Chapter 3

Results and Discussion

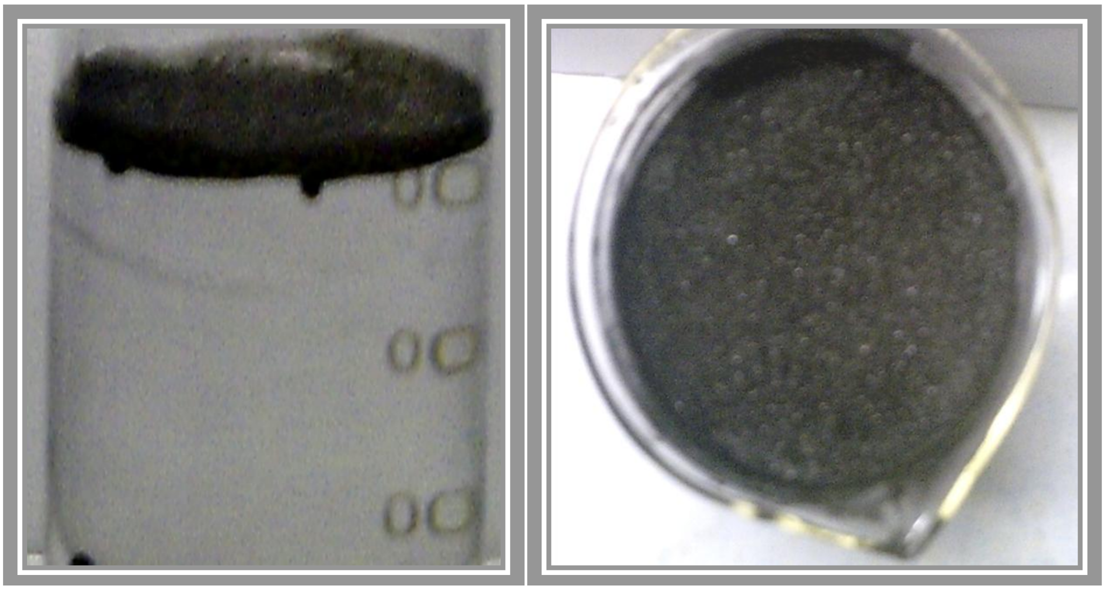
3.1: Visualizing the model

3.1.1: Determination of Uniform Dispersion Time

Some primary experiments were done to understand how the model works. Different stages of particles distribution were visualized by eye to include a series of patterns as follows:

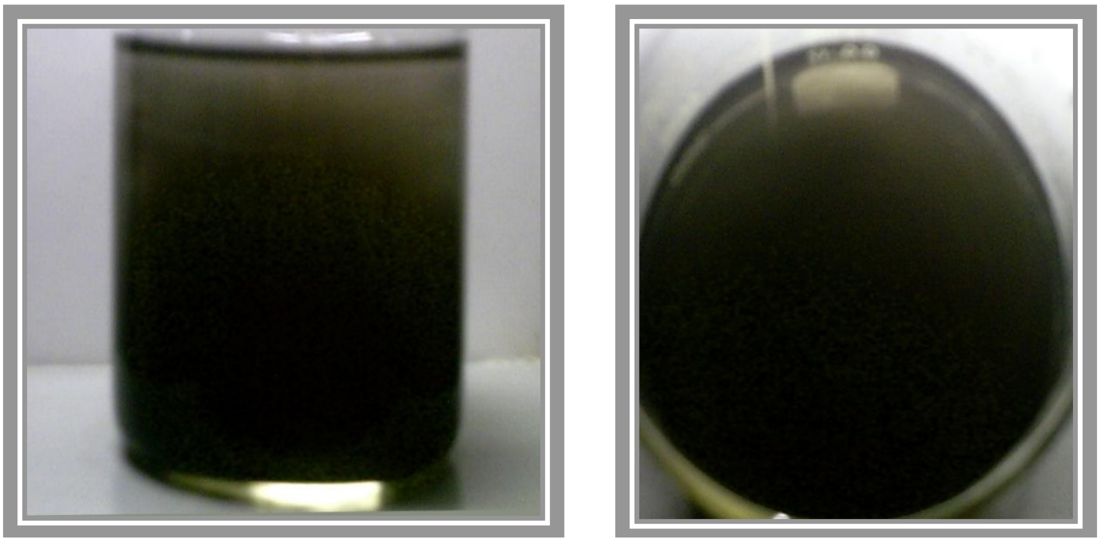
Collecting at the top of the fluid - mixing within the fluid - almost homogenous distribution - settling at the bottom.

Figures (3-1) to (3-6) show the different stages of the water/SiC particles and water/glycerol with SiC particles before and during and after reaching homogenous distribution. The figures show that initially all SiC particles are collected in the top of the fluid, that means that no dispersion of the particles occurred. After that a homogenous distribution state occurred for the SiC particles in both visualized models (water and water/glycerol) as seen in figureS (3-2) and (3-5). The figures show that the SiC particles reached a state of homogeneous distribution in all locations in the Pyrex beaker after the certain time that means that the dispersion of particles occurred, and this time was called dispersion time. After reaching homogeneous distributions of the SiC particles, further mixing in both visualized models (water and water/glycerol) led to various patterns as shown in figures (3-3) and (3-6). The figures show that after reaching the homogenous distribution most of the SiC particles settled in the bottom of the Pyrex beaker that means that the dispersion of particles became homogenous after a certain time and if mixing continued after that time the particles tend to settle at the bottom .



(a) (b)

Figure (3-1): Before stirring (water)
(a) side view (b) top view



(a) (b)

Figure (3-2): Homogenous distribution (water)
(a) side view (b) top view

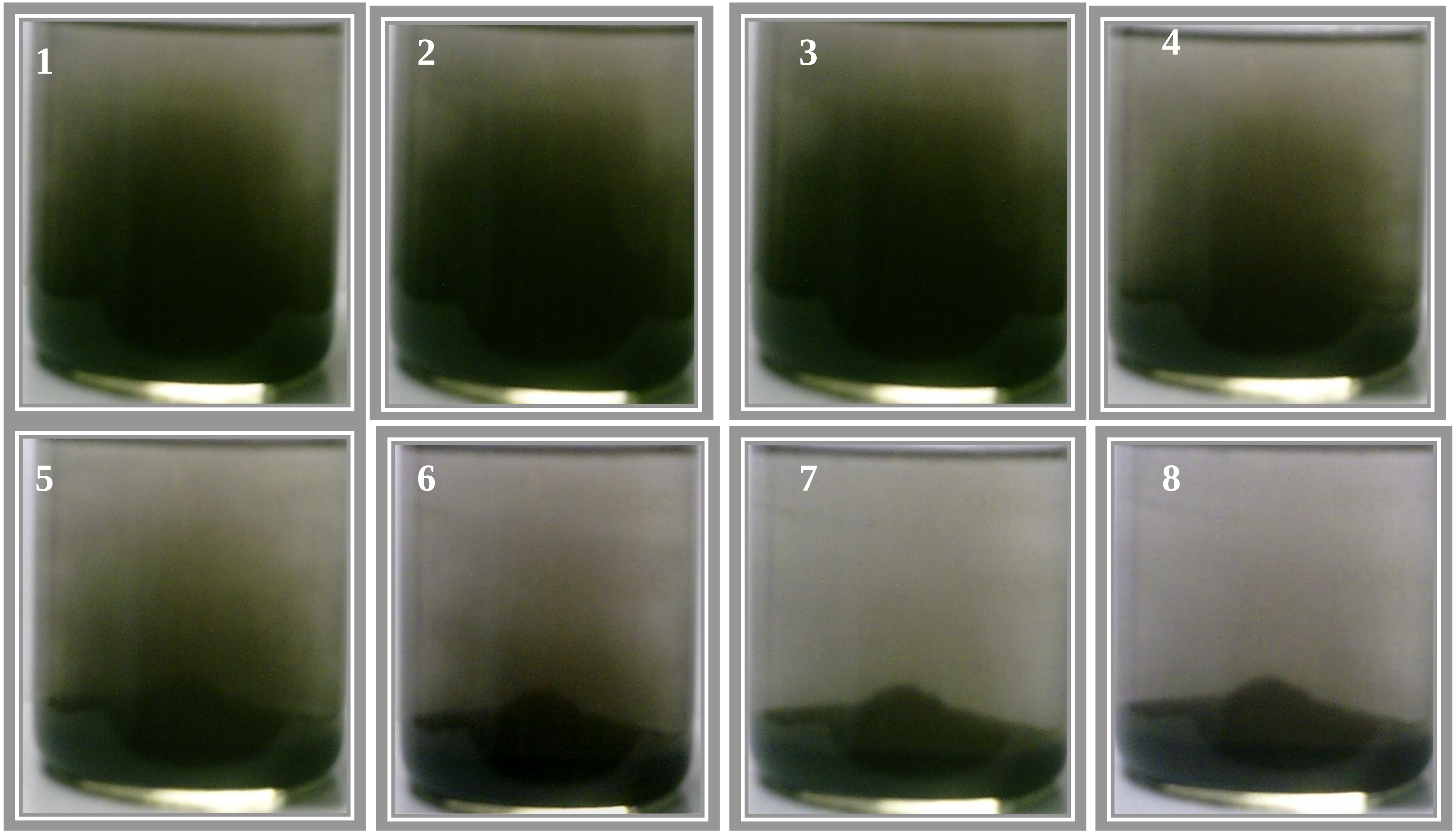
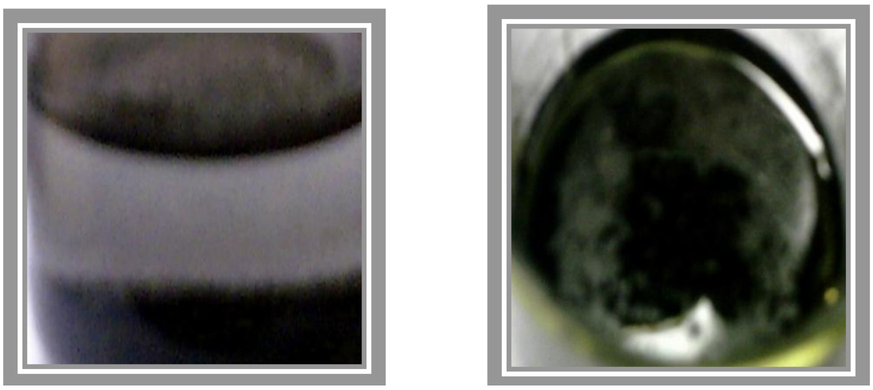
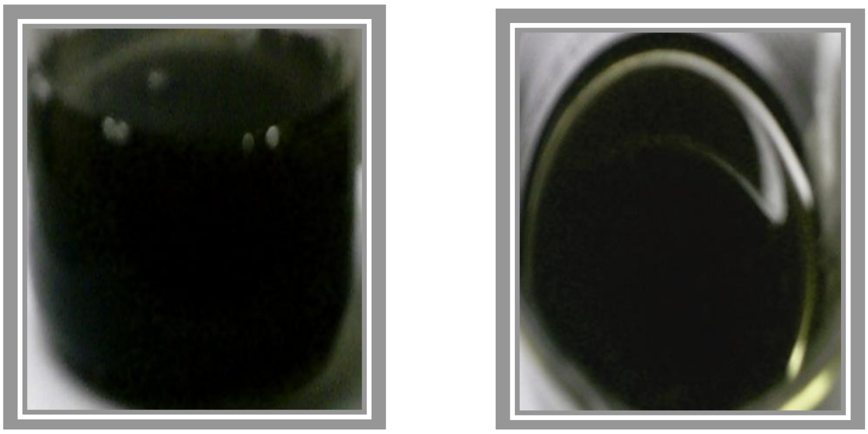


Figure (3-3): Particles distribution after stirring



(a) (b)

Figure (3-4): Before stirring (water/glycerol) model
(a) side view (b) top view



(a) (b)

Figure (3-5): The homogenous distribution in (water/glycerol) model
(a) side view (b) top view

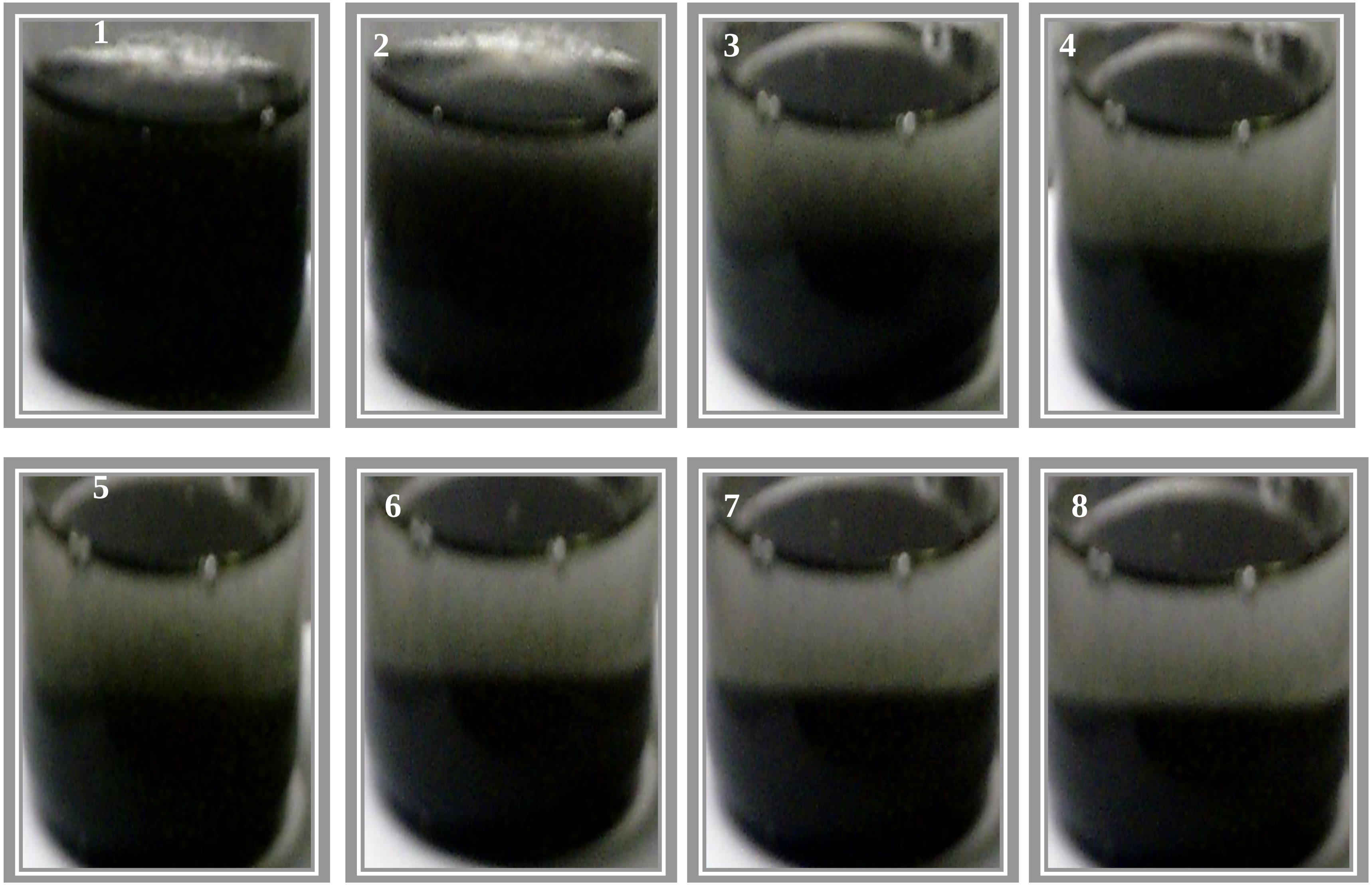


Figure (3-6): Particles distribution after stirring (water/glycerol) model

3.1.2: Influence of Stirring Parameters on Uniform Dispersion Time

A) In water

The volume fraction percentage of Silicon carbide particles for each combination of conditions illustrated in table (2-4) are represented in the figures (3-7, 3-8, 3-9) and (Appendix 2). The figures show the effect of stirrer height, blade angle, blade type, ratio of diameter of blade to beaker diameter and the weight and mixing speed on the distribution of the ceramic particles in the fluid with time. The results are summarized in (Appendix 3). The figures show the following observations:

1) at 100 rpm and with 0^0 and 30^0 blade angles at D/D_0 (0.5, 0.6, 0.7, 0.8 and 0.9) and h (10, 20, 30 and 40 mm) no uniform distribution resulted, for two, three and four blades but with 45^0,60^0 and 90^0 blade angles at D/D_0 (0.7, 0.8 and 0.9) and h (10, 20, 30 and 40 mm) there was full particulate dispersion for two, three and four blades at different times.

