Highest solar collector temperatures with different tilts and azimuths

1 Description of solar collectors

The maximum temperatures in the period between May 1 and September 30 achieved under Danish weather conditions in three different solar collectors from Sunda are determined by theoretical calculations. The collectors are SEIDO 1-16, SEIDO 5-16 and SEIDO 10-20. The characteristics of the three solar collectors are described in the following.

1.1 SEIDO 1-16

The aperture area of SEIDO 1-16 is 2.949 m^2 and the efficiency equation is: [1]

$$\eta = 0.694 - 2.118T_m^* - 0.004G{T_m^*}^2 \qquad (1)$$

The efficiency curve for a solar irradiance of 800W/m^2 is shown in fig.1.

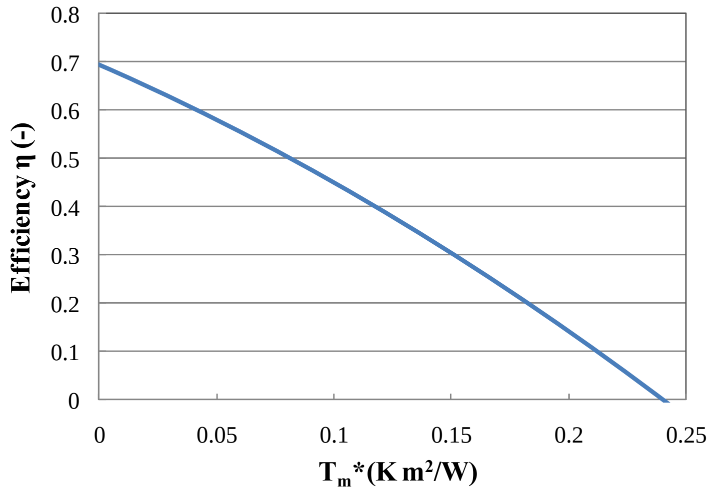

Fig.1 Efficiency curve for SEIDO 1-16

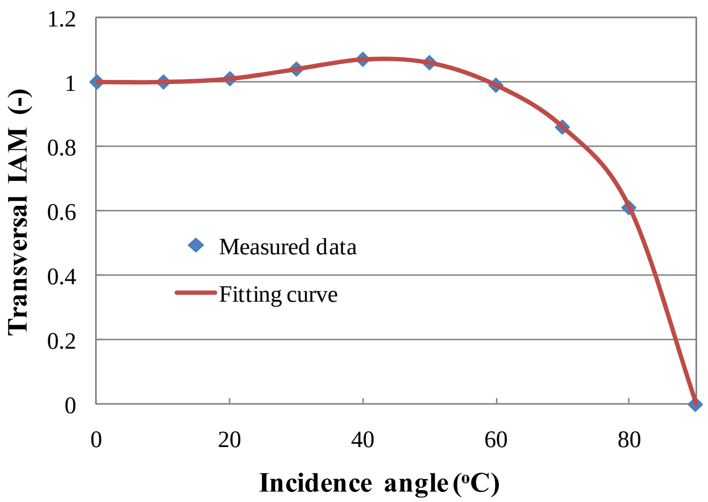

Fig.2 Measured data and fitting curve of transversal IAM for SEIDO 1-16

The transversal incidence angle modifier for SEIDO 1-16 is:

$$K_{\theta T} = 0.99996 + 0.00133\theta_T - 2.52916 \times 10^{-4}\,{\theta_T}^2 + 1.34509 \times 10^{-5}\,{\theta_T}^3 - 6.47813 \times 10^{-8}\,{\theta_T}^4 - 6.09967 \times 10^{-9}\,{\theta_T}^5 + 1.06863 \times 10^{-10}{\theta_T}^6 - 5.31046 \times 10^{-13}{\theta_T}^7 \quad (2)$$

The measured data and fitting curve of the transversal incidence angle modifier for SEIDO 1-16 are shown in fig.2.

The longitudinal incidence angle modifier for SEIDO 1-16 is:

$$K_{\theta L} = 1 - \tan^{5.421}(\theta_L/2) \quad (3)$$

The measured data and fitting curve of the longitudinal incidence angle modifier for SEIDO 1-16 are shown in fig.3.

