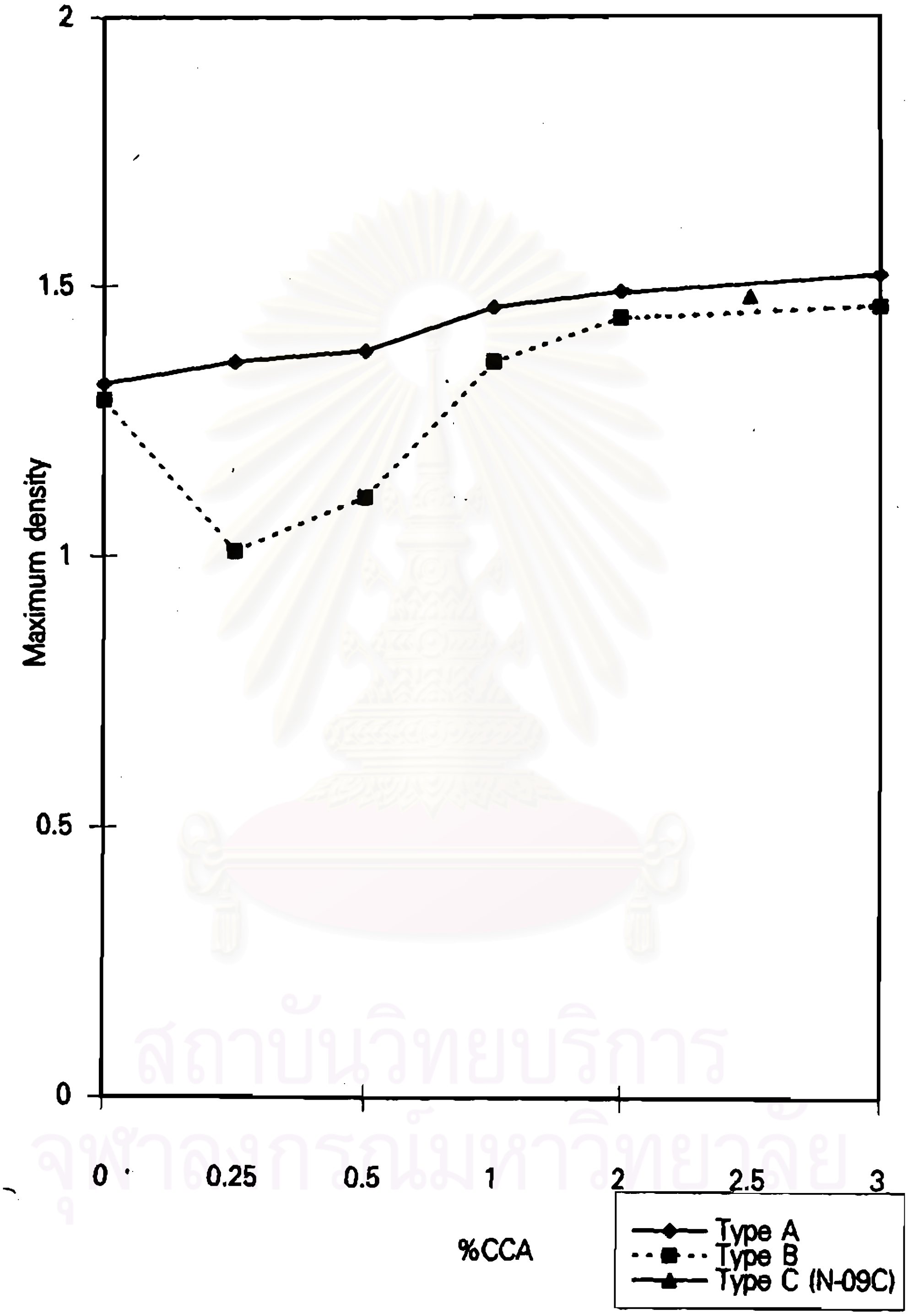


Figure 4-17 Dependence of maximum density on CCA amounts at various CCA types