2)at 200 and 300 rpm and with 0^0 , 30^0 , 45^0,60^0 and 90^0 blade angles at D/D_0 (0.5, 0.6, 0.7, 0.8 and 0.9) and h (10, 20, 30 and 40 mm) there was full particulate dispersion at three and four blades but at different times.

This may be explained by the fact that water is a Newtonian fluid which means that the viscosity will stay constant and low at low shear rate so, the SiCp will need long time to wet at low shear rate. If the time of the shear increases the fluid will be filled with air bubble, though the higher shear rate helps in wetting of the SiCp [78]. The previous observations are consistent with that noticed by S. Naher et al. [78], as they noticed that the higher blade angles and lower viscosity reduced the particulate dispersion time. Figure (3-10) and (Appendix 4) illustrate the relationships between the different stirrer types and uniform dispersion time at different heights (H), D°/D, and stirring speed.

The group of figures from (3-11) to (3-17) show the effect of changing stirrer height on time needed for particle homogenous dispersion at different set of parameters. It is clear from figures that the particulate dispersion time increases as the height of the stirrer increases. For example the time to reach the homogenous distribution increases from 45 s to 387 s when the height of the stirrer increases from 10 mm to 40 mm. On the other hand the time to reach the homogenous distribution decreases from 55 s to 22 s as the stirring speed increases from 200 to 300 rpm. This may be a result of the vortex in the water condition during the high stirring speed. Higher blade angles result in reduced particulate dispersion time. The results in figures show that the particulate dispersion time decreases from 92 s to 27 s as the blade angles increases from 0^0 to 90^0. The particles dispersion time is affected by the vortex structures, For the conditions studied, the vortex emergence has the maximum effect on particle dispersion, the influence of the vortex size affects the particle dynamics. The vortex size increases as the blade angle increases so the particle dynamics becomes progressively stronger [86-88]. The results shown in figures indicate that the particulate dispersion time decreases as the blade numbers increases from 2 blades to 4 blades. For example the time to reach the homogenous distribution decreases from 450s to 100 s when the blade numbers increases from 2 blades to 4 blades.

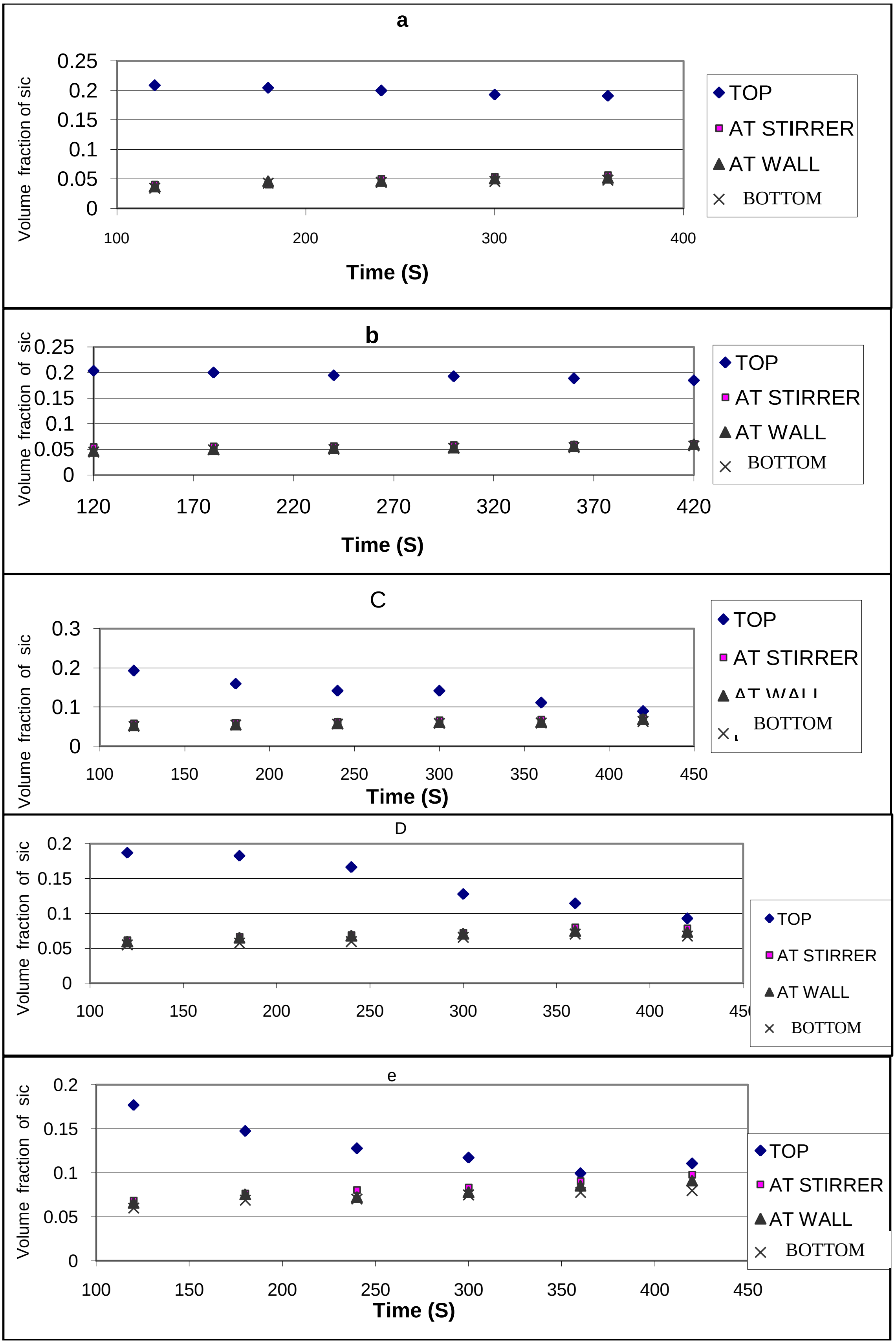


Figure (3-7): Relation ship between distribution SiCp and Time at Two- blade stirrer at 100 rpm, H=20 , D∘ /D = 0.7 and blade angle a) 0 ° b) 30 ° c) 45 ° d) 60 ° e) 90 ° (water experiment)

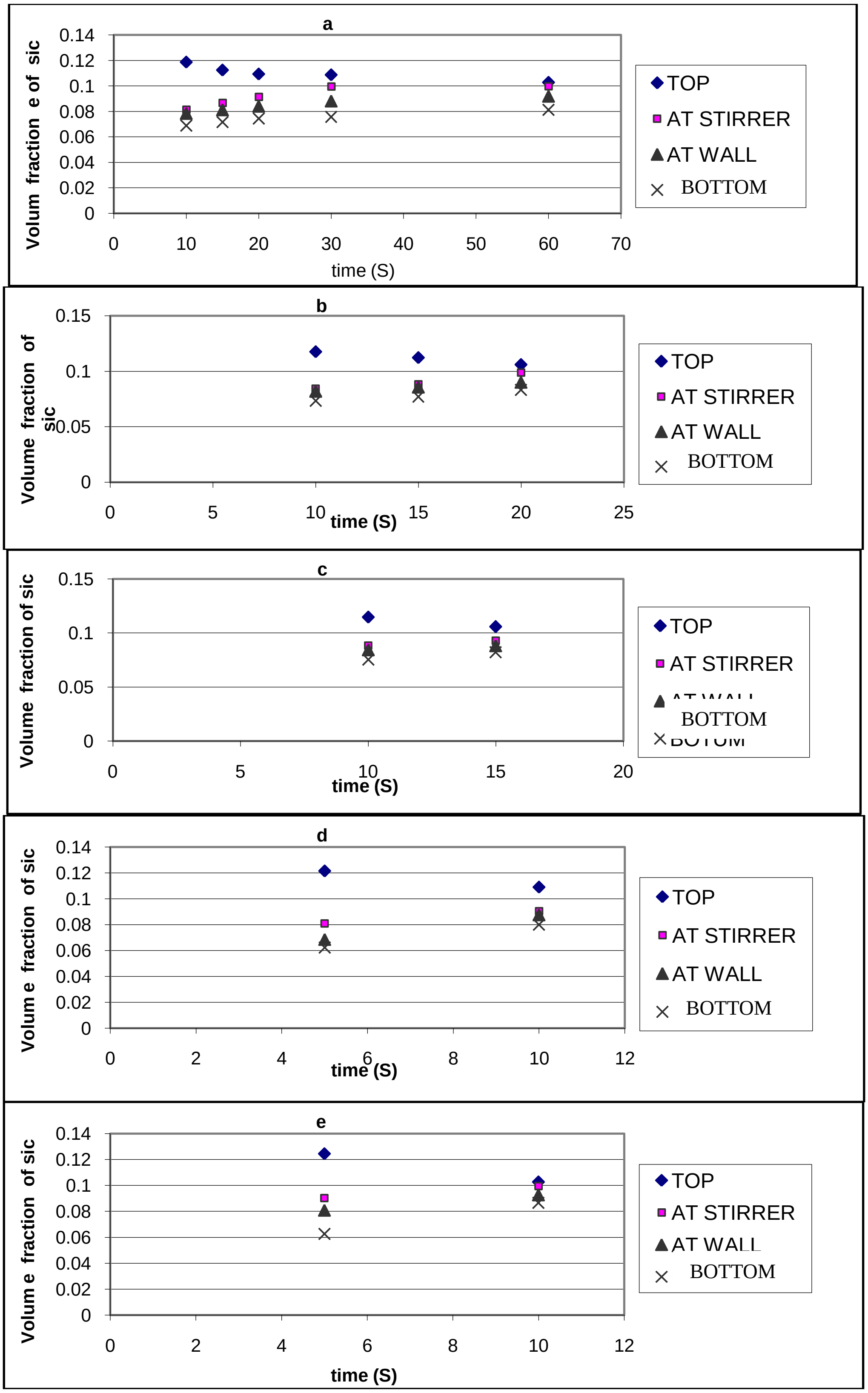


Figure (3-8): Relationship between distribution of SiCp and time at Three-blade stirrer 300 rpm, H=20 , D_o /D = 0.7 and blade angle a) 0 ° b) 30 ° c) 45 ° d) 60 ° e) 90 ° (water experiment)

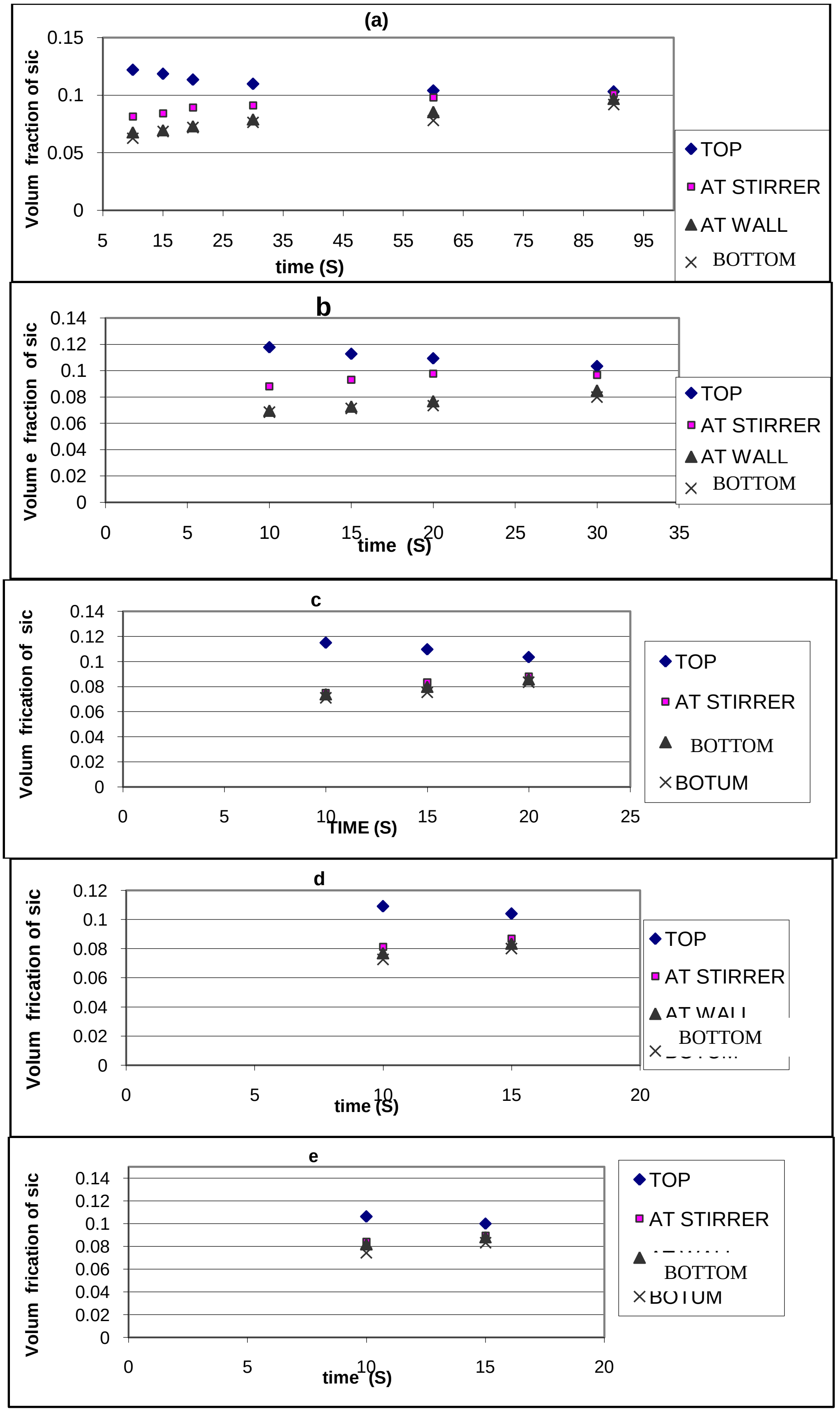


Figure 3.9: Relationship between distribution of SiCp and time at Two-blade stirrer 300 rpm, H=20 , D_o /D = 0.7 and blade angle a) 0 ° b) 30 ° c) 45 ° d) 60 ° e) 90 ° (water experiment)

