PO. 407

A Study of The Normal Turbulence Model in IEC61400-1

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Background

Turbulence intensity at offshore sites varies depending on the distance from the coastline and wind direction. Implying that the model applicable both to onshore and offshore site is needed.

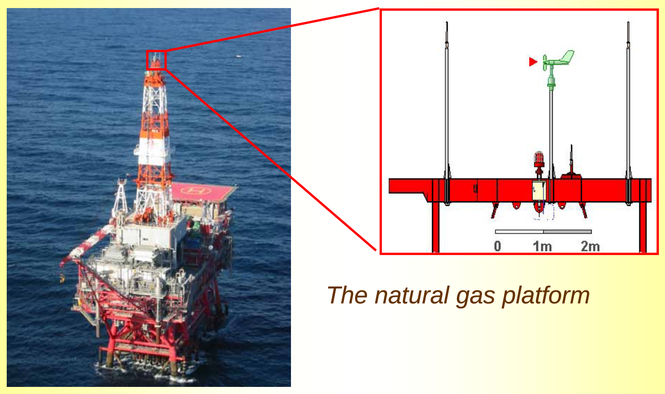
Tanigaki et al.(2009) showed the standard turbulence model parameters in IEC61400-1 does not shows good agreement with the identified parameters from various onshore measurement data in Japan.

The applicability of turbulence model in IEC61400-1 should be investigated for offshore sites.

Measurement

Site

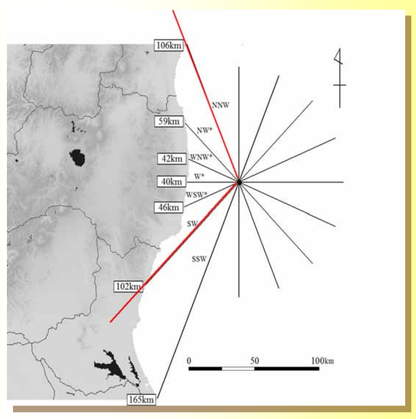
The offshore measurement are carried out at the top of a natural gas platform, which is located 37km offshore and the height of the anemometer is 95m a. s. l.



The natural gas platform

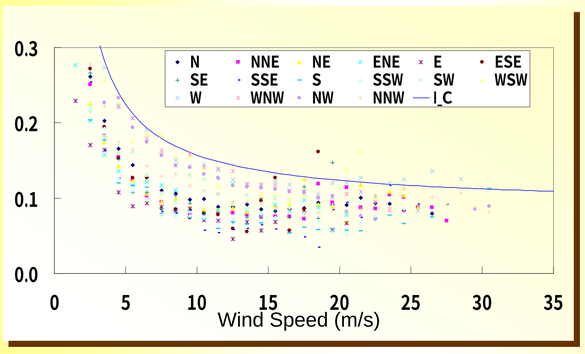
Explosion-proof anemometer was used to measure 10 minutes averaged wind speed and direction, and the 10minutes standard deviation of the wind speed. The measured data were transferred by mobile phone.

The map of the measurement site



The east side of the measurement site is Pacific Ocean and the west side is Japanese island. In addition, mountains of up to 1000m altitude are located at a distance of 40-90 km in the west direction.

Turbulence intensity



Turbulence Intensity for different wind speed

- For all the wind speed class, turbulence intensity is smaller than IEC-61400 turbulence class C
- The turbulence intensity depends on the wind direction, high turbulence for the wind from land and low turbulence for the wind from sea.

Normal turbulence model

IEC model

In IEC61400-1, normal turbulence model is modeled using 90 percentile of the standard deviation of the wind speed.

$$s_{90} = I_{\mathrm{ref}}\left(0.75U + 5.6\right)$$

I_{ref} is the turbulence intensity at 15m/s and a function of turbine class. This model is based on the following idea.

$I_{90} = s_{90}/U$	
$s_{90} = s_{\mathrm{ave}} + 1.28\,s_s$	Assumes normal distribution
$s_{\mathrm{ave}} = I_{\mathrm{ref}}\left(aU + b\right)$	a = 0.75, b = 3.8
$s_s = I_{\mathrm{ref}}\left(aU + b\right)$	a = 0.0, b = 1.4 (IEC) a = 0.12, b = 1.95 (Tanigaki)

Tanigaki et al. (2009) proposed a model for the standard deviation of mean wind speed.

Proposed parameters

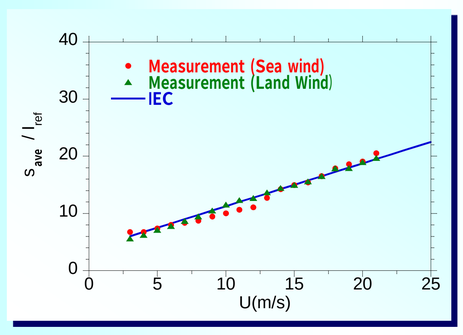
Measured data are divided into wind speed bin and two wind directions (Land and Sea), and model parameters are estimated by least square method.