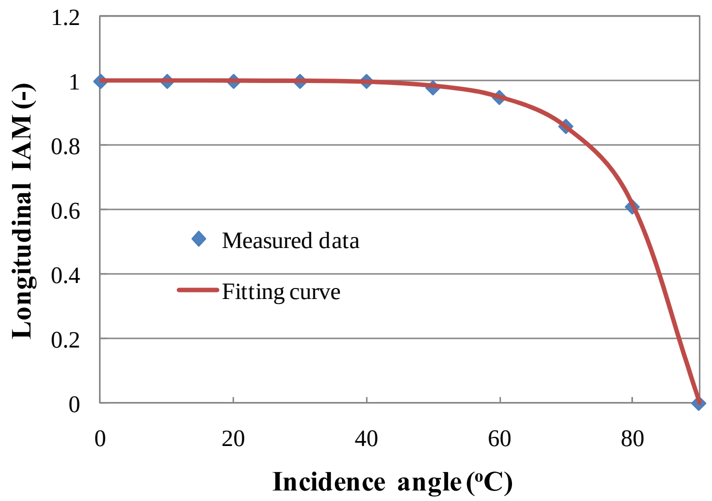

Fig.3 Measured data and fitting curve of transversal IAM for SEIDO 1-16

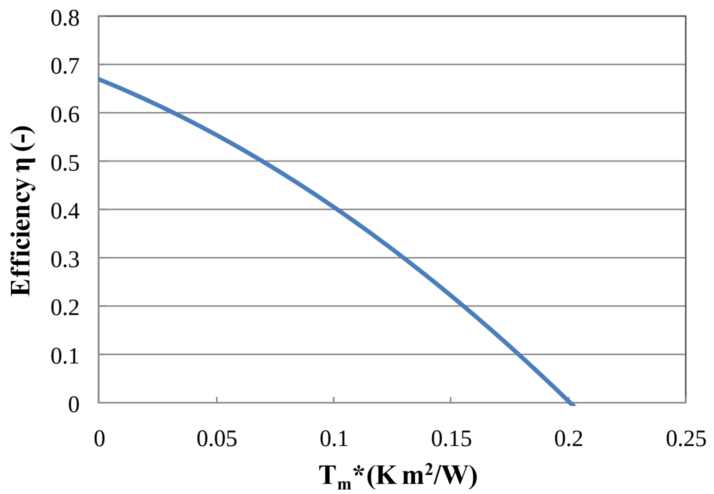

Fig.4 Efficiency curve for SEIDO 5-16

1.2 SEIDO 5-16

The aperture area of SEIDO 5-16 is 2.896 m^2 and the efficiency equation is: [1]

$$\eta = 0.671 - 1.959T_m^* - 0.0086G{T_m^*}^2 \tag{4}$$

The efficiency curve for a solar irradiance of 800W/m^2 is shown in fig.4.

The transversal incidence angle modifier for SEIDO 5-16 is:

$$K_{\theta T} = 1 - 0.00761\theta_T + 0.00208\,{\theta_T}^2 - 2.21122\times10^{-4}\,{\theta_T}^3 + 1.1966\times10^{-5}\,{\theta_T}^4$$
$$-3.70098\times10^{-7}\,{\theta_T}^5 + 7.01389\times10^{-9}{\theta_T}^6 - 8.11343\times10^{-11}{\theta_T}^7$$
$$+5.25794\times10^{-13}{\theta_T}^8 - 1.46054\times10^{-15}{\theta_T}^9 \tag{5}$$

The measured data and fitting curve of the transversal incidence angle modifier for SEIDO 5-16 are shown in fig.5.