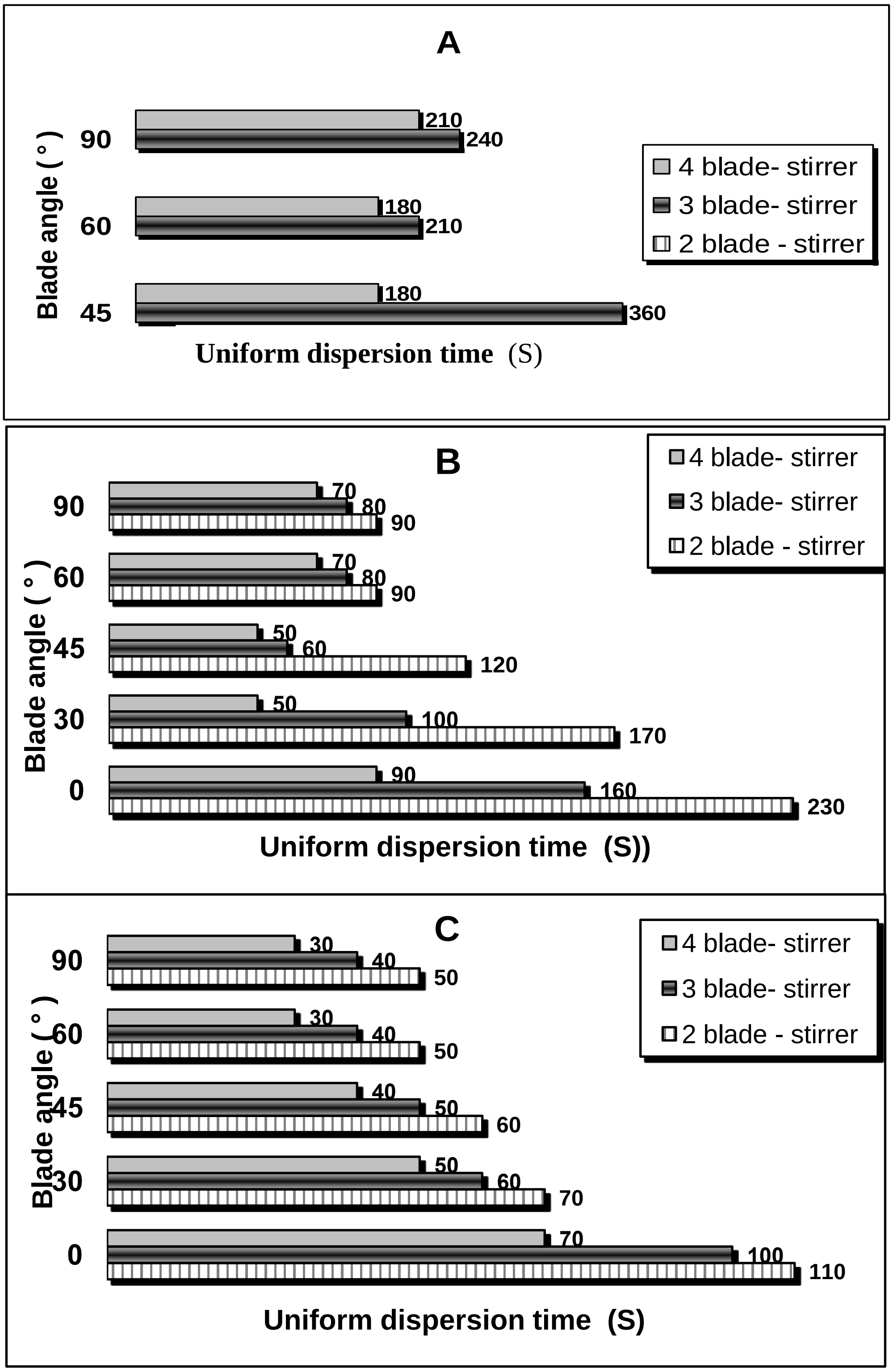
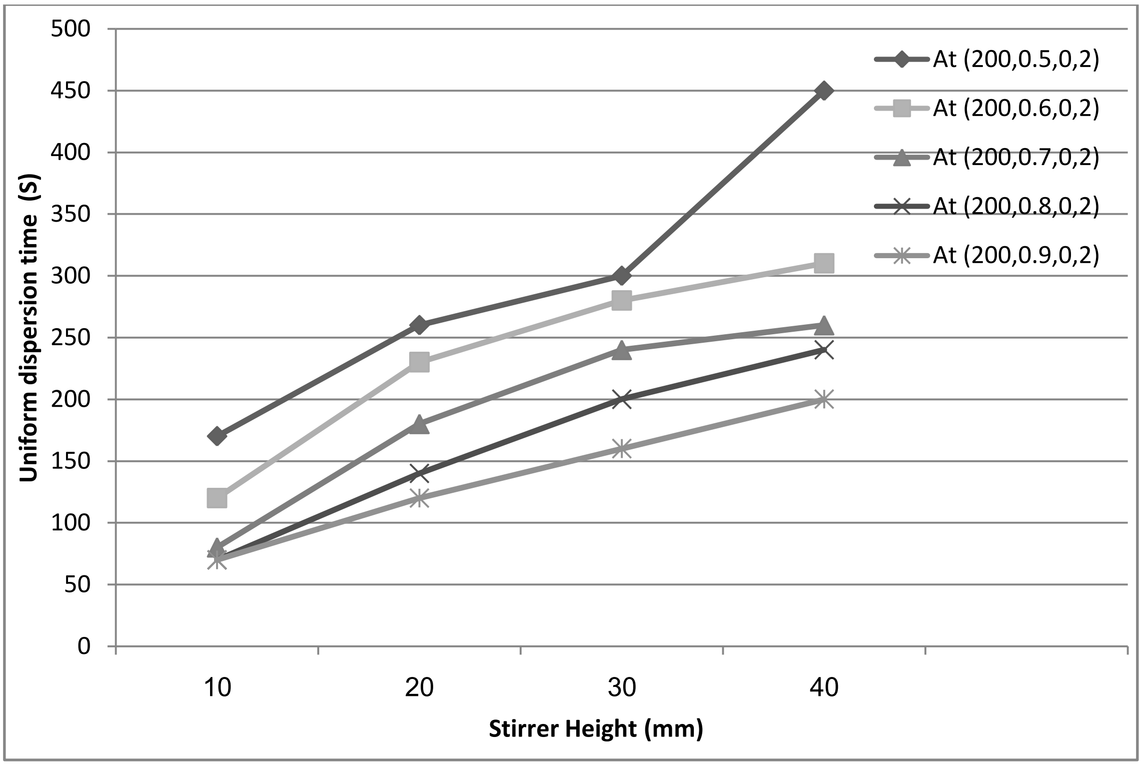


Figure (3-10): Relationship between the different stirrer types and uniform dispersion time at h= 10 mm, D◦/D = 0.5 and stirring speed (rpm) A) 100 B) 200 C) 300 (water experiment)



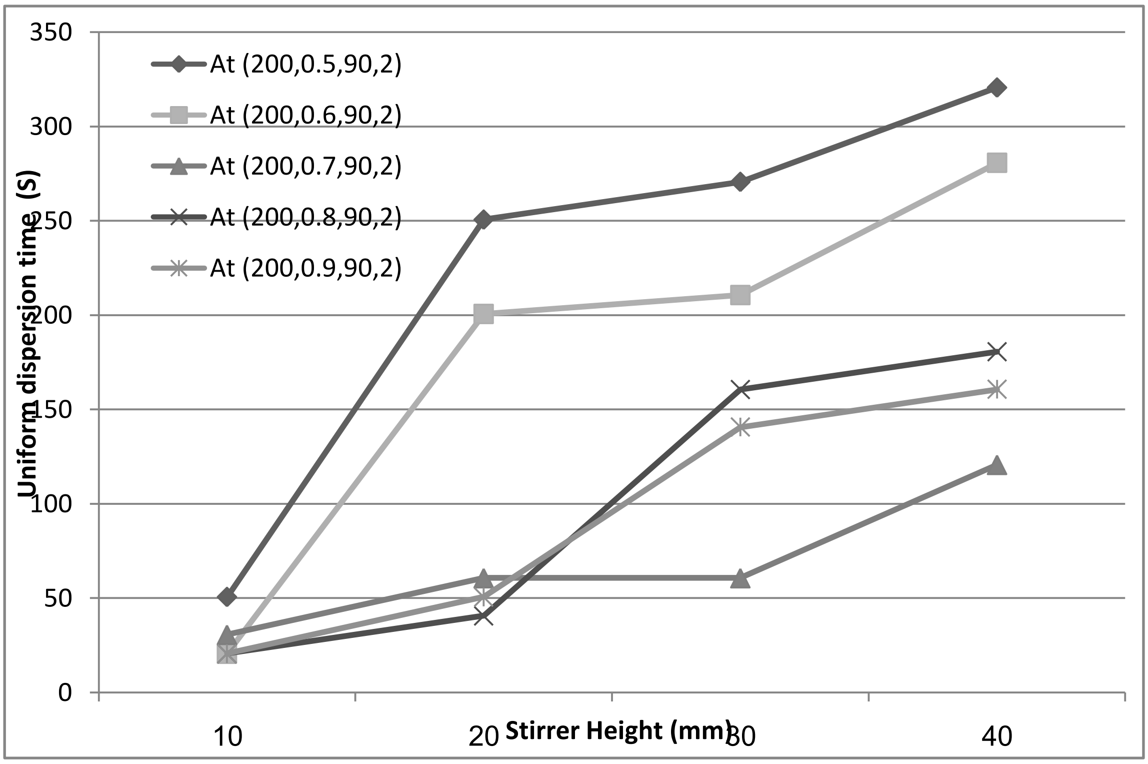


Figure (3-11): Relationship between the stirrer height (mm) and uniform dispersion time at (stirring speed (rpm), D◦/D , blade angle (o), No. Of blade) (water experiment)

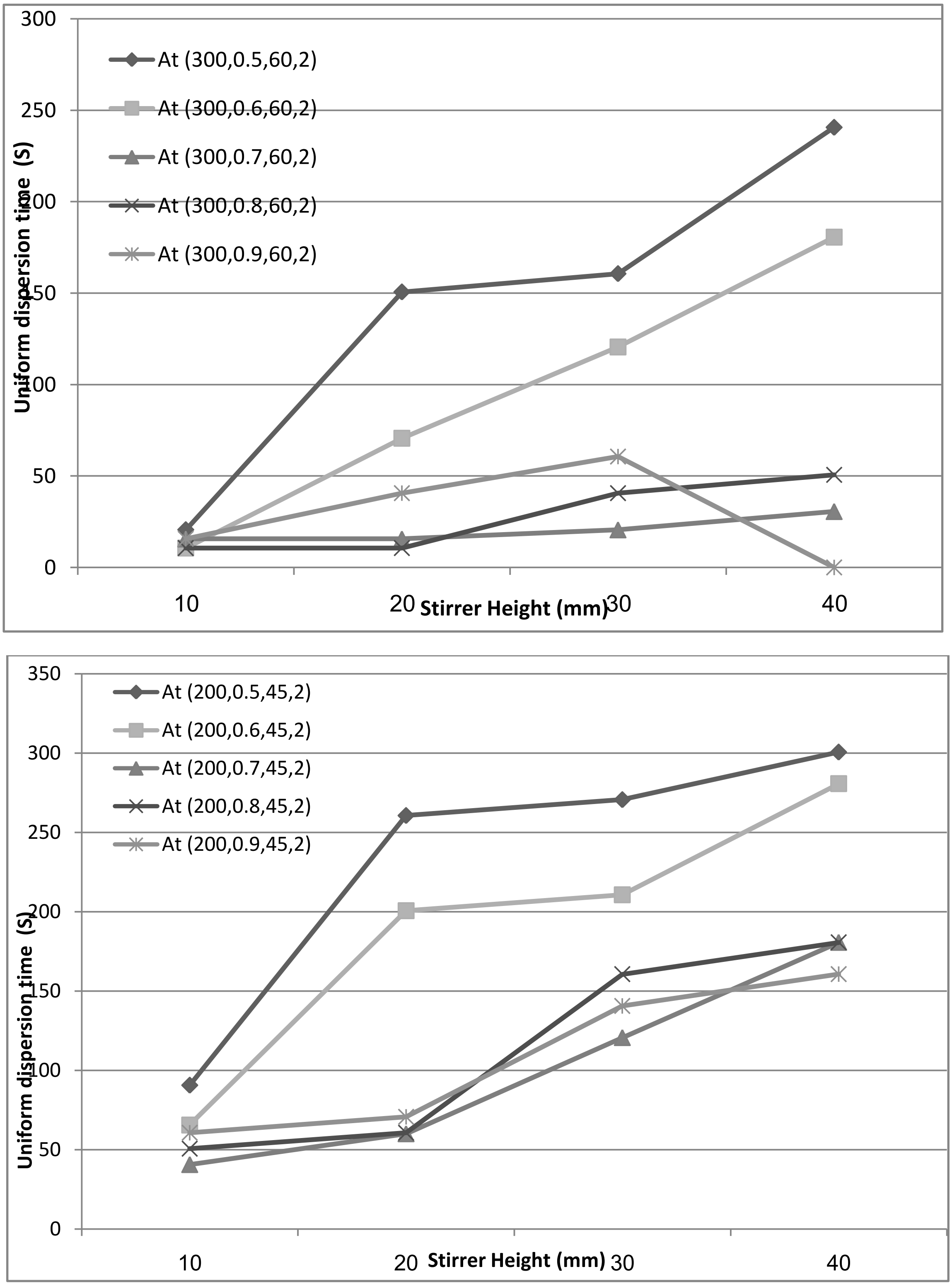
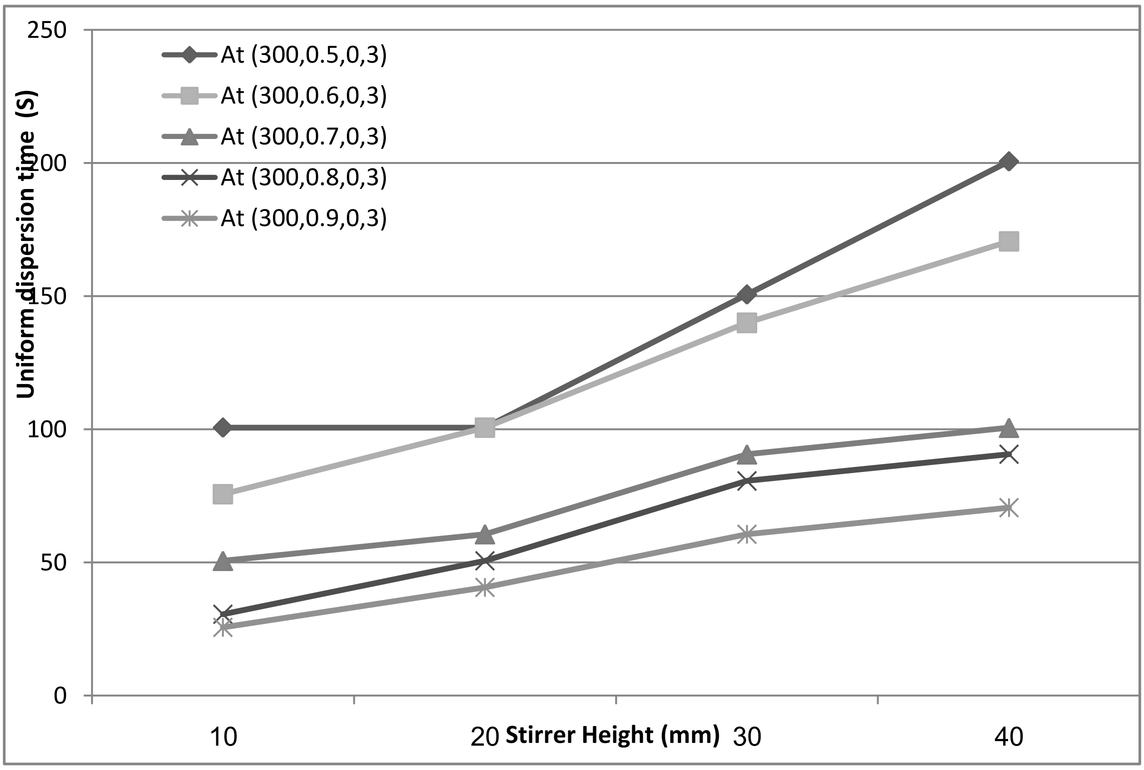