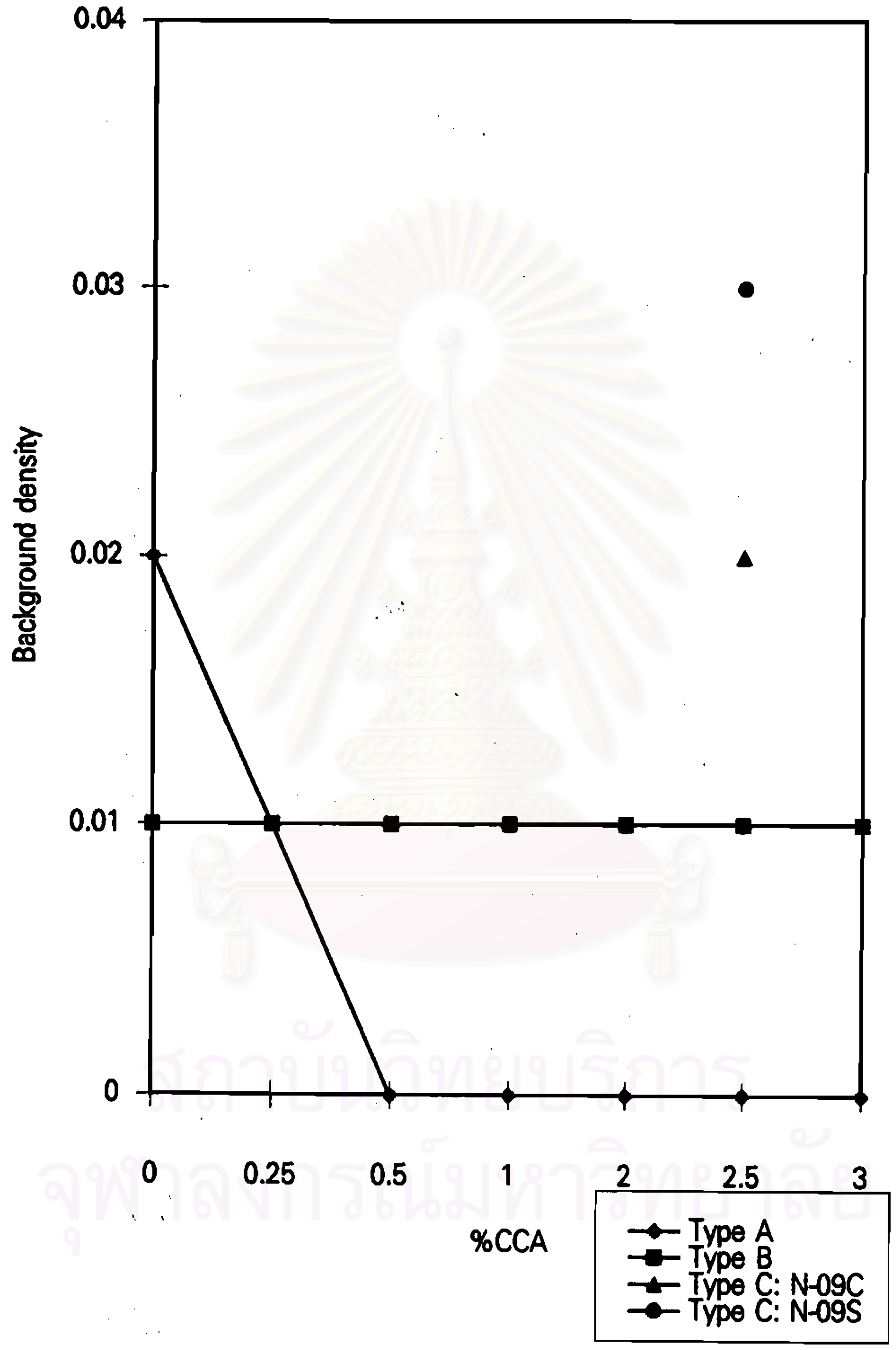


Figure 4-18 Dependence of background density on CCA amounts at various CCA types