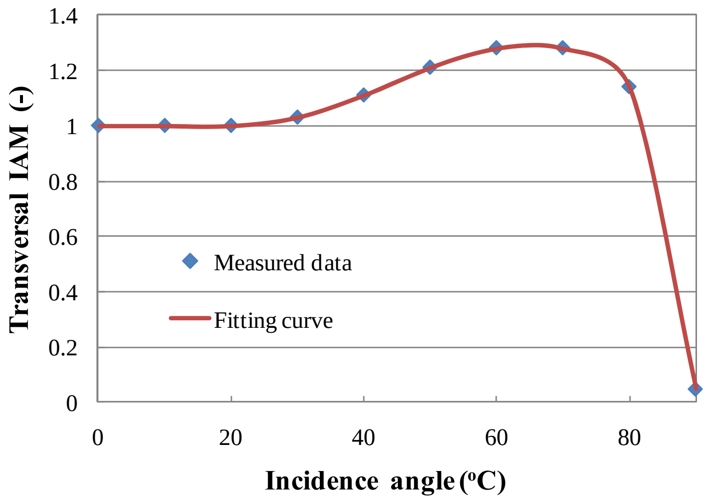

Fig.5 Measured data and fitting curve of transversal IAM for SEIDO 5-16

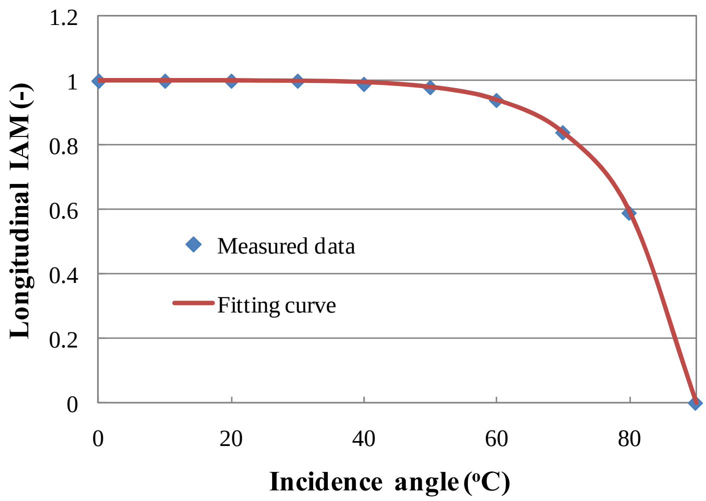

Fig.6 Measured data and fitting curve of transversal IAM for SEIDO 5-16

The longitudinal incidence angle modifier for SEIDO 5-16 is:

$$K_{\theta L} = 1 - \tan^{5.106}(\theta_L/2) \tag{6}$$

The measured data and fitting curve of the longitudinal incidence angle modifier for SEIDO 5-16 are shown in fig.6.

1.3 SEIDO 10-20

The aperture area of SEIDO 10-20 is 2.222 m^2 and the efficiency equation is: [1]

$$\eta = 0.659 - 1.8T_m^* - 0.0068GT_m^{*\,2} \qquad (7)$$

The efficiency curve for a solar irradiance of 800W/m^2 based on aperture area for SEIDO 10-20 is shown in fig.7.

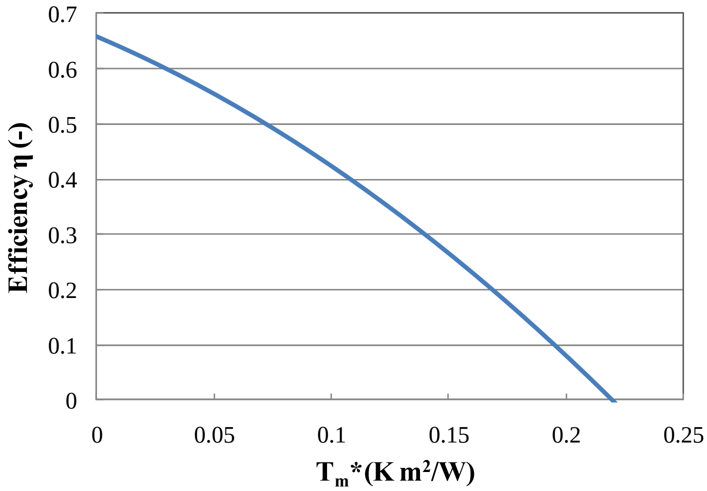

Fig.7 Efficiency curve for SEIDO 10-20

The transversal incidence angle modifier for SEIDO 10-20 is:

$$K_{\theta T} = 1 - 0.00156\theta_T - 3.71528\times10^{-5}{\theta_T}^2 + 6.67075\times10^{-5}\,{\theta_T}^3 - 7.66615\times10^{-6}\,{\theta_T}^4$$
$$+3.76314\times10^{-7}\,{\theta_T}^5 - 9.53125\times10^{-9}{\theta_T}^6 + 1.30539\times10^{-10}{\theta_T}^7$$
$$-9.20139\times10^{-13}{\theta_T}^8 + 2.61795\times10^{-15}{\theta_T}^9 \qquad (8)$$