Figure (3-12): Relationship between the stirrer height (mm) and uniform dispersion time at (stirring speed (rpm), D◦/D , blade angle (o), No. Of blade) (water experiment)



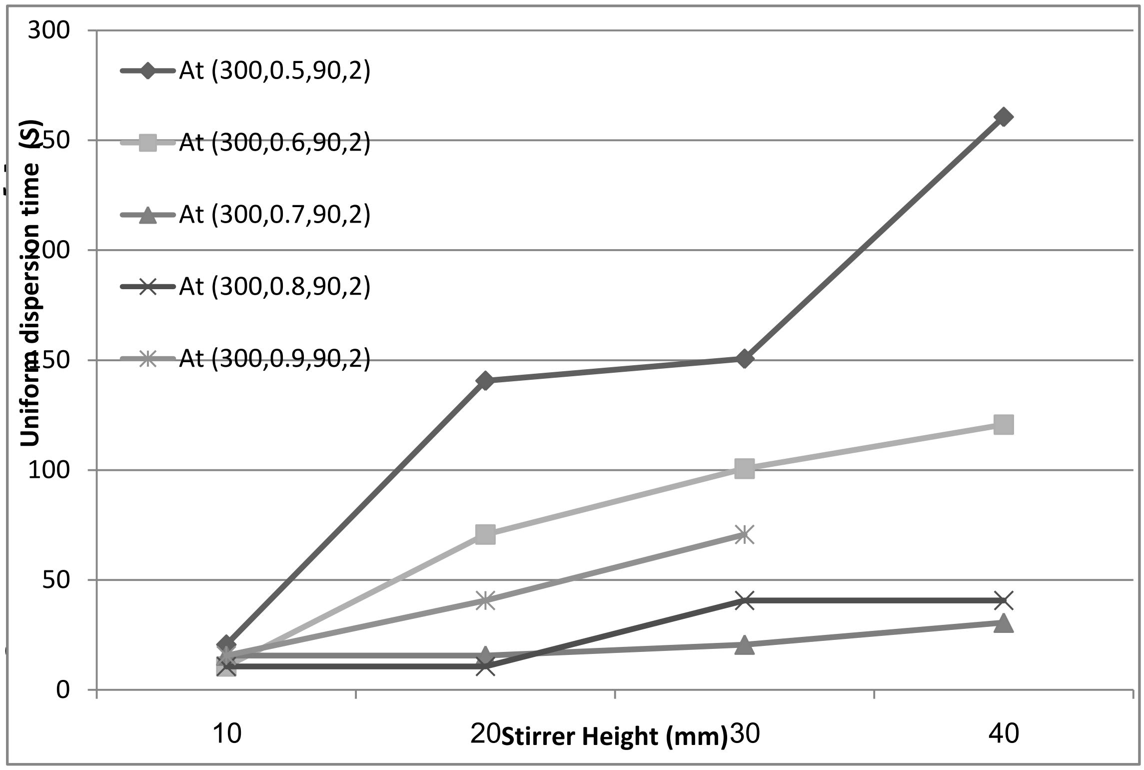
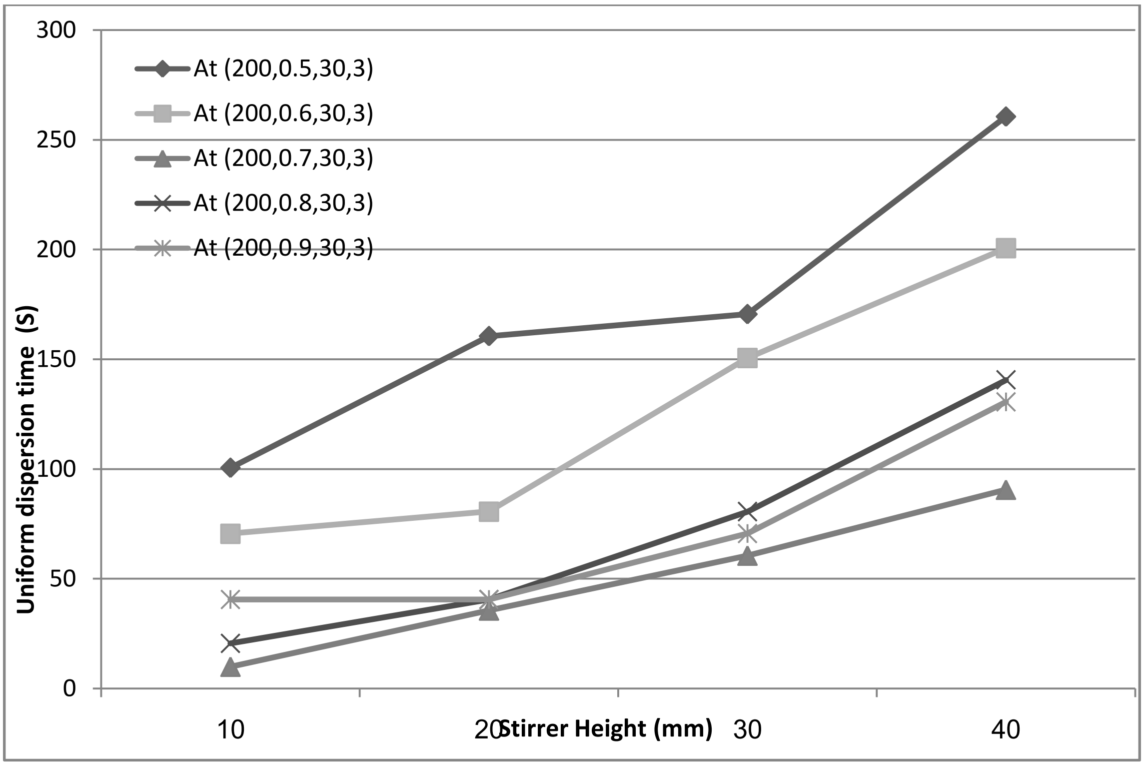


Figure (3-13): Relationship between the stirrer height (mm) and uniform dispersion time at (stirring speed (rpm), D◦/D , blade angle (o),No. Of blade) (water experiment)



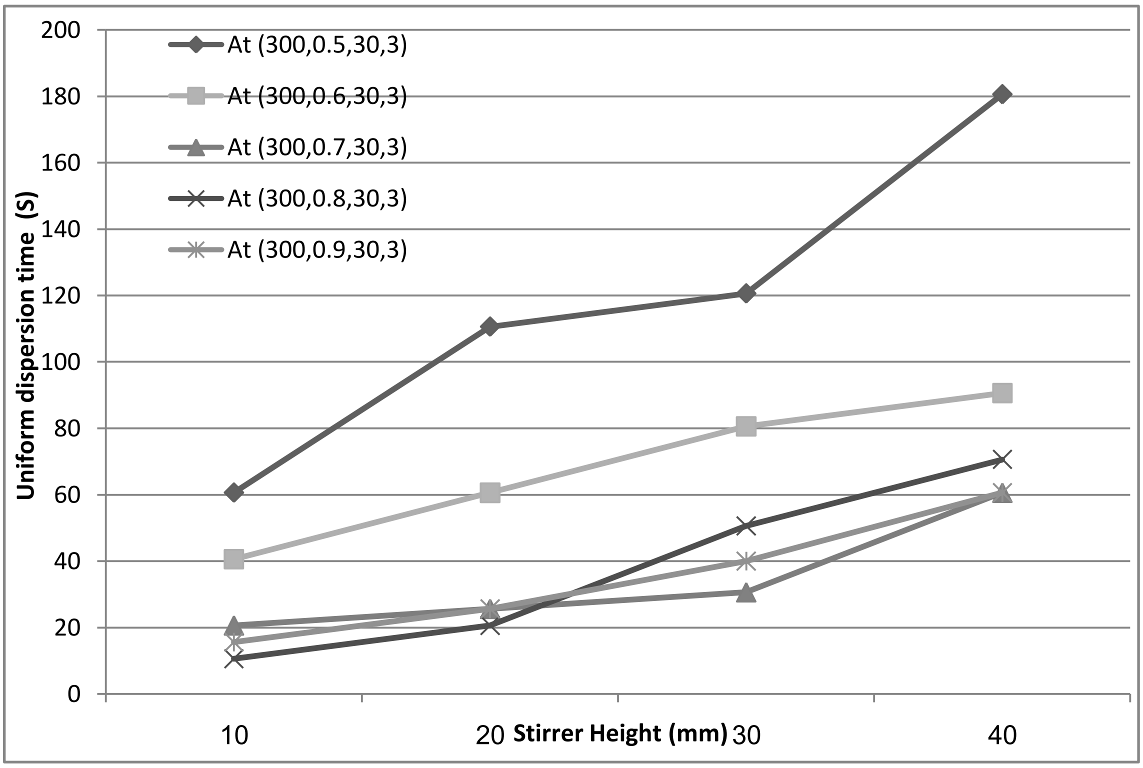
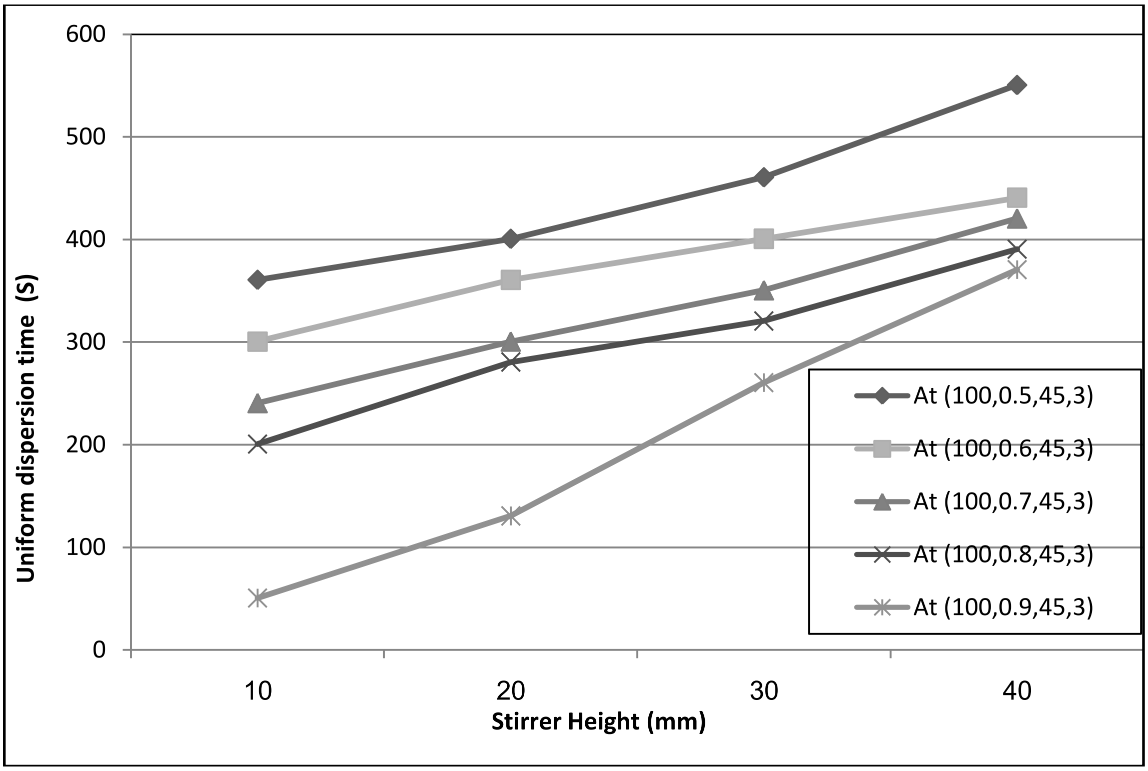


Figure (3-14): Relationship between the stirrer height (mm) and uniform dispersion time at (stirring speed (rpm), D◦/D , blade angle (o), No. Of blade) (water experiment)