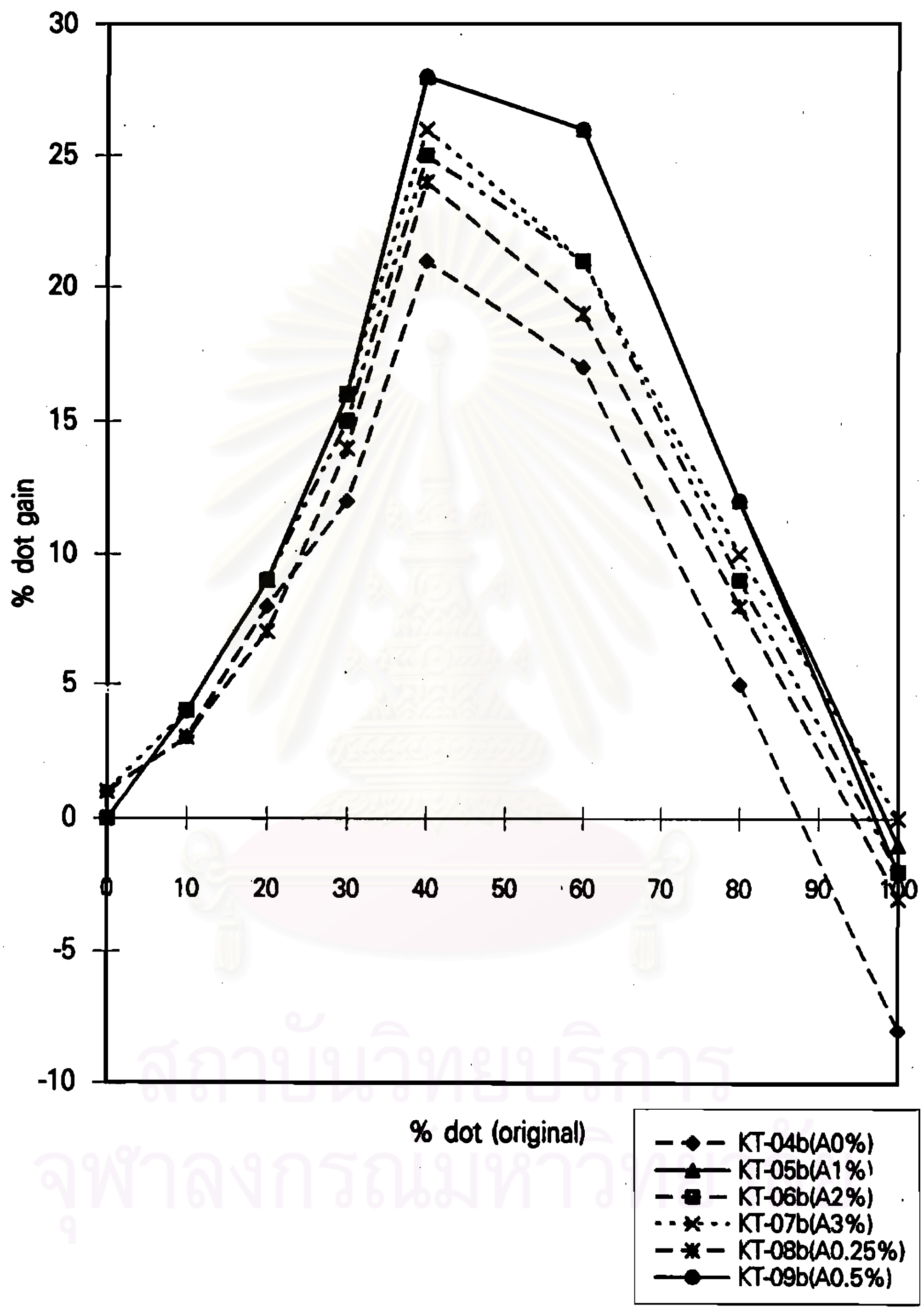


Figure 4-19 Dependence of %dot gain on %dot original at various amounts of CCA type A