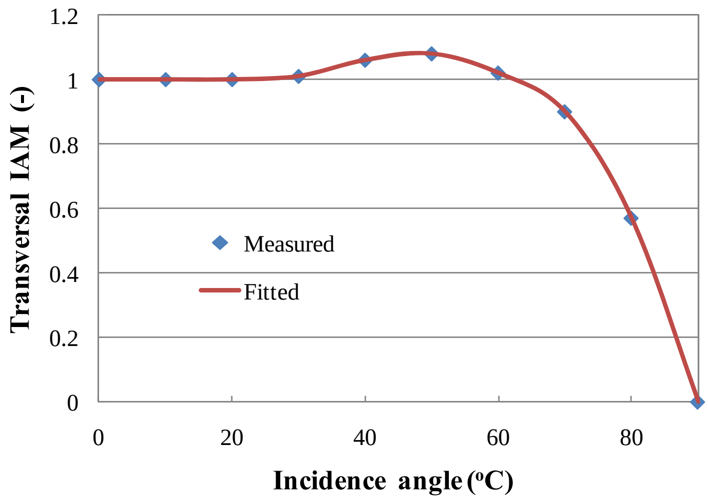

Fig.8 Measured data and fitting curve of transversal IAM for SEIDO 10-20

The measured data and fitting curve of the transversal incidence angle modifier for SEIDO 10-20 are shown in fig.8.

The longitudinal incidence angle modifier for SEIDO 10-20 is:

$$K_{\theta L} = 1 - \tan^{4.823}(\theta_L/2) \quad (9)$$

The measured data and fitting curve of the longitudinal incidence angle modifier for SEIDO 10-20 are shown in fig.9.

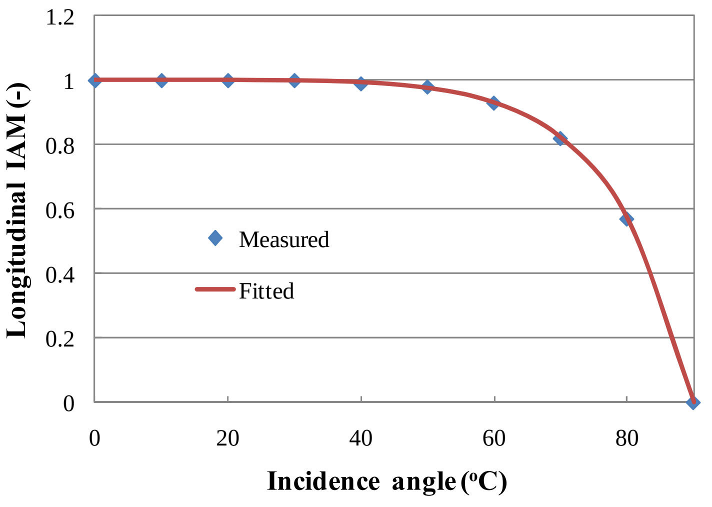

Fig.9 Measured data and fitting curve of transversal IAM for SEIDO 5-16

2 Analysis of the highest temperature of the solar collectors

The correlation of the highest temperatures of the solar collectors, SEIDO 1-16, SEIDO 5-16 and SEIDO 10-20, with azimuth and tilt are determined based on the test data of the efficiency and incidence angler modifier of the collectors and weather data in Copenhagen.