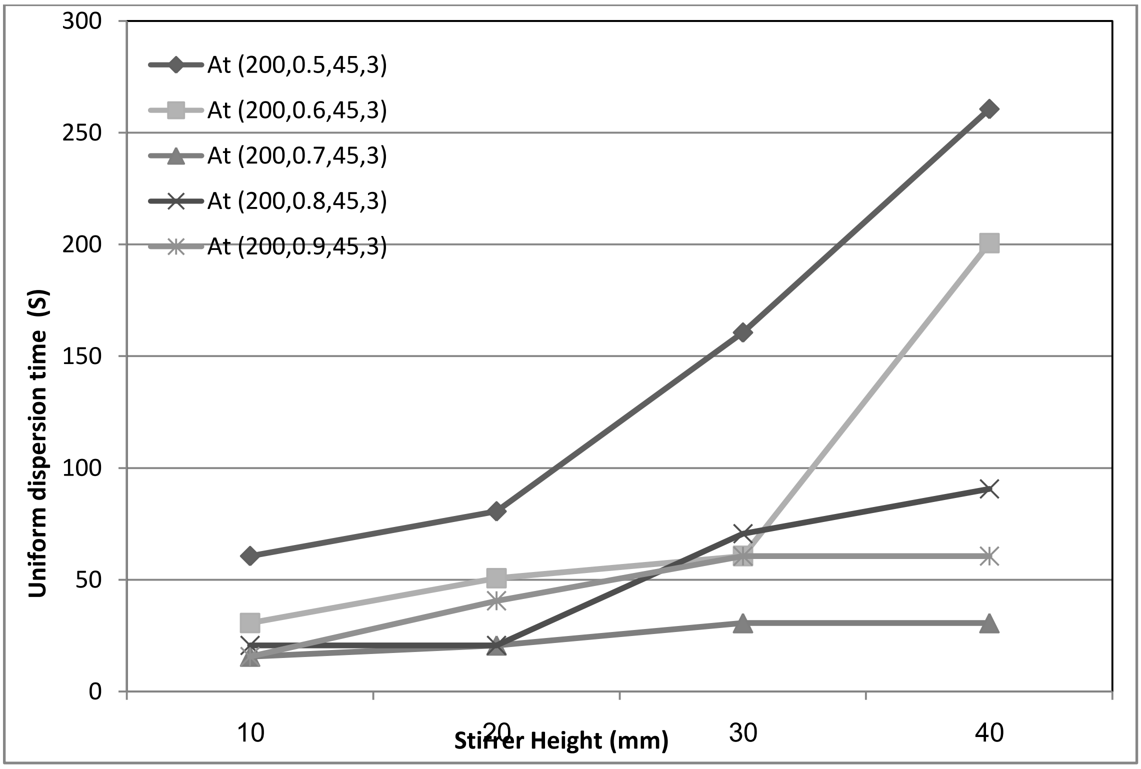
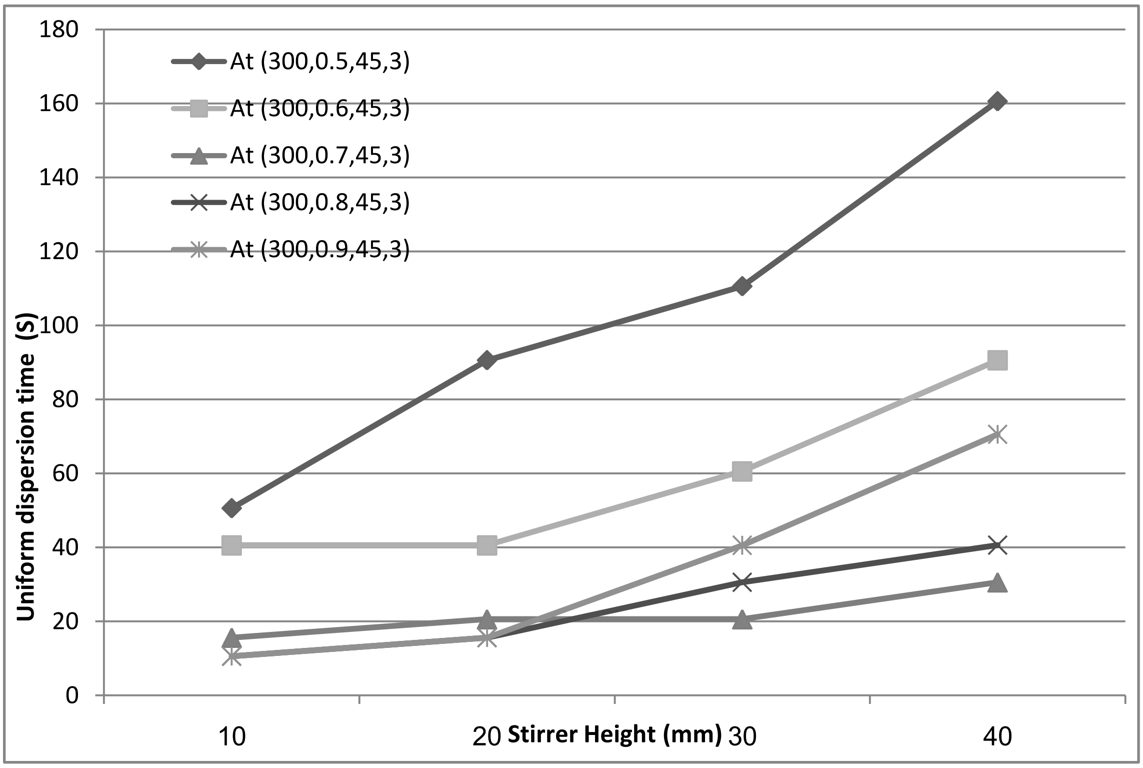


Figure (3-15): Relationship between the stirrer height (mm) and uniform dispersion time at (stirring speed (rpm), D◦/D , blade angle (o), No. Of blade) (Water experiment)



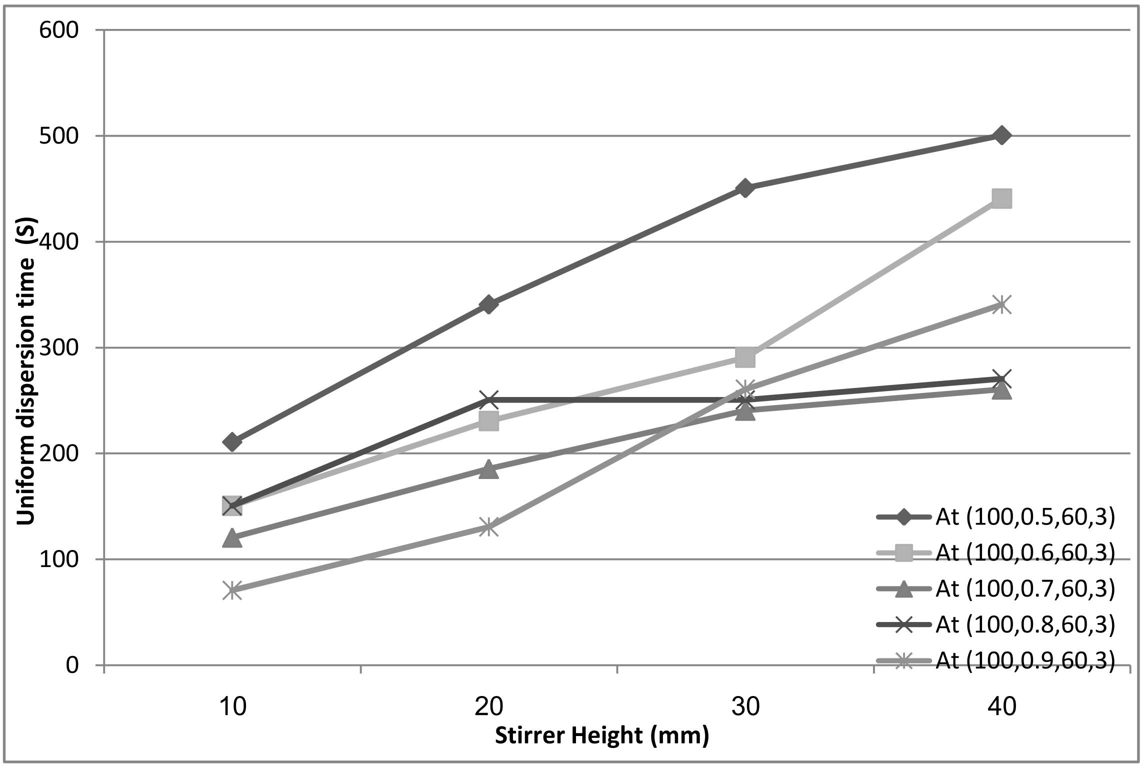
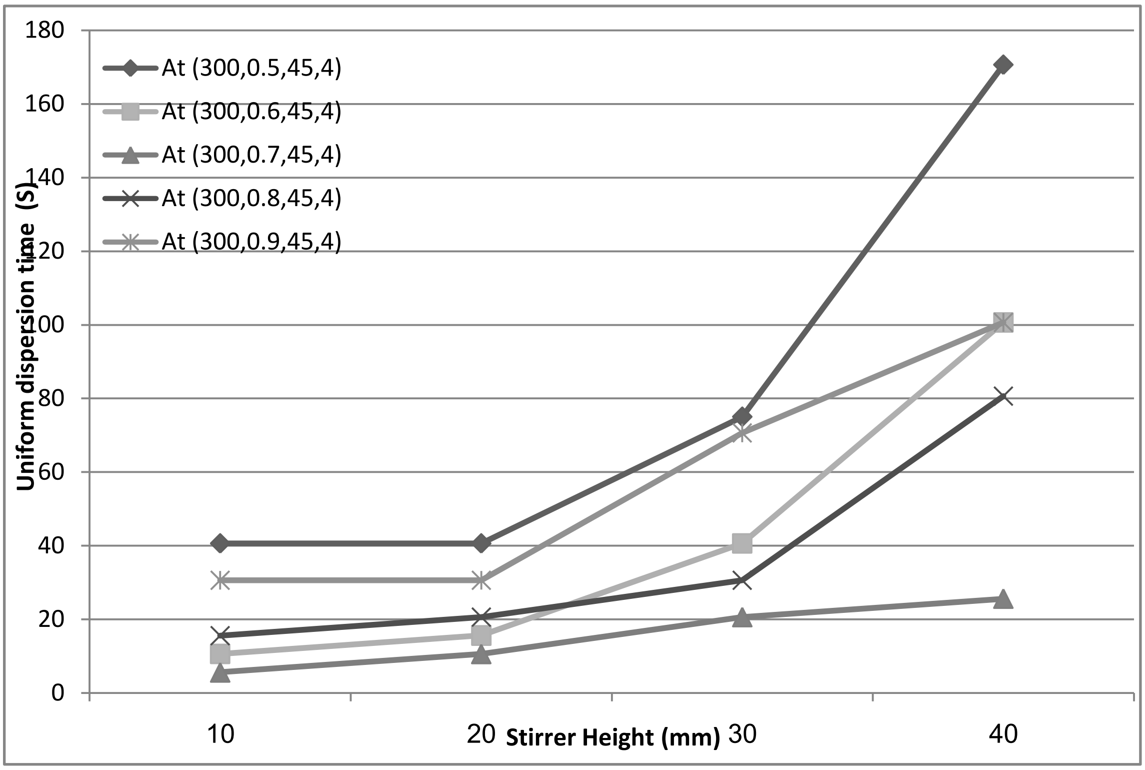


Figure (3-16): Relationship between the stirrer height (mm) and uniform dispersion time at (stirring speed (rpm), D◦/D , blade angle (o),No. Of blade) (water experiment)



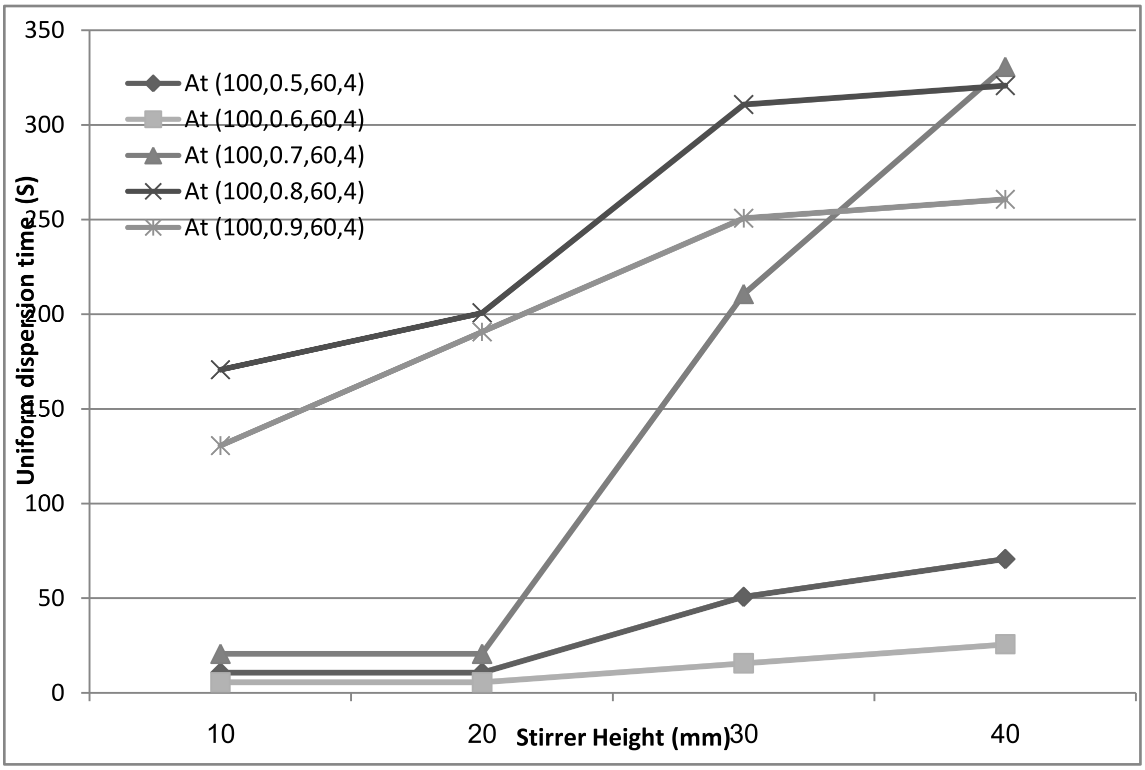


Figure (3-17): Relationship between the stirrer height (mm) and uniform dispersion time at (stirring speed (rpm), D◦/D , blade angle (o), No. Of blade) (water experiment)

B) In glycerol/water solution

Again , the SiC percentages for all combination of conditions are represented in the figures (3- 18- 20) and (Appendix 5). The figures show the effect of stirrer heights, blade angle, blade type, and diameter of blade to beaker diameter, weight and mixing speed on the distribution of the ceramic particles in the fluid during time. The results are summarized in (Appendix 6). The following may be concluded:

1) At 200 rpm no homogenous dispersion occurred for the Water/Glycerol solution at D/D_0 (0.5,0.6, 0.7, 0.8 and 0.9), 2 blades with angles 0^0, 30^0, 45^0,60^0 and 90^0 and h (10, 20, 30 and 40 mm).

2) At 250 and 300 rpm and (three and four) blades with angles (0^0, 30^0, 45^0,60^0 and 90^0) at D/D_0 (0.5,0.6, 0.7, 0.8 and 0.9) and h (10 and 20 mm) there was full particulate dispersion but at different times.

3) At 250 and 300 rpm and (three and four) blades with angles (0^0, 30^0, 45^0,60^0 and 90^0) at D/D_0 (0.5,0.6, 0.7, 0.8 and 0.9) and h (30 and 40) no homogenous dispersion occurred.

Because Water/Glycerol solution represents thixotropic semisolid which can be approximated as a Newtonian fluid for modeling purposes meaning that the viscosity will keep constant so the SiCp need long time to wet at low shear rate as shown in (figure 3.18).If the time of the shear increases the fluid will be filled with air bubble, but at the same time (figure 3.20) the higher shear rate helps in wetting the SiCp. Since the height of the stirrer has an important effect on the distribution time of the SiCp no dispersion occurred when H increases (figure 3.22). The previous observations are consistent with that noticed by S. Naher et al. [78]. They suggest the increasing of viscosity has a tremendous effect on the SiC dispersion and settling time. Figures (3-21) and (Appendix7) illustrate the relationships between the different stirrer types and uniform dispersion time at different heights (H), $D_\circ/D$, and stirring speeds.