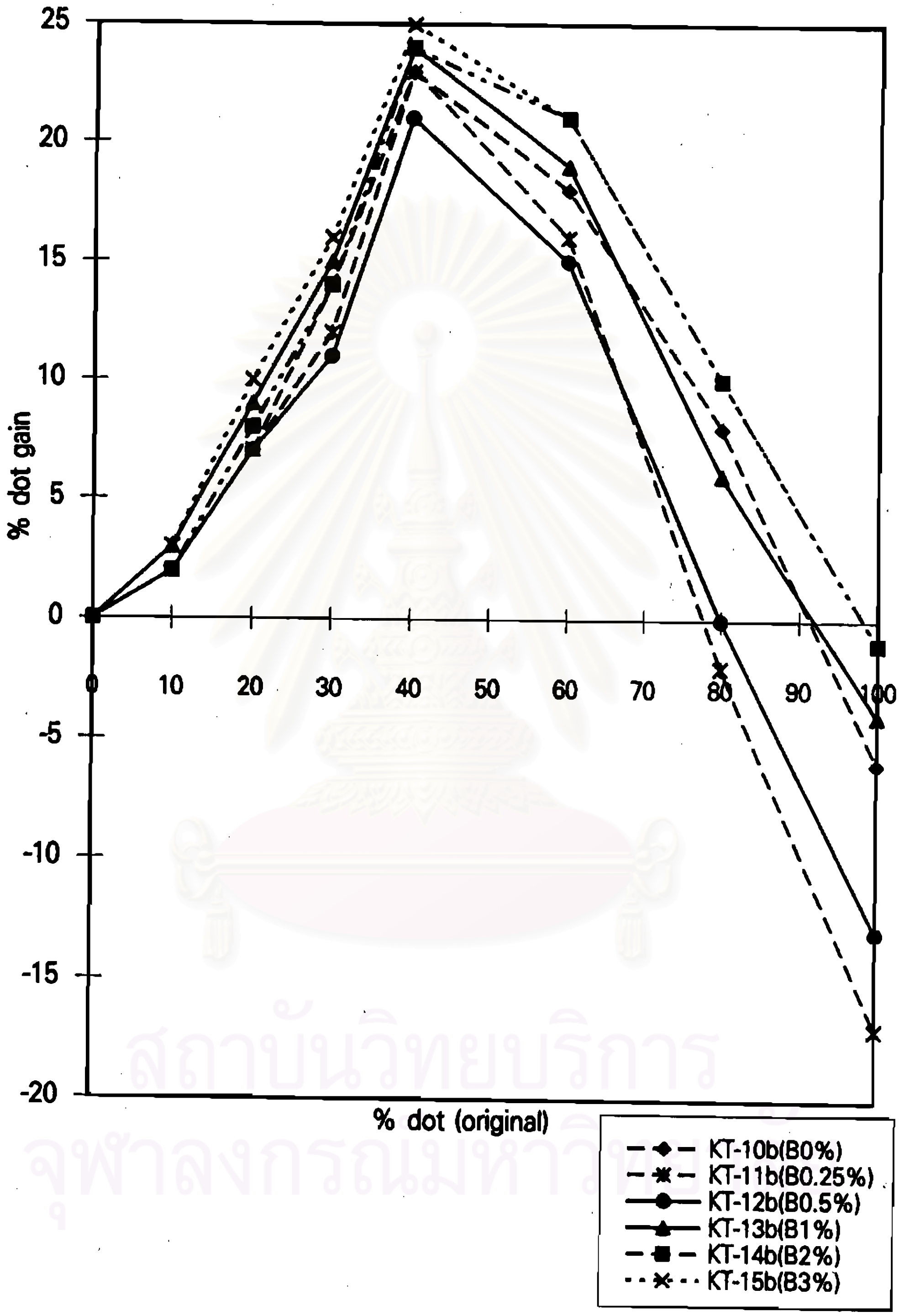


Figure 4-20 Dependence of %dot gain on %dot original at various amounts of CCA type B

The dot gain percentage by using the toners without CCA is lower than the toner with CCA. The dot gain percentages are increased when increasing CCA amounts with those of KT-05b and KT-09b the highest. The CCA shape dependency of dot gain percentages on CCA types A and B are somewhat the same. The dot gain percentages by using the toner with CCA type A are higher than that of type B, and nearly the same amount of dot gain when CCA amounts are 2 and 3% as shown in Table A-7 (see Appendix A). The dot gain percentages by using the irregularly-shaped toner are lower than those of the spherical-shaped toner as shown in Figure 4-21, because the latter produces the ghost images which increase the %dot areas in each tone reproduction by measuring with the reflection densitometer.

There are two noteworthy remarks for N-09S. First, the ghost images, which occurred on the non-printing areas, led to the background density. Second, the solid tone is a matte surface when measuring with a micro glossmeter, Sheen Ref. 155 according to TAPPI T 480 om-92, the gloss value of solid areas of N-09C is 5.7 and that of N-09S is 4.0. The density of N-09S which is measured by the reflection densitometer is therefore lower than it should be. For this result, it may be postulated that the toner, N-09S, cannot be transferred completely to the paper by a transfer roll or it is not properly fused by a fuser roll.

4.6 Humidity Effect

The KT-04a, KT-04b, KT-05a, and KT-05b toners, were mixed with F-200 carrier by a rotating roller. The toner charge was measured by a blow off measurement unit. The results are shown in Figures 4-22 to 4-23. In Figure 4-22, the q/m values of the toner without CCA and silica, KT-04a, are decreased when increasing the