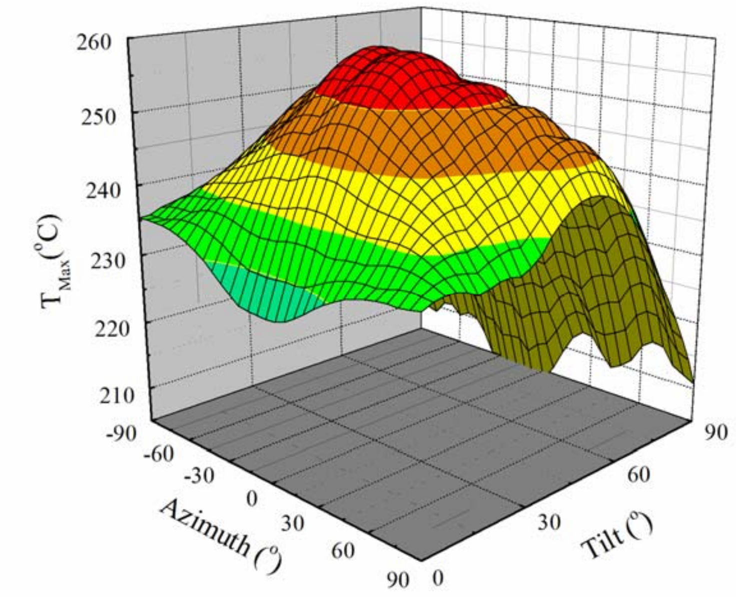

Fig.10 Correlation of the highest temperatures of solar collector with azimuths and tilts for SEIDO 1-16

2.1 SEIDO 1-16

By varying the azimuth and the tilt from -90° to 90° and from 0° to 90°, the highest temperatures of SEIDO 1-16 in Copenhagen are calculated and shown in fig.10 and fig.11.

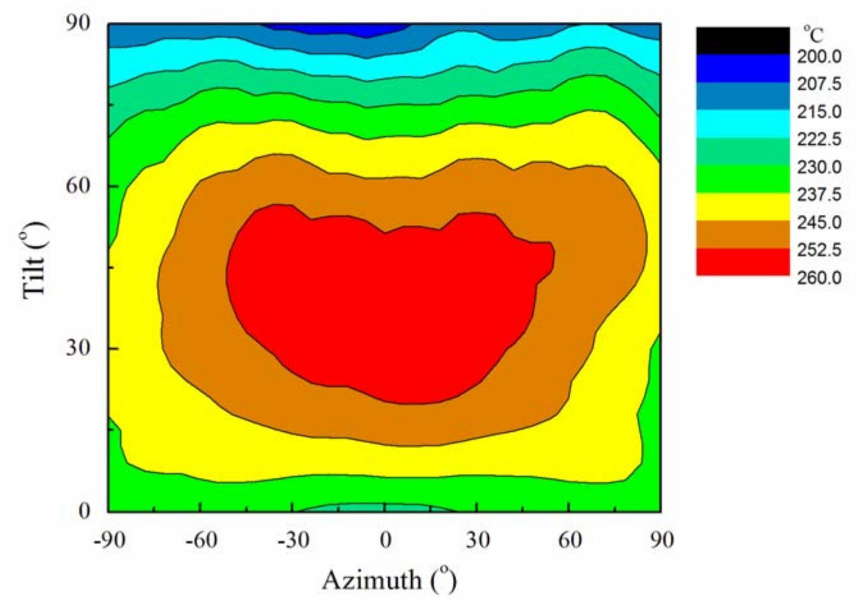

Fig.11 Contour of highest temperatures of solar collector varying with azimuths and tilts for SEIDO 1-16

If the azimuth is 0°, the highest temperatures of the solar collector for different collector tilts are shown in fig.12.

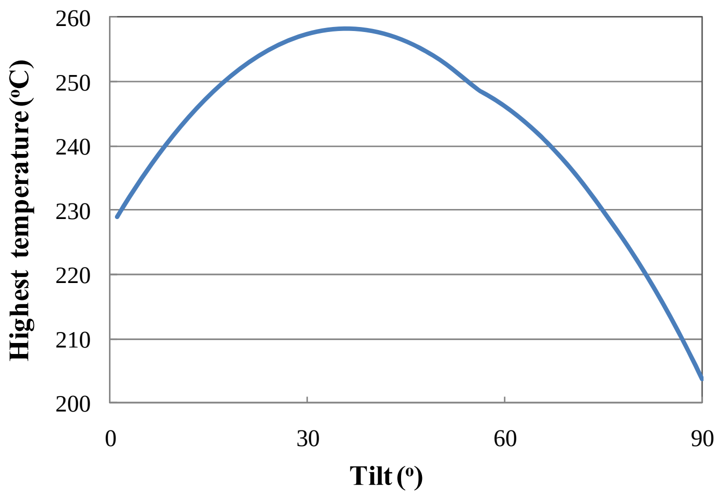

Fig.12 Highest temperatures of solar collector for SEIDO 1-16 for different tilts and with a collector azimuth of 0°