The height of the stirrer is seen to have an important effect on the distribution time of the SiC. This is particularly true for the higher viscosity glycerol/water solutions. This may be a result of dispersion time dependence on fluid viscosity [86]. A slight increase in viscosity however allows for much longer time before processing. Particulate dispersion time is in general longer than dispersion time in water model. It is clear from figures (3-22) to (3-45) that the particulate dispersion time increases as the height of the stirrer increases. For example the time to reach the homogenous distribution increases from 2440 s to 2730 s when the height of the stirrer increases from 10 mm to 20 mm. On the other hand the time to reach the homogenous distribution decreases from 2600 s to 1800 s as the stirring speed increases from 250 to 300 rpm. This may be a result of the vortex in the water/glycerol condition during the high stirring speed. Higher blade angles result in reduced particulate dispersion time. The results in figures (3-31) and (3-45) show that the particulate dispersion time decreases from 2000 s to 1900 s as the blade angles increases from 0^0 to 90^0. The particles dispersion time are affected by the vortex structures, For the conditions studied, the vortex emergence has the maximum effect on particle dispersion, due to the influence of the vortex size effect on the particle dynamics. The vortex size increases as the blade angle increases so the particle dynamics become progressively stronger [85-87].

The whole group of results obtained through this study are summarised in figures (3-31) to (3-45). For the figures it is generally seen that the particles dispersion time decreases at the blade numbers increase from 2 to 4 blades. For example the time to reach the homogeneous distribution decreases from 2000s to 1270s when the numbers of blades increase from 2 to 4 blades.

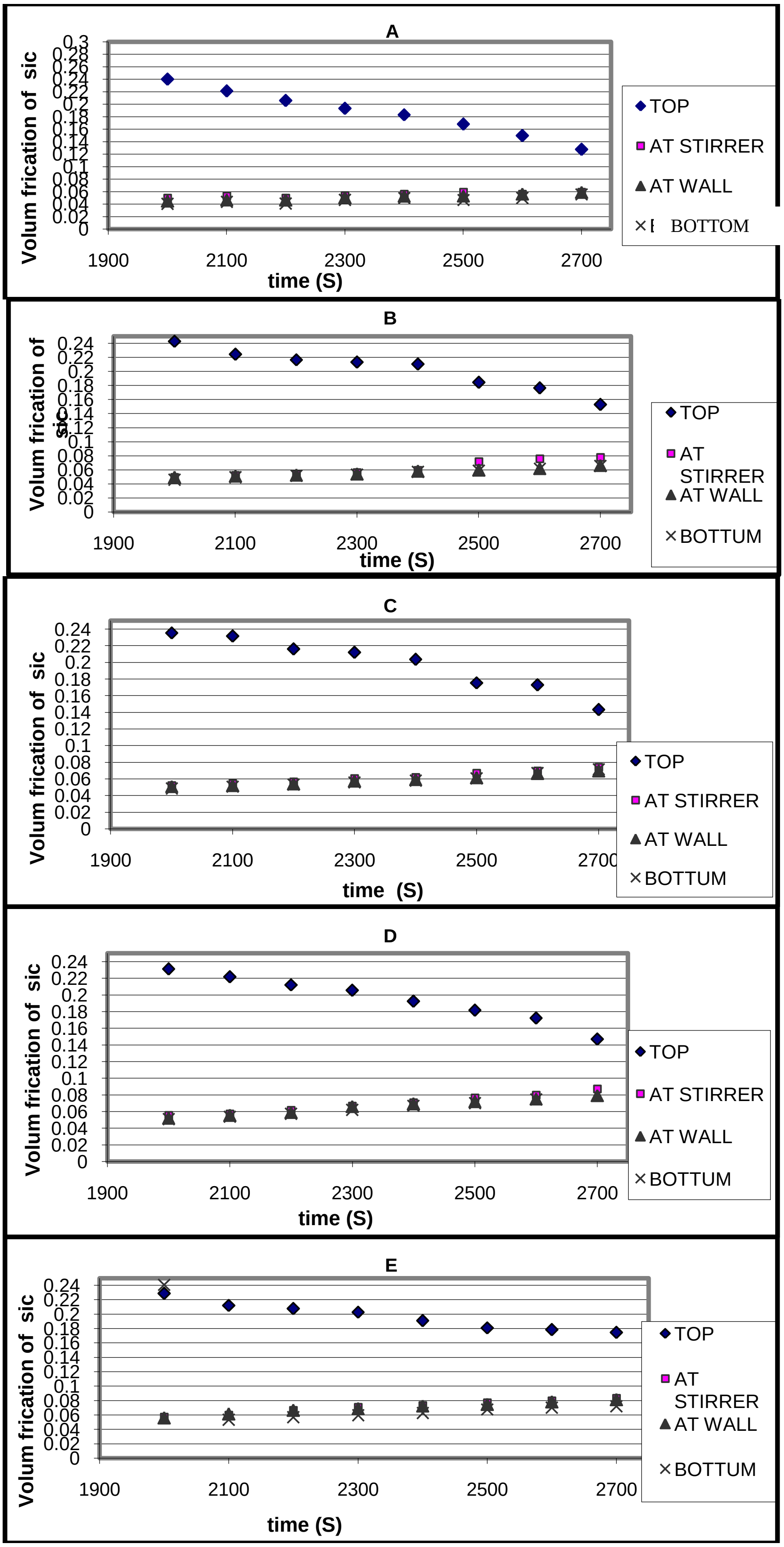


Figure (3-18): Relation ship between distribution SiCp and Time At H = 20 mm, 200 rpm , 2 blade-stirrer, D/D°=0.9 and blade angle A) 0° B) 30° C)45° D)60° E)90° glycerol/water experiments

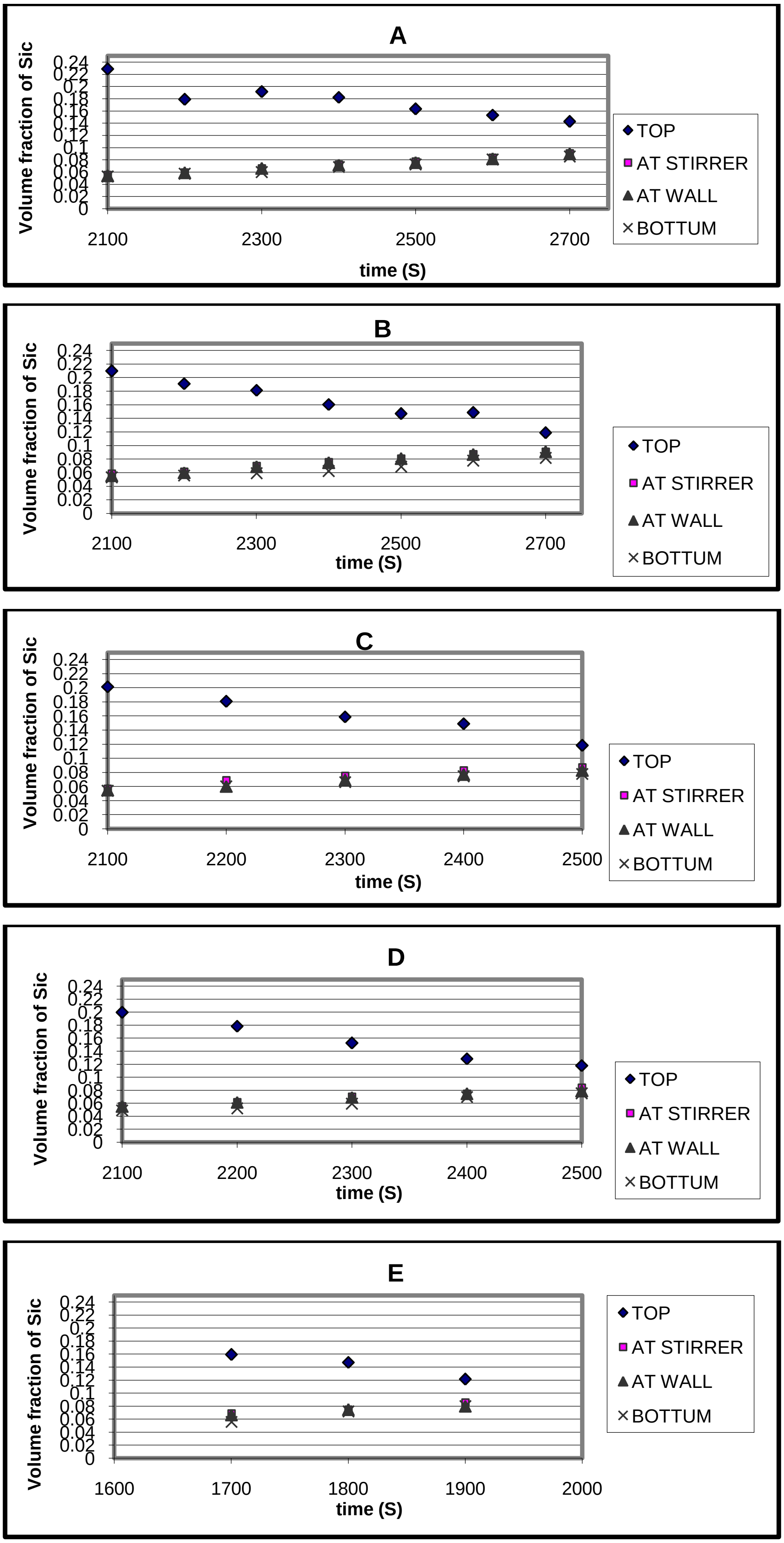


Figure 3-19: Relationship between distribution of SiCp and time at H = 20 mm ,250 rpm , 2 blade-stirrer , D/D°= 0.9and blade angle A) 0° B) 30° C)45° D)60° E)90° glycerol/water experiments

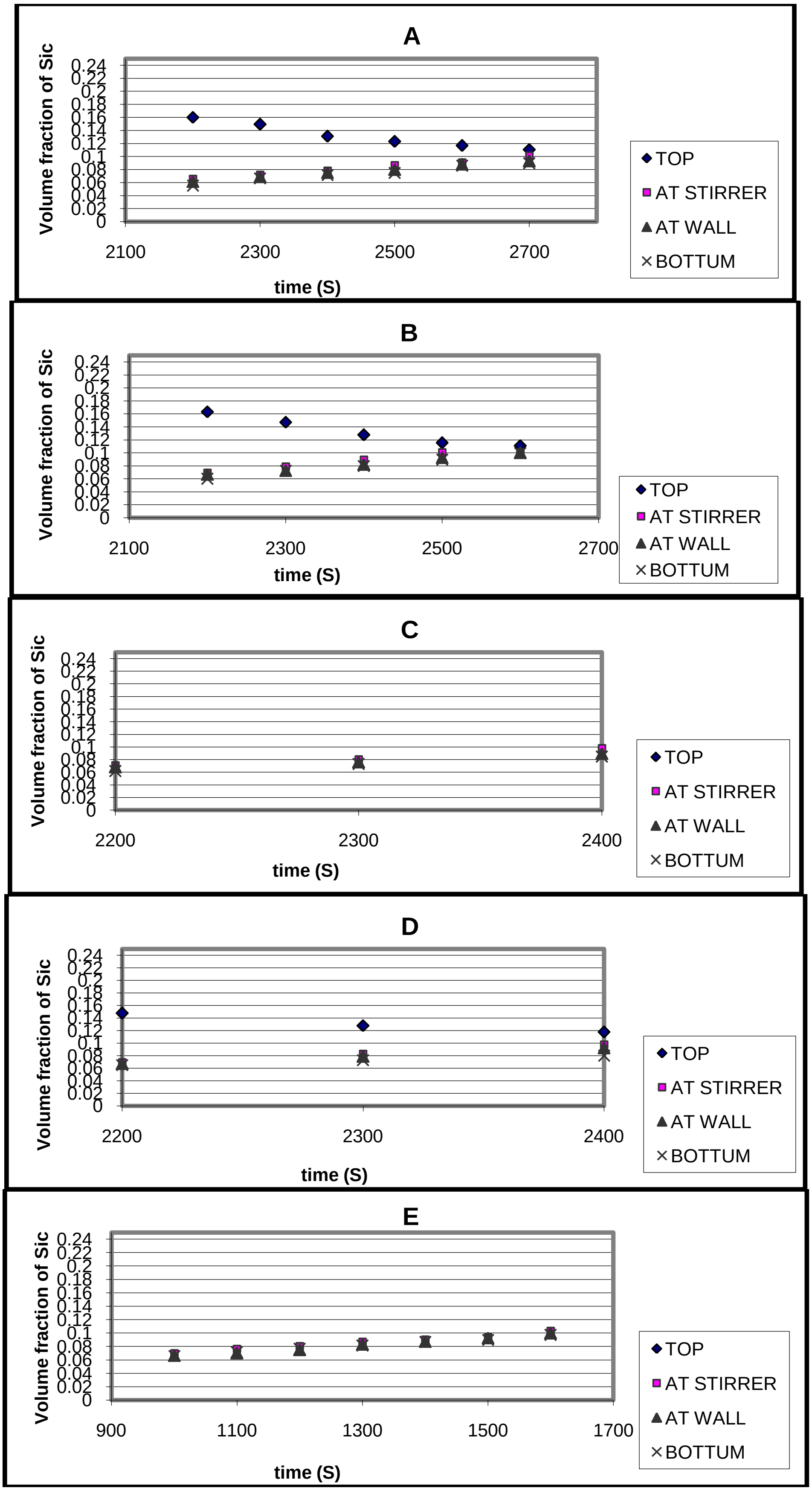


Figure 3.20: Relationship between distribution of SiCp and time At H = 30 mm, 300 rpm , 3 blade-stirrer, D/D° = 0.7 and blade angle A) 0° B) 30° C)45° D)60° E)90° glycerol/water experiments

