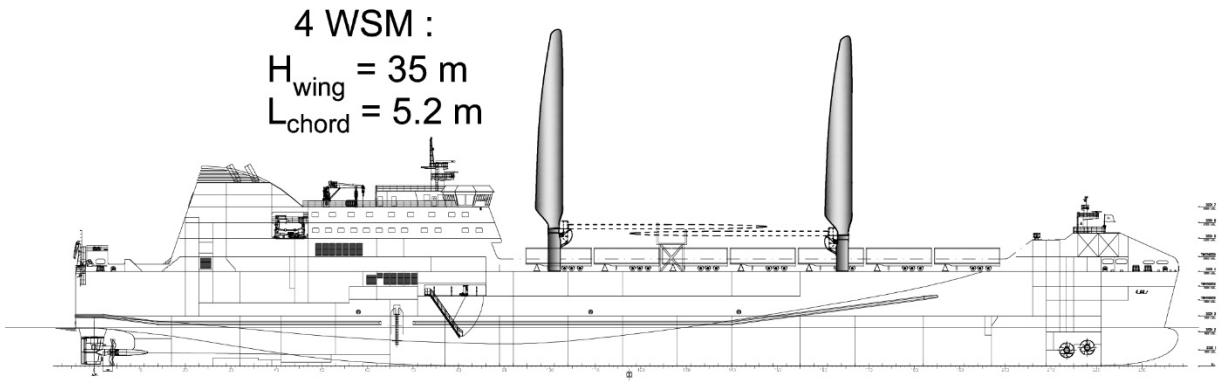
Flettner Rotors vs Wingsails (WSM)

Preamble

Scope of this report is to compare performances of two different system for Wind assisted propulsion; the Flettner rotors system and the Wing Sail Module system.

The Flettner rotor is presently promoted by a couple of companies, still in a “experimental” stage. Very little has been reported on the present installations.



Nomenclature

TWA	True Wind Angle
TWS	True Wind Speed
H_{wing}	Height of Wingsail
L_{chord}	Length of the profile chord
A_{wing}	Transversal Wingsail Area
$H_{Flettner}$	Height of Flettner Rotor
$d_{cylinder}$	Diameter of Flettner Rotor
$A_{Flettner}$	Transversal Flettner rotor Area
V_{ship}	Ship Speed
P_e	Effective power produced by wind devices
P_B	Main-engine equivalent power produced by wind devices

Geometrical Data

In the following table we have reported the geometrical setting of the two different energy recovery devices:

Flettner Rotors Data		
$H_{Flettner}$	24	[m]
$d_{cylinder}$	4	[m]
$A_{Flettner}$	96	[m^2]
Rotors N°	2	[m]
Tot $A_{flettner}$	192	[m^2]

Wingsails Data		
H_{wing}	35	[m]
L_{chord}	5.2	[m]
A_{wing}	182	[m^2]
Wings N°	4	
Tot A_{wings}	728	[m^2]

Performances

To compare the performances of the two devices, we have considered a True Wind Speed (TWS) of 8 m/s, which is the annual average as provided by https://globalwindatlas.info/area/Australia/Tasmania.

Thrust and Side Force are reported below for two different ship speeds and three different angles of wind with respect to the ship course.; TWA=40, 90, 140 DEG;

V_{ship} 18 kn		Average TWA		
		40 DEG	**90 DEG**	**140 DEG**
Flettner	Thrust [kN]	8.04	31.54	12.06
	Side Force [kN]	129.35	66.84	13.66
	Thrust/Side ratio	***0.06***	***0.47***	***0.88***
WSM	Thrust [kN]	38.84	50.13	16.41
	Side Force [kN]	140.14	66.06	12.20
	Thrust/Side ratio	***0.28***	***0.76***	***1.35***

V_{ship} 20 kn		Average TWA		
		40 DEG	**90 DEG**	**140 DEG**
Flettner	Thrust [kN]	6.31	31.96	12.46
	Side Force [kN]	145.88	77.83	18.45
	Thrust/Side ratio	***0.04***	***0.41***	***0.68***
WSM	Thrust [kN]	40.78	53.15	17.96
	Side Force [kN]	158.69	78.03	17.37
	Thrust/Side ratio	***0.26***	***0.68***	***1.03***

From those forces, the potential power saving has been calculated with the following assumption:

1. Mechanical energy lost to spin Flettner rotors is quantified in 7% of P_e.
2. Comparison between the devices, 2 Flettner Rotors against 4 Wingsails, was based on a similar Side Force.
3. The Flettner Rotor due to its remarkable Side Force, has been set at its best aerodynamic efficiency.
4. Added steering resistance has been neglected

The thrust forces generated by wind systems shall practically reduce the total ship resistance, therefore reducing the propeller power by the same amount divided by the propulsion efficiency.

Assuming ETA D = 0.7:

V_{ship} 18 kn		Average TWA		
		40 DEG	**90 DEG**	**140 DEG**
Flettner	Thrust [kN]	8.0	31.5	12.1
	$P_{e,Flettner}$ [kW]	74.5	292.0	111.6
	$P_{B,Net}$ [kW]	104.5	409.6	156.5
WSM	Thrust [kN]	38.8	50.1	16.4
	$P_{e,wings}$ [kW]	359.7	464.2	151.9
	P_B [kW]	529.7	683.7	223.7

V_{ship} 20 kn		Average TWA		
		40 DEG	**90 DEG**	**140 DEG**
Flettner	Thrust [kN]	6.3	32.0	12.5
	$P_{e,Flettner}$ [kW]	64.9	328.8	128.2
	$P_{B,Net}$ [kW]	91.0	461.2	179.8
WSM	Thrust [kN]	40.8	53.2	18.0
	$P_{e,wings}$ [kW]	419.6	546.8	184.8
	P_B [kW]	618.0	805.3	272.2

Side Force by Flettner during port maneuvering

Wingsails modules are conceived so that they can be folded down whenever necessary, or simply feathered with wind, while Flettner rotors remains in their standing positions with the same size, reducing significantly the side thrusters effectiveness.

The amount of such apparent Thruster Power Reduction is indicated in the following table;

2 Flettner rotors:

TWS [kn]					
20	25	30	35	40	45
Side Force 2 Flettner in port, beam wind [kN]					
9.02	14.10	20.30	27.64	36.10	45.69
Effective Thruster Power reduction (kW)					
56	88	127	173	225	285

4 WSM:

TWS [kn]					
20	25	30	35	40	45
Side Force 4 WSM in port, beam wind [kN]					
0.63	0.99	1.43	1.94	2.54	3.21
Effective Thruster Power reduction (kW)					
4	6	9	12	16	20

Conclusions

Wingsails has generally more efficiency and wider working range in term of wing/course angle.

Wingsails system can be quickly “shut down” to reduce forces, while the minimum force generated by a Flettner rotor is much bigger. In case of head wind, port maneuvering or excessive wind force, WSM can be feathered or folded down, almost cancelling its resistance, which is not possible (or difficult) with a Flettner rotor; even in a standing position, WSM can be oriented with the wind, obtaining a much lower resistance.

At equal thrust force, 4 Wingsails produce lower Side Force if compared to 2 Flettner Rotors, that means less added steering resistance.
WSM can be installed on the ship side without interfere with the RoRO cargo, while Flettner can be installed only at the very aft and fore part of the ship; wind gusts concentrated on one extremity may transiently unbalance the ship in a dangerous way, especially during maneuvering. Also in navigation, the two rotors so apart away may create course instability.