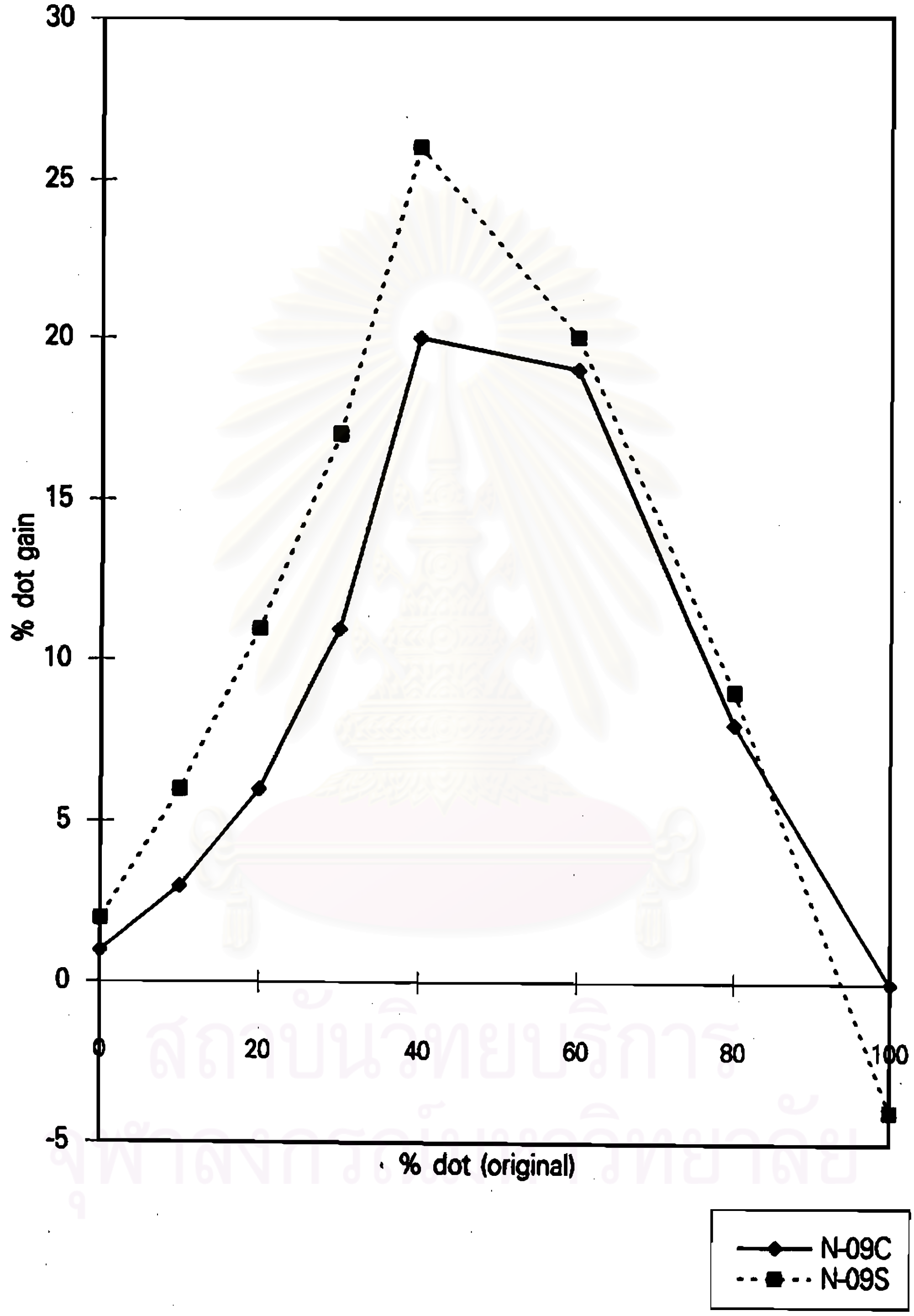


Figure 4-21 Dependence of %dot gain on %dot original at various toner shapes