Estimated model parameters

	a	b	a	b
Land	0.75	3.8	0.15	3.0
Sea	0.75	3.8	0.25	3.0
IEC	0.75	3.8	–	1.4

- For the parameters a and b, the estimated value shows good agreement with the IEC model.
- Estimated a and b are significantly different from the IEC model.

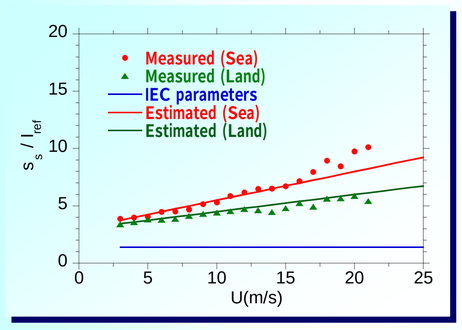
Parameters a and b



Mean value of standard deviation of wind speed for different mean wind speed

- Parameters a and b are related with mean value of standard deviation. Estimated parameters are identical to the ones in IEC61400-1, meaning that IEC models can clearly explains the offshore turbulence characteristics in terms of mean value of standard deviation of wind speed.

Parameters *a* and *b*



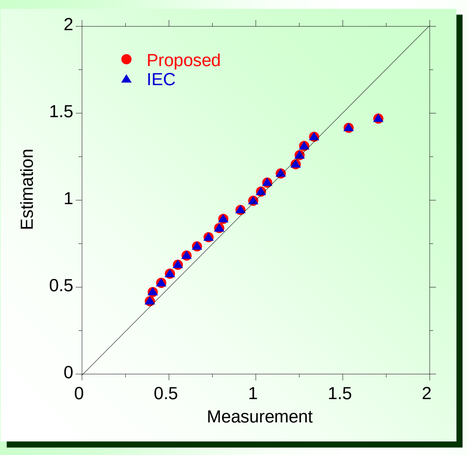
Standard deviation of standard deviation of wind speed for different mean wind speed

- IEC model parameters underestimates the standard deviation of standard deviation of wind speed for all mean wind speed bins.
- For the wind blowing from sea, the standard deviation of the standard deviation of wind speed is larger than that from land.
- The standard deviation of standard deviation of wind speed increases with the mean wind speed.

Verification

Proposed model is applied for the estimation of turbulence characteristics.

Mean value of *s*



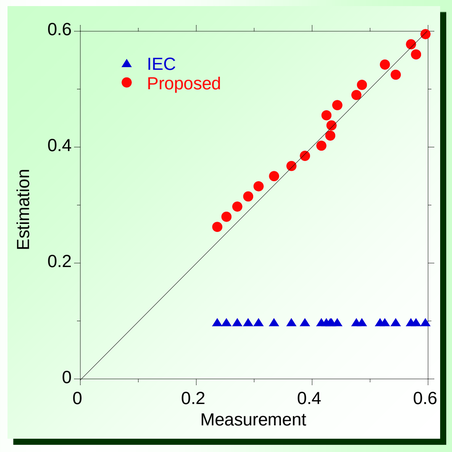
Comparison of observed and estimated mean value of the standard deviation of wind speed

- Both the proposed model and the IEC model show good agreement with the measurement.

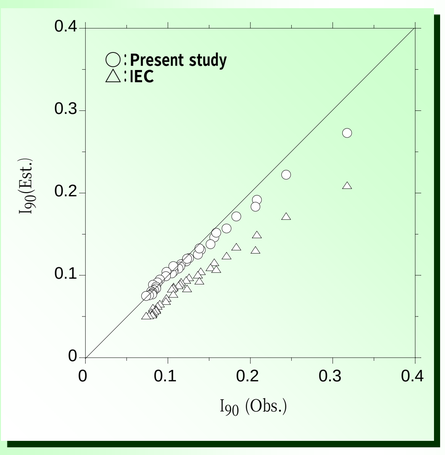
Standard deviation of *s*

Comparison of observed and estimated standard deviation of the standard deviation of wind speed

- IEC model underestimates the measurements while the proposed model show good agreement with the measurement.



Estimation of I_{90}



Comparison of observed and estimated 90 percentile of the turbulence intensity

- IEC model underestimates the measurements while the proposed model show good agreement with the measurement.

Conclusions

- The identified model parameters for the mean value of turbulence intensity, show close agreement with those defined in NTM of IEC.
- The identified model parameters for the standard deviation of turbulence intencity are significantly larger than those used in NTM of IEC.
- A new model parameters are proposed for the standard deviation of turbulent intensity, which shows good agreement with the measurement.

Acknowledgement

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