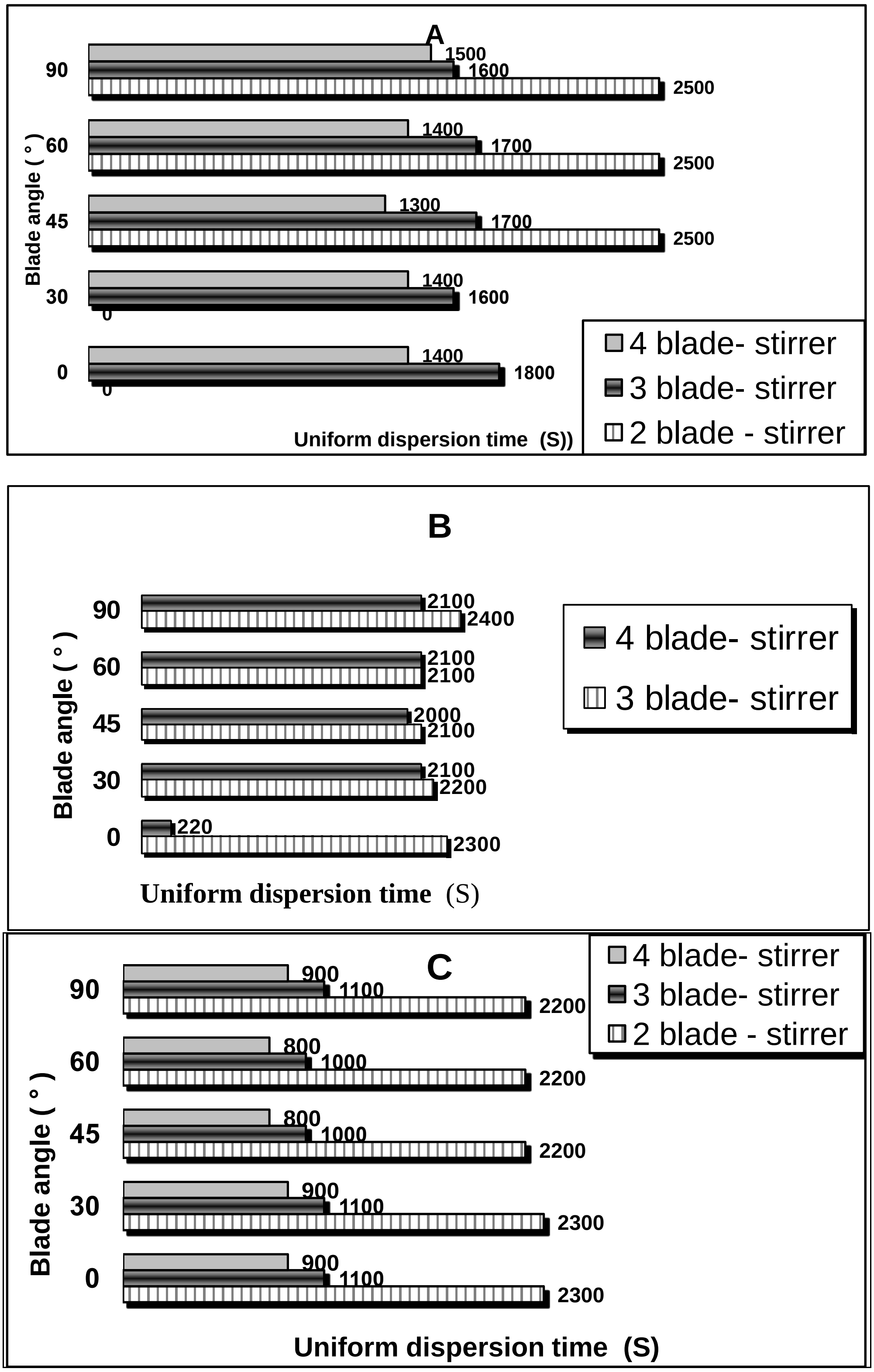


Figure (3-21): Relationship between the different stirrer types and uniform dispersion time at H= 20 mm, D◦/D = 0.9 and stirring speed (rpm) A) 200 B) 250 C) 300 glycerol/water experiments

The pervious results can be summarized as:

1- Homogeneous uniform dispersion time of particles in the liquid state is achieved only if:

   a) The stirring speeds >100 rpm.

   b) The blades numbers > 2 blades.

   c) The blades angles > 30^0.

   d) The height of stirrer from the bottom < = 20 mm.

   - The diameter ratio between the crucible and stirrer < 0.9.

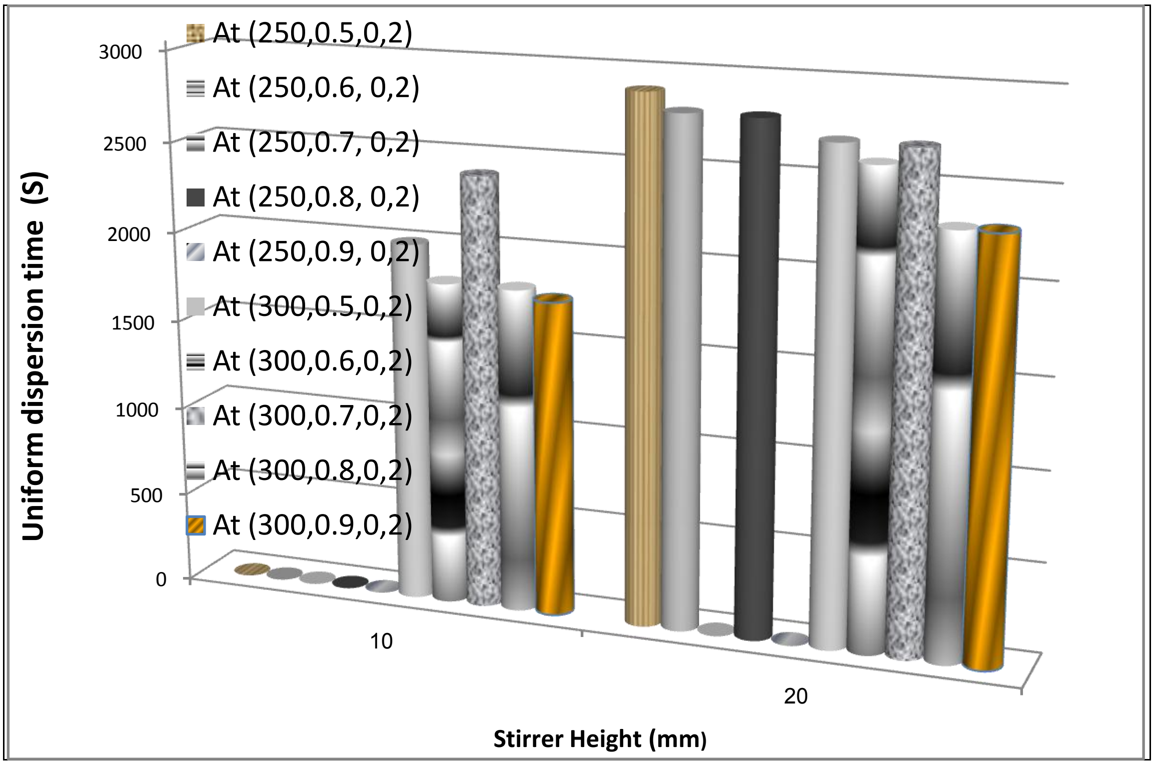
2- Homogeneous uniform dispersion time of particles in the semisolid state is achieved only if:

   a) The stirring speeds > 200 rpm.

   b) The blades numbers >2 blades.

   c) The blades angles > 30^0.

   d) The diameter ratio between the crucible and stirrer < 0.9.



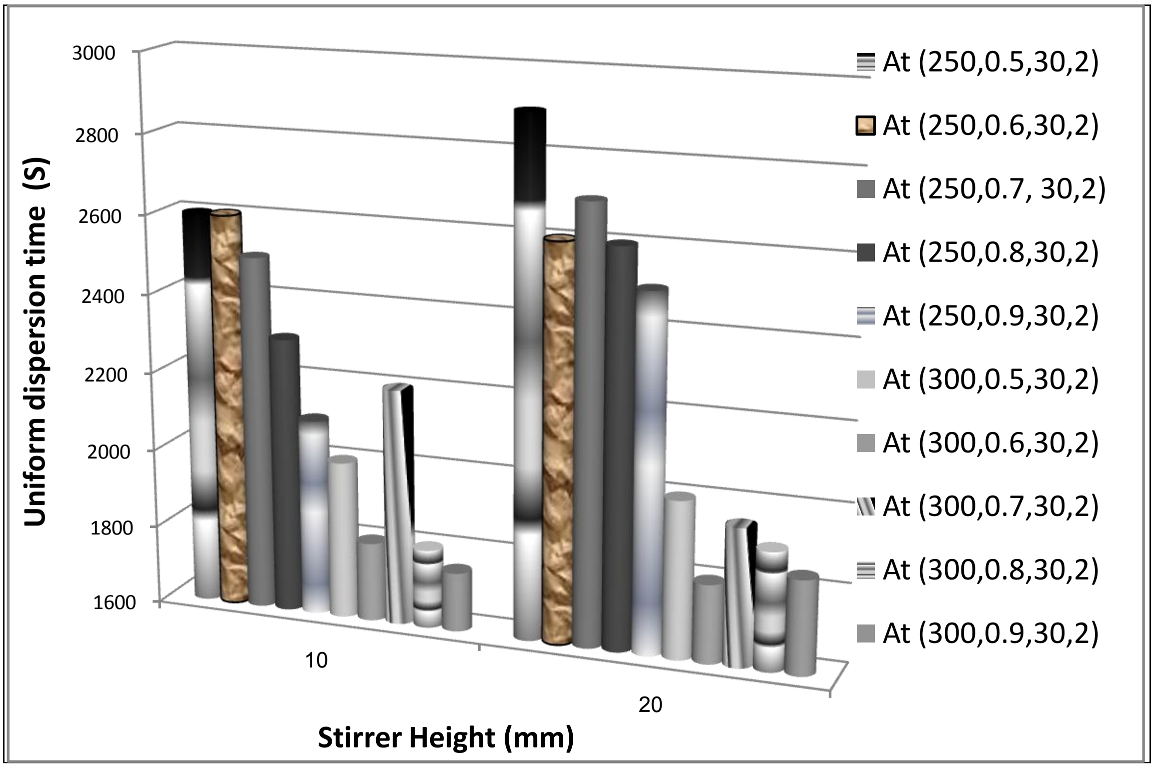
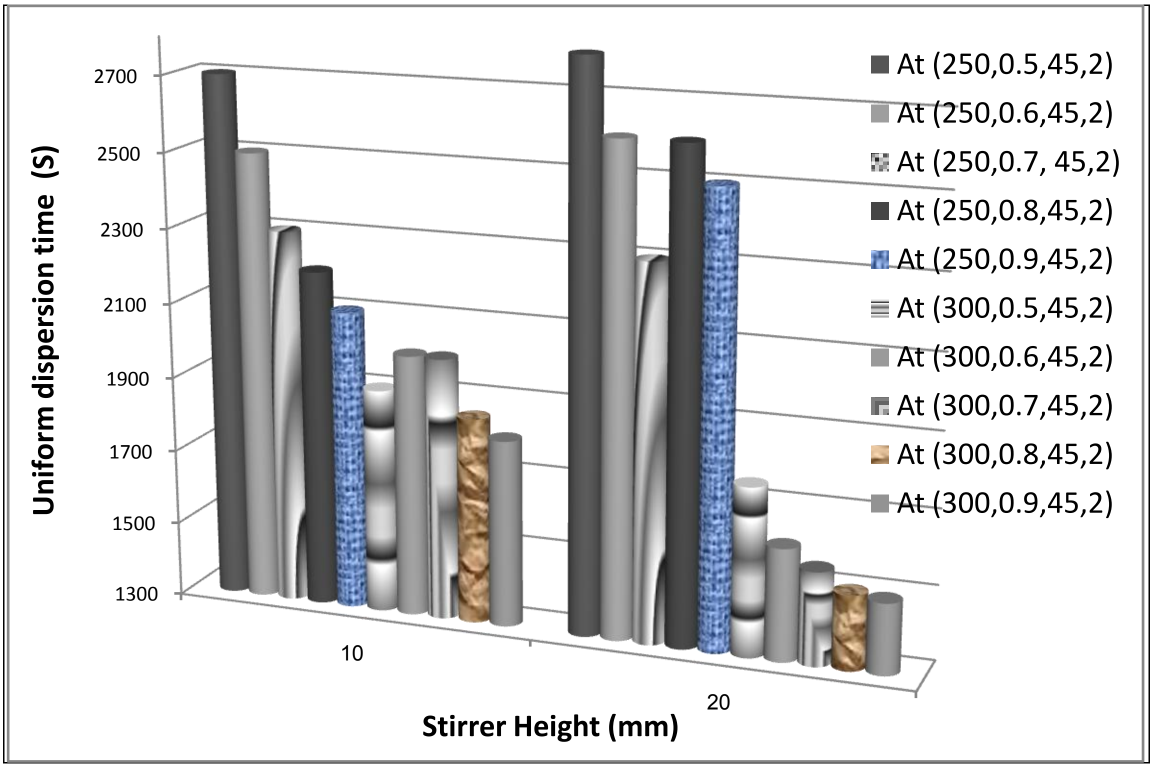


Figure (3-21): Relationship between the stirrer height (mm) and uniform dispersion time at (stirring speed (rpm), D◦/D , blade angle (o), No. Of blade)



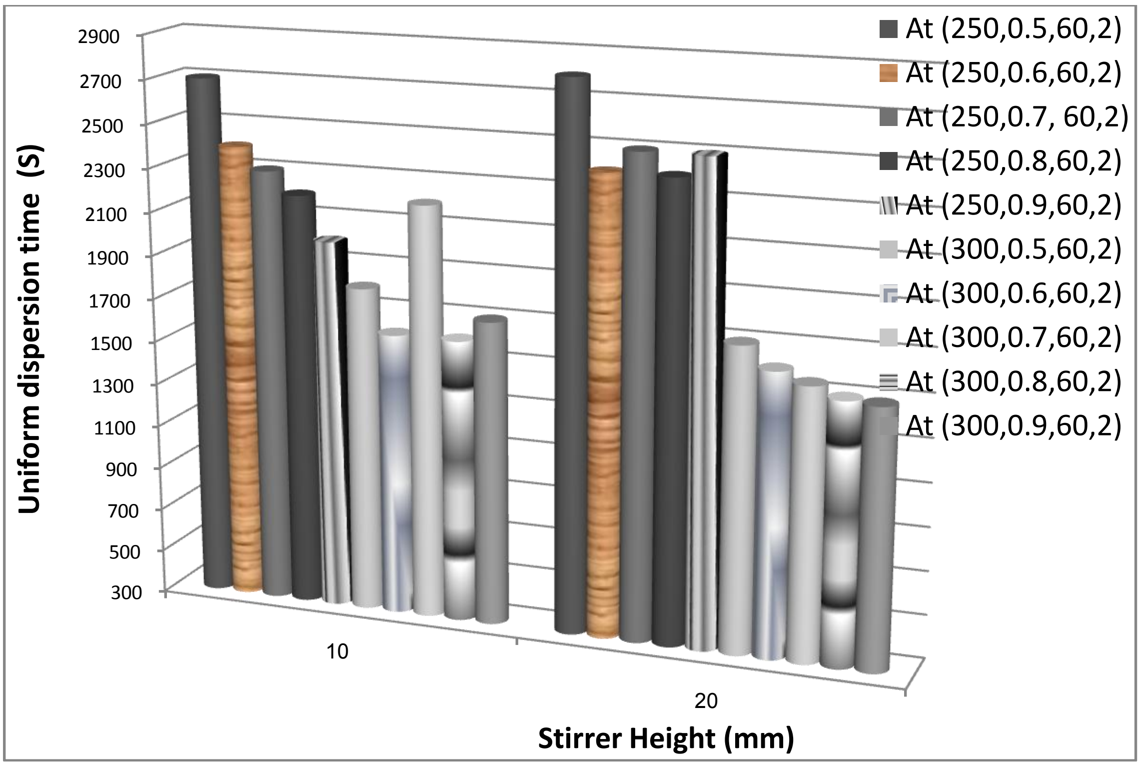
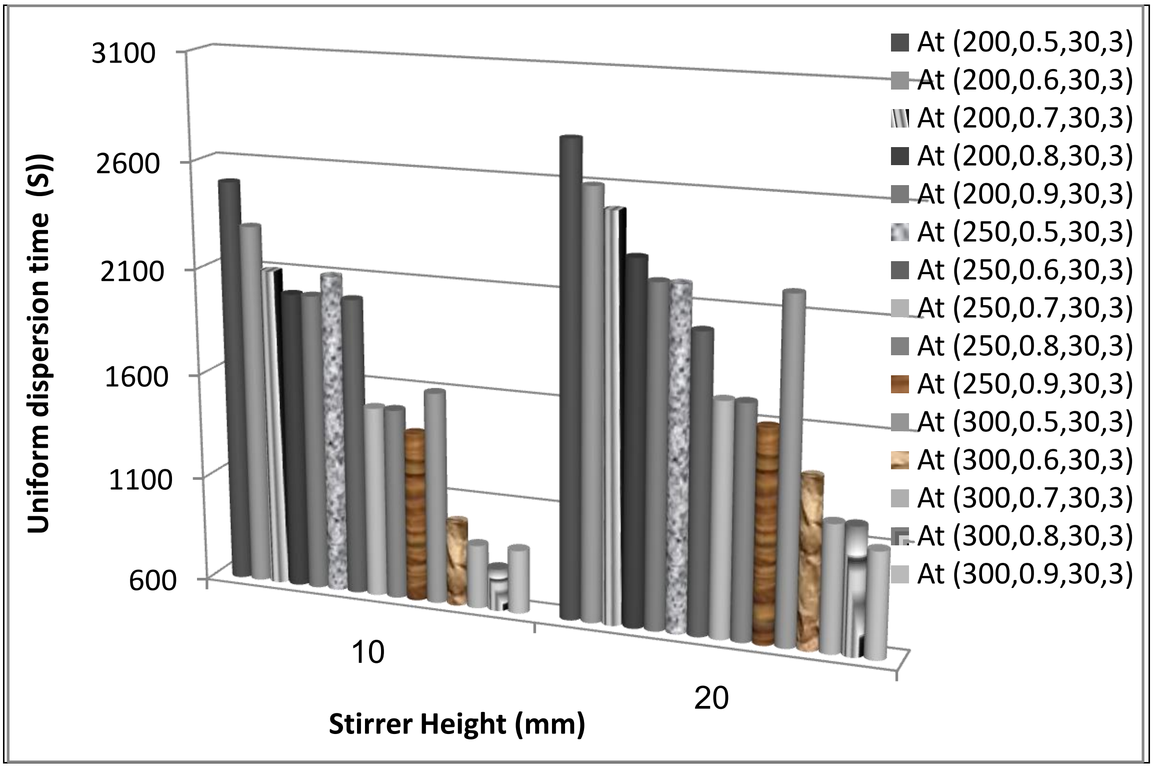