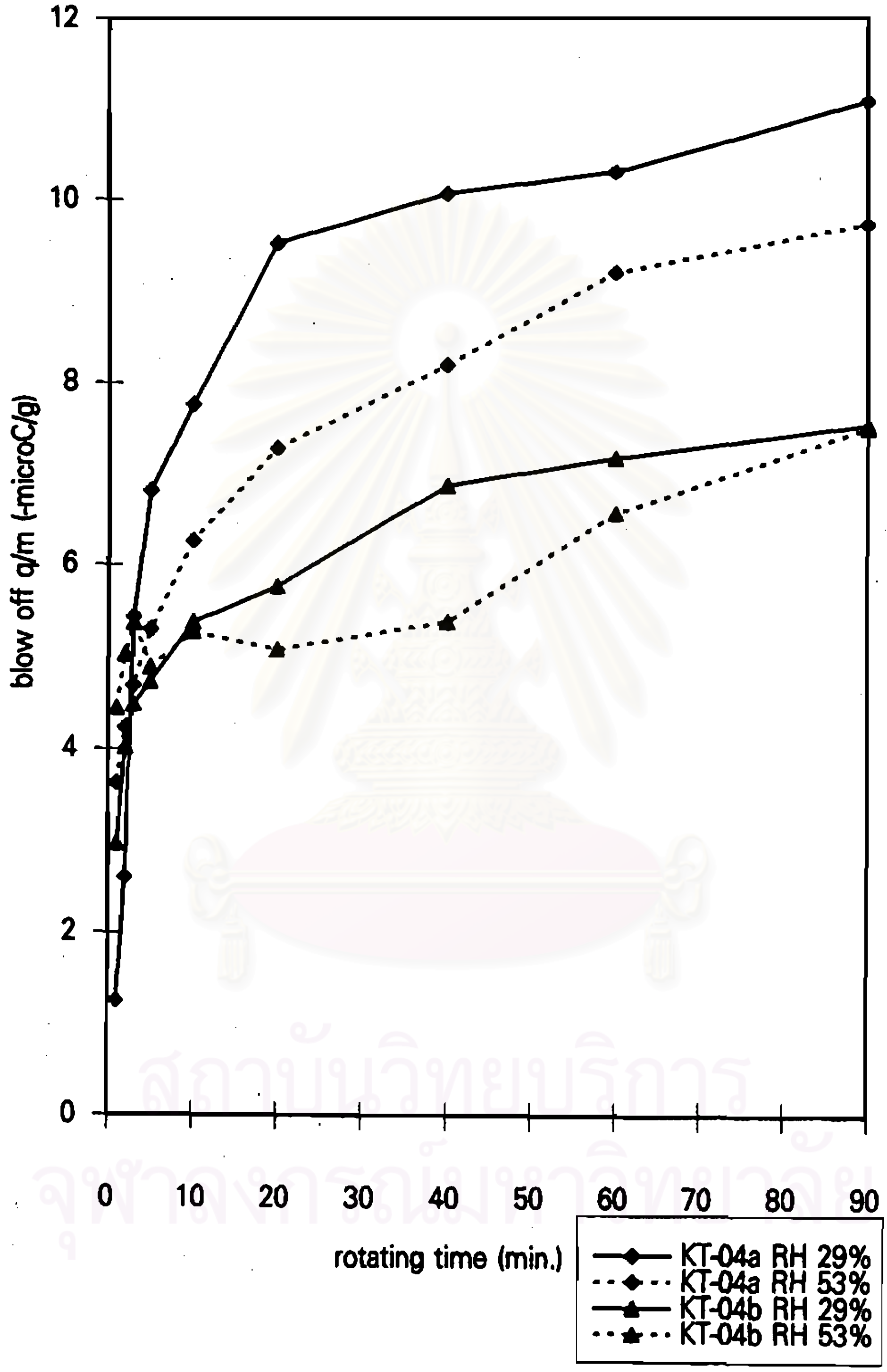


Figure 4-22 Dependence of q/m (blow off) on rotating time in the toners without CCA at different humidity