2.2 SEIDO 5-16

By varying the azimuth and the tilt from -90° to 90° and from 0° to 90°, the highest temperatures of SEIDO 5-16 in Copenhagen are calculated and shown in fig.13 and fig.14.

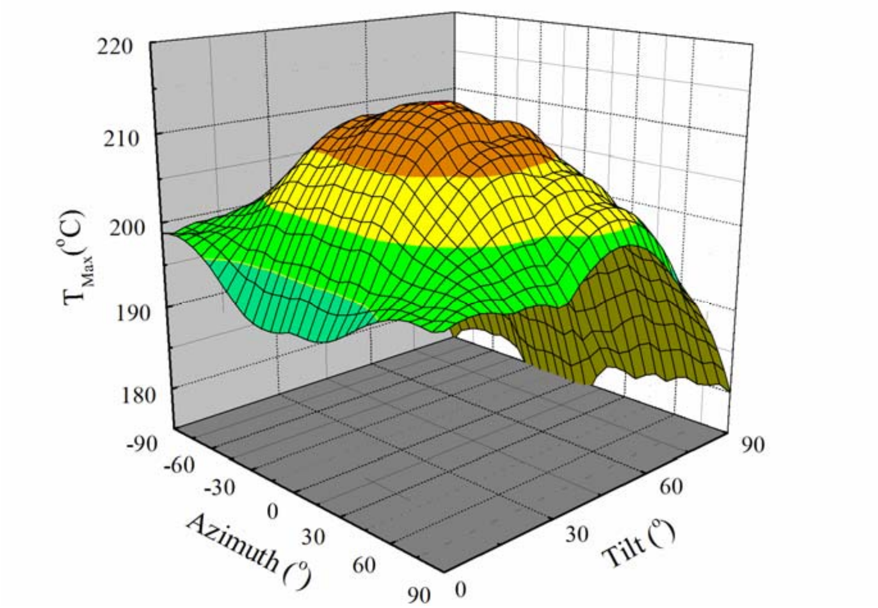

Fig.13 Correlation of highest temperatures of solar collector with azimuths and tilts for SEIDO 5-16

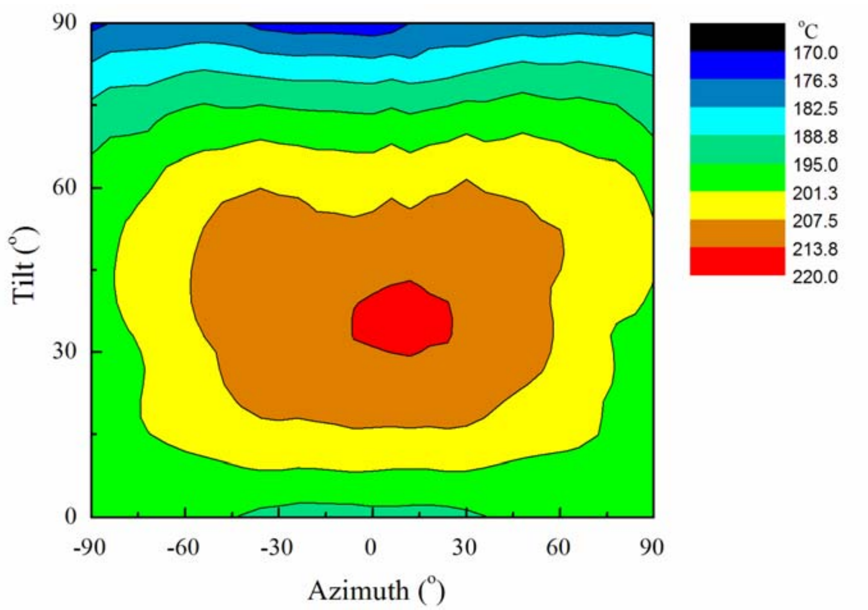

Fig.14 Contour of highest temperatures of solar collector for SEIDO 5-16 for different azimuths and tilts

If the azimuth is 0°, the highest temperatures of the solar collector for different collector tilts are shown in fig.15.

