Marine Icing and Anti/De-icing Systems

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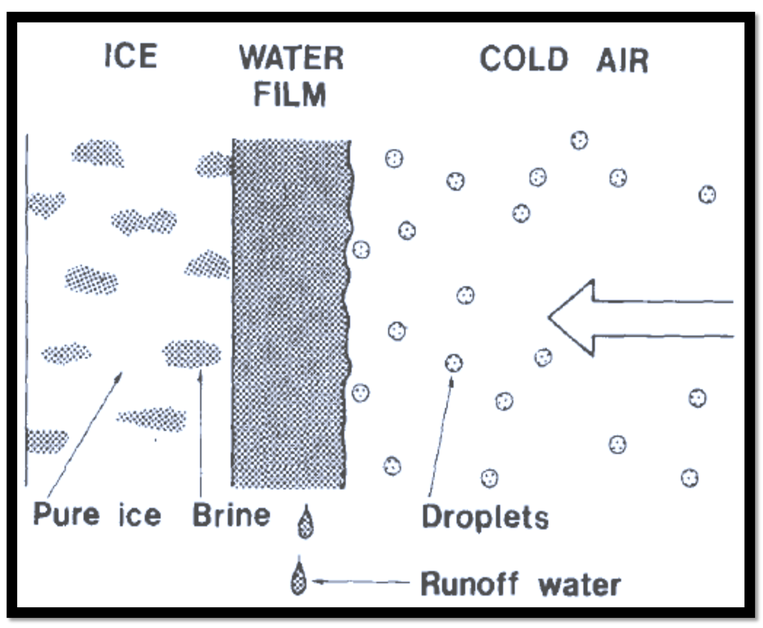
Abstract

Shipping operations are on the rise in the Arctic region. Due to these increased activities, maritime transport operations are encountering significant challenges with respect to the safety and reliability. These shipping operations are comprised of commercial vessels such as oil tankers, container ships, fishing vessels, tourism cruises, research and offshore exploration vessels and icebreakers
In this work, an effort is being made to review icing phenomenon in the marine operations. Two primary sources of icing are focused namely: atmospheric and sea spray. It is found from the literature that sea spray icing is the main contributor towards the marine icing. This work discusses the available ice accretion prediction models on the ship and offshore structures. This work also reviews the anti/de-icing technologies that can be implemented on ships for operations in cold climate region. The significance of ice detection is acknowledged, and a brief review of various ice detection technologies is discussed.

Marine Icing Phenomenon



Sea Spray Icing

Icing Source	Droplet diameter Range (µm)	Mean droplet Diameter (µm)	Liquid water Content (g/m³)	Droplet concentration (droplets per cm³)
Breaking Waves	1000 – 3500	2400	4600	
Wave Crests	60 – 1000	150 -200		
Fog:				
Advection	6 - 64	20	0.17	40
Radiation	4 - 36	10	0.11	200
Convection	~ 120	46	0.13	
Clouds:				
Stratus	1.5 – 43	4.9	0.05 – 0.25	
Cumulus	4 - 200	40	2.5	72

Droplets Characteristics of Various Icing Sources

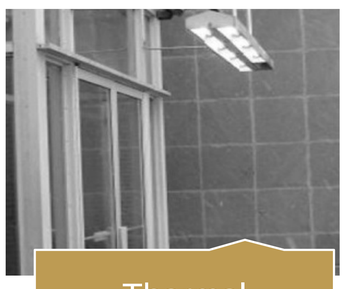
Liquid Water Content (LWC) Correlations

LWC Correlation	Correlation Variables
$w = w_o H_s v_r^2 e^{-0.55h}$	w is LWC of spray cloud (Kg/m³)
$w = w_o' H_s^{2.5} e^{-0.55h}$	w' is averaged LWC of spray cloud (Kg/m³)
$w = 1.35 H_s^2 e^{-0.53z'}$	H_s is significant wave height (m)
$w' = 1.7x10^{-4} H_s$	z is spray cloud elevation above mean sea level (m)
$w' = 10^{-3} H_s$	h is elevation above the vessel deck (m)
$w = 0.1 H_s e^{(H_s - 2z)}$	H_{rms} root mean square wave height (m)
$w = 4.6e^{-\left(\frac{2z}{H_{rms}}\right)^2}$	z' is spray cloud elevation above wave wash zone (m)
	v_r is ship speed relative to incoming wave (m/s)
	$w_o = 6.36x10^{-5}$ (empirical constant)
	$w_o' = 1.3715x10^{-3}$ (empirical constant)

LWC correlations contributing to Icing

Anti De-Icing Methods


Chemical


Thermal


Mechanical

Conclusion

Cold Climate operations has increased due to various interests in the region. Severe ice accretion phenomenon is a challenge in cold climate region. The challenge can be encountered during marine operations, mainly caused by sea spray and atmospheric factors. The ice removal on the marine platforms is suggested to be achieved through suitable combination of ice detection and de/anti-icing methods.

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