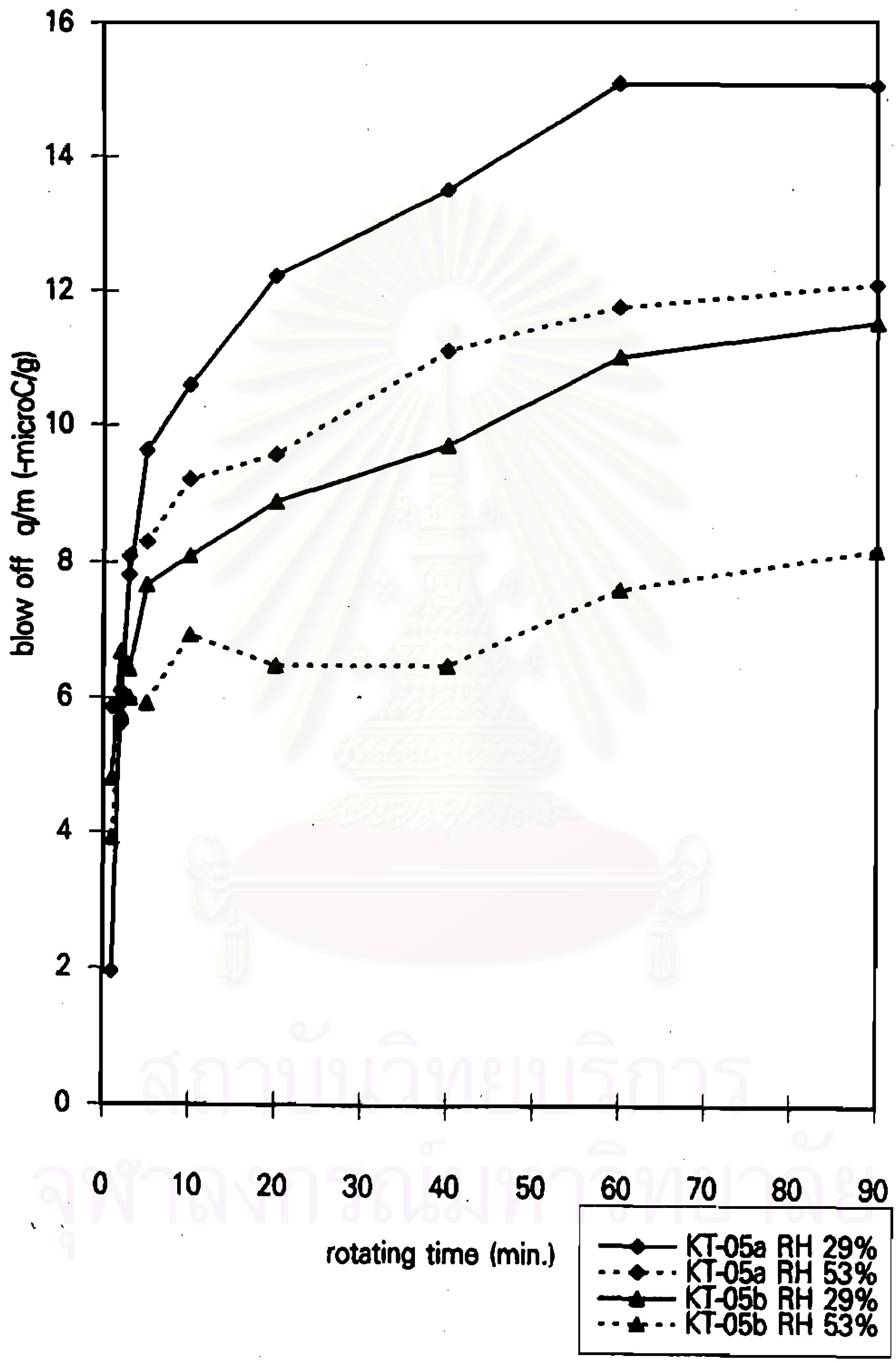


Figure 4-23 Dependence of q/m (blow off) on rotating time in the toners with CCA at different humidity

relative humidity, similar to that without CCA and with silica, KT-04b. In Figure 4-23, the q/m values of the toner with CCA and without silica, KT-05a, are decreased when increasing the relative humidity, the same as that of the toner with CCA and silica, KT-05b. From both figures, they indicate that the presence of CCA decreases the q/m values in a constant proportion; the addition of silica lowers the q/m values more than that contains no silica. It can be concluded that the additions of CCA and silica into the toner affect the toner charge when the humidity is varied. The moisture absorption on toner surface may produce charge decay. This is conformed to the literature that the charging is sensitive to the relative humidity when silica is used with the toners.[32]

4.7 Comparison of q/m Values between E-SPART and Blow Off Techniques

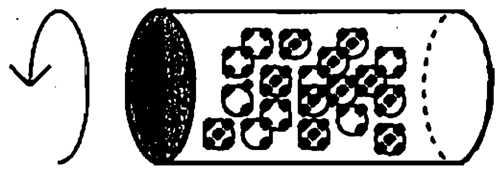
The toners, KT-04b, KT-05b, KT-07b, KT-10b, KT-14b, N-09C, and N-09S, were selected to measure their charge properties by the E-SPART analyzer. The comparison of q/m values between E-SPART and blow off techniques is shown in Table 4-1. For E-SPART data, the q/m values of the toners without CCA are lower than those of the toners with CCA. The q/m values of the toners with CCA type A, KT-07b, are higher than that of CCA type B, KT-14b, at the same wt%. The q/m values of the spherical-shaped toner are higher than that of the irregular-shaped toner. For the blow off data, the trend of q/m values is the same as the E-SPART data. From the results, it shows that the q/m value of each measurement technique is different, therefore, neither can be a representative value. For example, KT-07b toner has a q/m value of -14.8 μC/g by the printing charging mechanism, which gives the highest density and without a background density. It cannot be mentioned that the q/m value, which gives the good print quality, is -14.8 μC/g. In conclusion, the expression of q/m value should be specified along with the charging mechanism and the measurement technique.