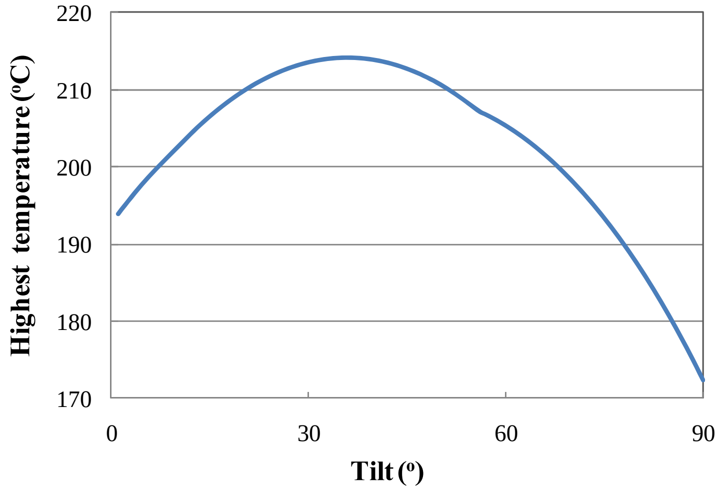

Fig.15 Highest temperatures of solar collector for SEIDO 5-16 for different tilts and with a collector azimuth of 0°

2.3 SEIDO 10-20

By varying the azimuth and the tilt from -90° to 90° and from 0° to 90°, the highest temperatures of SEIDO 10-20 in Copenhagen are calculated and shown in fig.16 and fig.17.

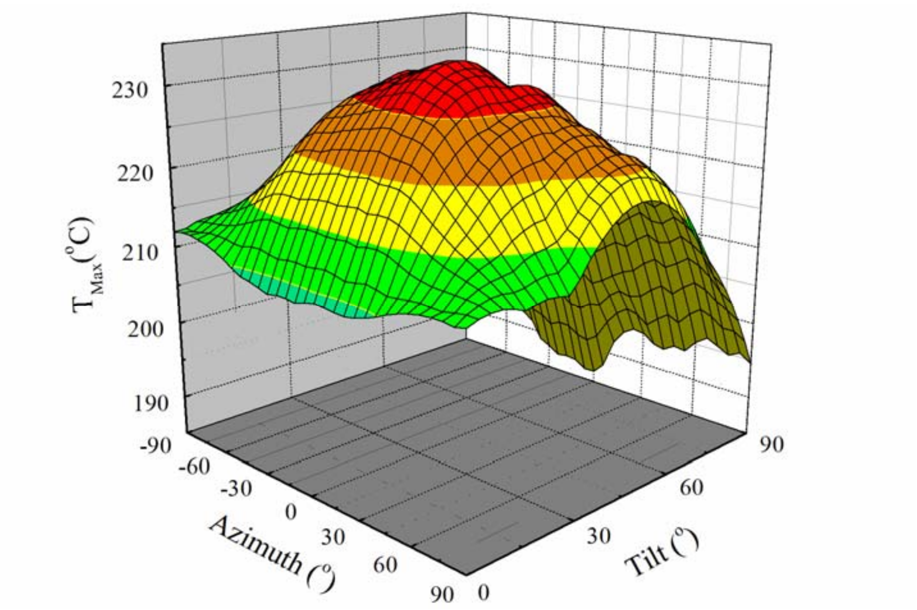

Fig.16 Correlation of highest temperatures of solar collector for SEIDO 10-20 with different azimuths and tilts

If the azimuth is 0°, the highest temperatures of the solar collector for different collector tilts are shown in fig.18.