Figure (3-22): Relationship between the stirrer height (mm) and uniform dispersion time at (stirring speed (rpm), D◦/D , blade angle (o), No. Of blade)



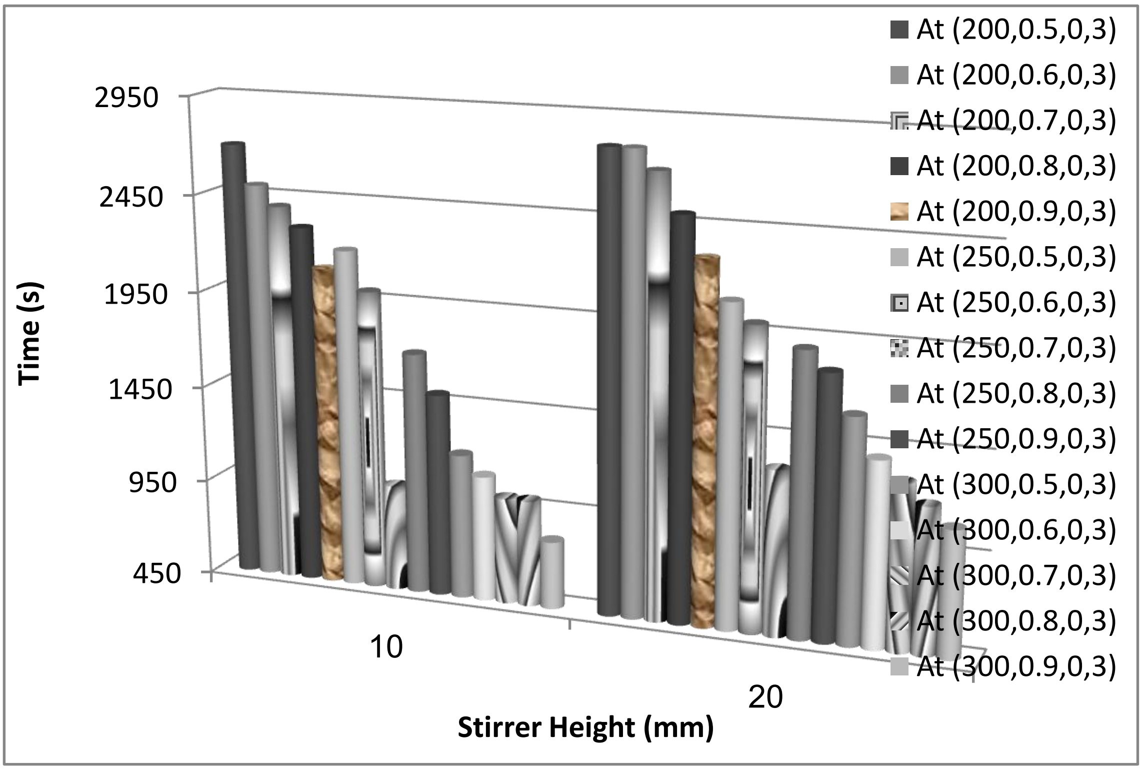
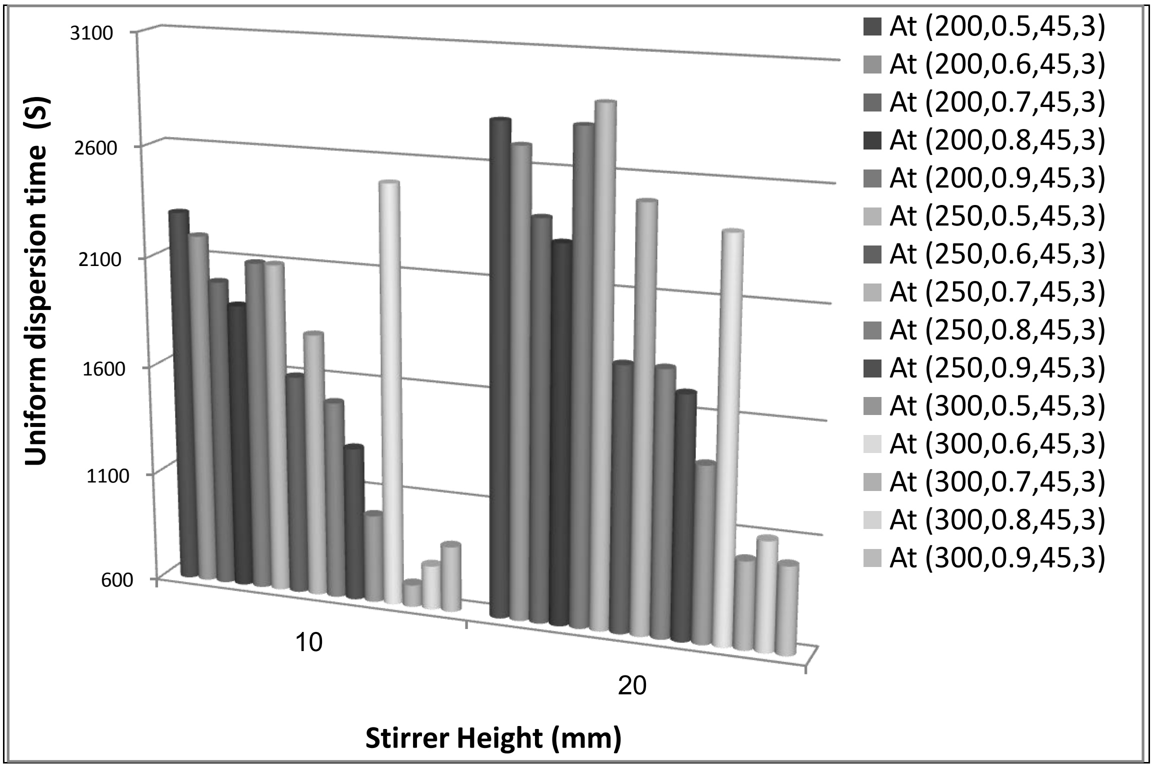


Figure (3-23): Relationship between the stirrer height (mm) and uniform dispersion time at (stirring speed (rpm), D◦/D , blade angle (o), No. Of blade)



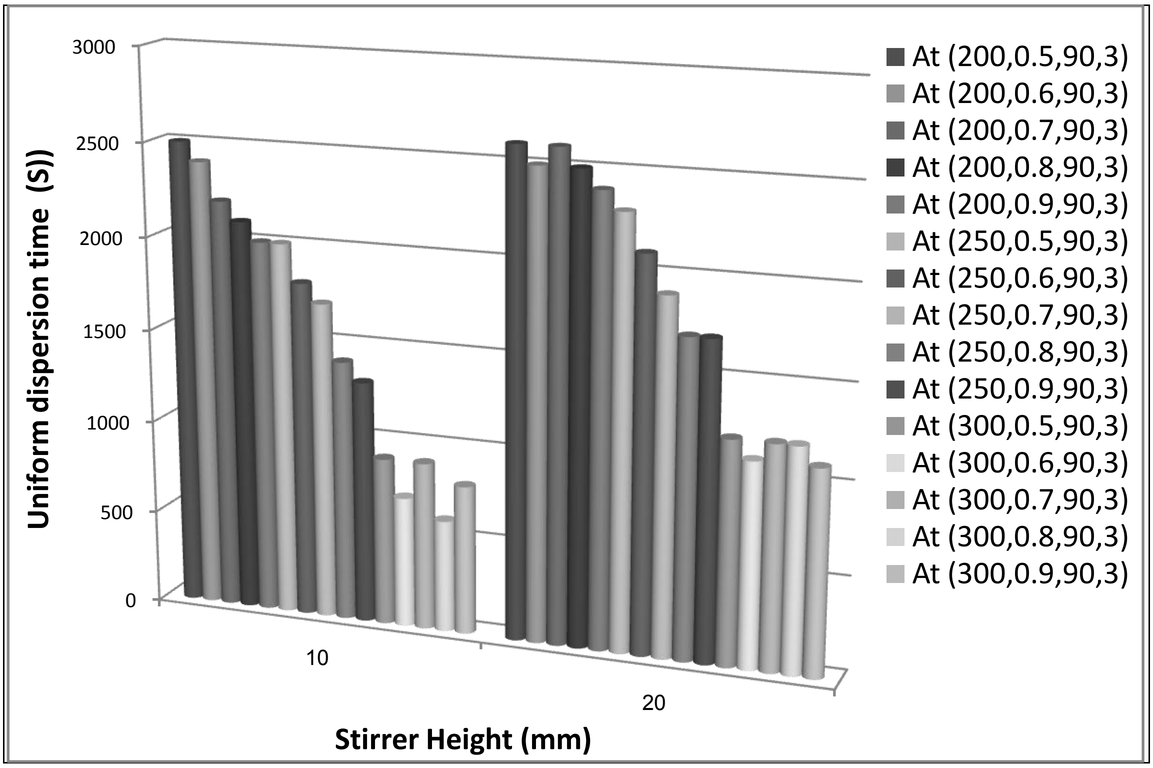


Figure (3-24): Relationship between the stirrer height (mm) and uniform dispersion time at (stirring speed (rpm), D◦/D , blade angle (o), No. Of blade)

3.2: Verification of Experimental Model

3.2.1: Differential Scanning Calorimetry Experiment Results

Figure (3-45) shows the DSC curve for the A356 alloy. The figure shows that there are two main peaks these peaks represent the transformation of phases. First peak illustrates the process of melting of eutectic phase, the second phase illustrates the melting process of the alpha phase. Eutectic phase starts at 557.2 ^{0}C and finishes at 600 ^{0}C and alpha phase starts at 600 ^{0}C and finishes at 612.8 ^{0}C. Corresponding to the solidus and liquidus temperatures the mushy zone temperature range for the A356 is about 55.6 ^{0}C .Stirring process was carried out at 605 ^{0}C (when the liquid fraction percent is 70%). Figure (3-26) illustrates the relationship between the liquid fraction percentage and temperature.

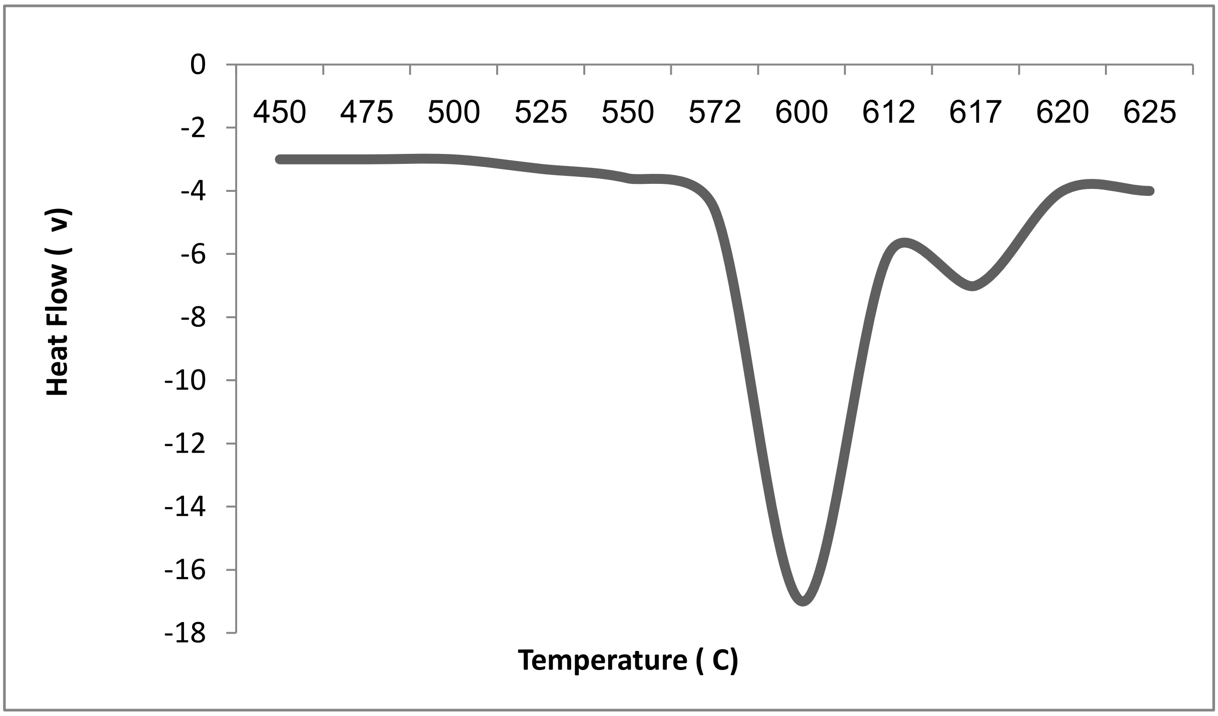


Figure (3-25): The DSC curve of the A356 alloy