Table 4-1 Comparison of q/m values between E-SPART and blow off techniques

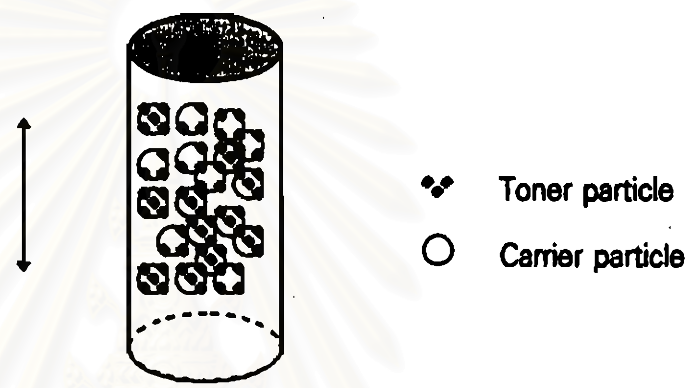
Toners	q/m values of E-SPART (-microC/g)		q/m values of blow off (-microC/g)	
	1	2	a rotation-charging	a printing-charging
KT-04b	4.9	4.7	7.5	5.8
KT-05b	7.8	7.9	8.2	13
KT-07b	7.8	7.4	10.4	14.8
KT-10b	5.1	4.8	4.4	6.3
KT-14b	7.3	7.2	7.7	10.9
N-09C	12.1	10.7	16.5	22.5
N-09S	16.8	16.4	23.5	24.6

4.8 Possibly Charging Mechanism

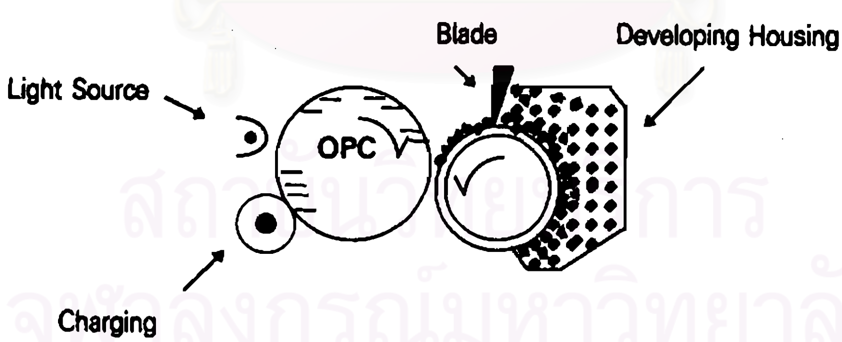
The charging property, q/m, of a toner depends on various factors: a charging mechanism, components of the toner, and/or an environment. The charging mechanisms are proposed in Figure 4-24. For a rotation-charging mechanism shown in Figure 4-24 (a), a toner particle was changed by rubbing together with a carrier particle while rotating, therefore, the factor which affect this mechanism is a rotating speed. It depended on a diameter of a roller. For a hand shaking charging mechanism as shown in Figure 4-24 (b), the toner particle was changed by rubbing



(a) a rotation-charging



(b) a hand shaking charging



(c) a printing-charging

Figure 4-24 A model of various charging mechanisms: (a) a rotation-charging, (b) a hand shaking charging, (c) a printing-charging together with a carrier particle while shaking. The factor affects this mechanism is a shaking rate, which is not a constant value for any person who carried out the experiment. The shaking rate relates to the speed and the distance of the particle movement. For a printing-charging mechanism as shown in Figure 4-24 (c), the toner particle was charged by rubbing together with a development roller, therefore, the material, which is made of the roller affects the q/m. Moreover, the physical chemistry of the toner and the carrier components are also an effective factor on q/m. The physical characteristics are interrelated to their size and shape. The chemistry characteristics are concerned with each substance, in terms of chemistry nature, and its amount, and a toner-to-carrier ratio. In addition, the humidity sometimes affects the q/m, however, it depends on the chemistry of the toner components.

4.8.1 *Relationship between rubbing method and q/m value*

4.8.1.1 Rotation-charging mechanism

When the rotation of the sample holder on a rotating roller takes place, some parts of the carrier surface contact with the cylindrical wall in the direction of the roller movement, charging sites of the carrier are decreased due to that they cannot accept any toner. The charged sites with toners are erased when the movement of the cylinder is continued. Most of the charges are lost to give a lower q/m values.

4.8.1.2 Hand shaking charging mechanism

Both the toners and carrier particles move up and down along the length of the sample holder, the charging sites of one carrier particle are higher than the rotation-charging mechanism leading to the higher q/m values as indicated in the experimental result. This type of collision may be assumed elastically due to that most of the charges are stored on the toners.

4.8.1.3 Printing-charging mechanism

This mechanism is totally different from the above two mechanisms. Since it is a one component development, the toners stay still while the magnetic roller is moving. The smooth surface of the roller, considered as a tribocharge medium, can better transfer charges to the toners. This mechanism can also be considered as an elastic charging, which results in the highest q/m values.