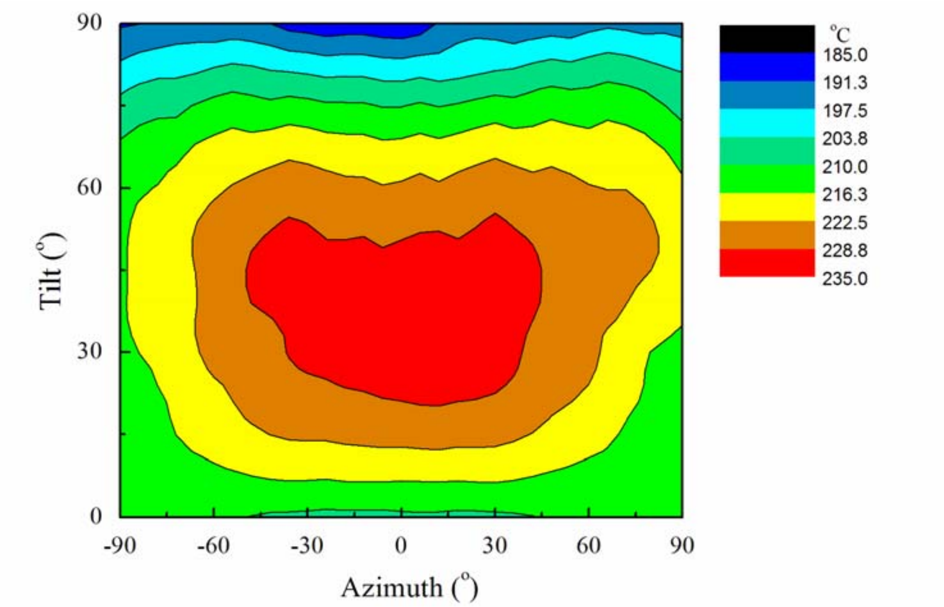

Fig.17 Contour of highest temperatures of solar collector for SEIDO 10-20 for different azimuths and tilts

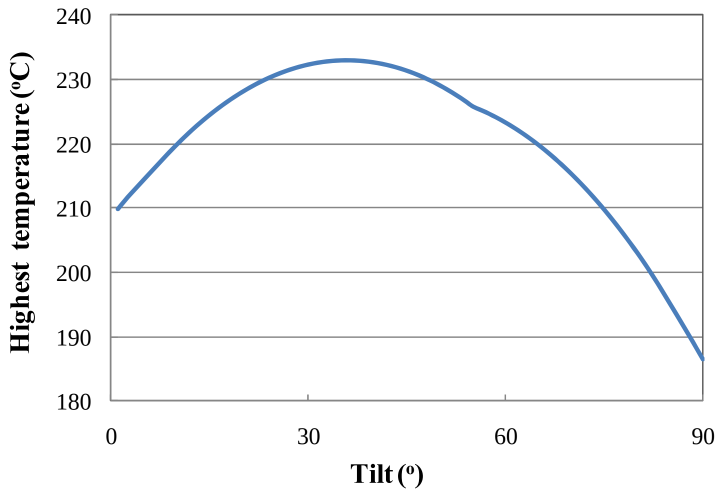

Fig.18 Highest temperatures of solar collector for SEIDO 10-20 for different tilts and with a collector azimuth of 0°

3 Conclusions

By theoretically calculating based on the weather data in Denmark in the period between May 1 and September 30 it shows that:

(1) The lowest highest-temperatures for SEIDO 1-16, SEIDO 5-10 and SEIDO 10-20 for different azimuths from -90° to 90° and different collector tilts from 0° to 90° are much higher than the boiling temperature of water and glycol/water mixture normally used for solar collector system. Therefore, if these three kinds of collectors are used for solar heating systems the stagnation phenomena are unavoidable when the circulation pump stops.

(2) The highest temperatures for SEIDO 1-16, SEIDO 5-10 and SEIDO 10-20 appear with a

collector tilt of 36^{o}C while the three collector are installed facing south.

(3) The range for different azimuths and tilts to achieve highest highest-temperatures for SEIDO 1-16 and SEIDO 10-20 is larger than that for SEIDO 5-10.

References

[1] http://solarkey.dk/solarkeymarkdata/qCollectorCertificates/ShowQCollectorCertificatesTable.aspx