FIBER-METAL HYBRID LAMINATES AS STRUCTURAL MATERIAL IN TOWERS FOR OFFSHORE WIND ENERGY CONVERTERS

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Introduction

Composite laminates are widely becoming the choices for many structural applications especially in offshore industry fields, driven by lightweight and corrosion resistance compared to traditional metal[1].The prospect of offshore wind energy exploration and multi-MW turbine's application is generating a new impetus for high performance material[2], which aims at increasing load bearing capability and if possible saving weight and cost simultaneously. Performance of a new fiber-metal hybrid material developed specifically for the marine industry is presented in this paper. Simulation models of benchmark mono-steel towers with new hybrid material were analyzed in different locations. Results show that within certain limits and with optimal configurations, the new hybrid material is efficient both from the points of mechanical performance and weight competitiveness compared to his counterpart metal.

Numerical Simulations

Fiber-Metal Hybrid Material-MALECON

MALECON is a patented fiber-metal hybrid material of ETS Ingenieros Navales of Universidad Politécnica de Madrid (UPM) developed specifically for marine industry use, which stands for 'Material Laminado Estructural para Construcción Naval'[3]. Basic concept of it is configurations of layers of metal sheet alternating with plies of composite material EPLUS2 which is connected with outer metal layers by structural adhesives, as shown in Fig.1.The reinforcement of the material would be typical E-GLASS fibers with Vinyl Ester matrix and the metal sheet.

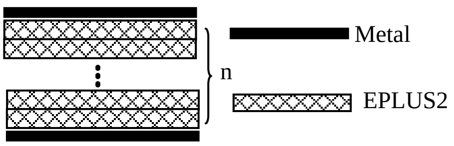

Fig. 1 Concept of fiber-metal laminates-MALECON

Hybrid Tower Concept

Towers for offshore wind energy converters currently used are typical tubular steel structure, tapering from bottom to top at a certain ratio. Larger tower diameters would be required for next generation wind turbines because the structural design of tubular steel tower is dominated by ultimate and fatigue limit state, especially the shell buckling leads to high dimensions for the steel sections. Similar to a hybrid tower concept[4][5], as shown in Fig.2, models with different tubular parts, where the upper part is a mono-steel shell and lower parts are fiber-metal hybrid laminates MALECON are assumed here to illuminate detailed performance of the new hybrid material in use of tower structure of offshore wind energy converters.

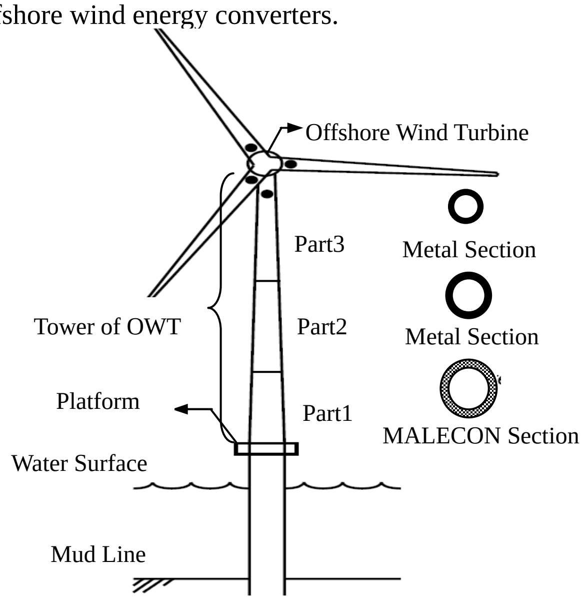

Fig. 2 Concept of hybrid tower

Benchmark Tower Models

Benchmark models of steel tubular tower is composed by three parts, tapering from diameter 4.274m at the bottom to 2.345m at the top of tower are used here as a counterpart of MALECON hybrid tower. Detailed model configurations are listed in Table1.

Table 1 Configuration of tower

Tower: overall height 76.899m, mass 119t, parts 3			
Parts	1st part	2st part	3st part
Dia.max(m)	4.274	3.959	3.303
Dia. Min(m)	3.959	3.303	2.345
Length(m)	19.369	28.833	28.697
Mass(t)	44.97	47.54	26.49
Mass ratio	37.79%	39.95%	22.26%
No.of plates	8	12	12
Thickness(mm)	26,26,24,24, 22,22,20,20	20,20,20,20, 20,18,18,18, 18,18,16,16	16,14,14,14, 14,14,12,12, 12,12,12,14

Simulation models of Part1, Part1+2, Part1+2+3 of MALECON are constructed by ABAQUS software with composite shell elements, so do the mono-steel counterparts for comparison. Clamped conditions are assumed at the bottom and top of sections for Part1 and Part1+2 models, while for Part1+2+3, the top section is set free. Eigenvalue buckling analysis method is used here to obtain estimates of top edge buckling compressive loads and modes.

Results and Discussion

Buckling loads of MALECON part1 with 40%, 50%, 60% of steel layer thickness (5.2,6.5,7.8 mm) of bottom diameter of part1 (26mm) can be above those of mono-steel structure when the number of EPLUS2 is reaching to 4,3,2. Mass of the MALECON models can be reduced to 62.50%, 69.82%, 77.15% of steel model respectively, as shown in Fig.3.

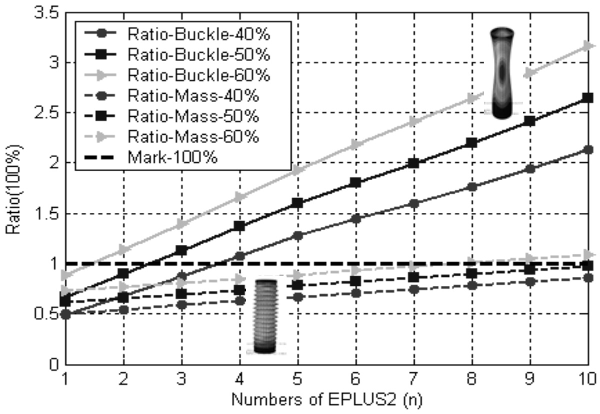

Fig. 3 Buckling load and mass ratio of part1

Buckling loads of MALECON part1+part2 tower with 40%, 50%, 60% of steel layer thickness (5.2,6.5,7.8 mm)of bottom diameter of part1 (26mm), (4,5,6 mm) of bottom diameter of part2(20mm)can be above those of mono-steel tower when the number of EPLUS2 is reaching to 4,3,2.Mass of MALECON models can be reduced to 63.64%, 70.21%, 76.79% of mono-steel model respectively. MALECON shows less efficient contribution in buckling load when the number of EPLUS2 keeps increasing. The buckling mode shapes of the structure change from shell buckling to typical column buckling, shown as Fig.4.

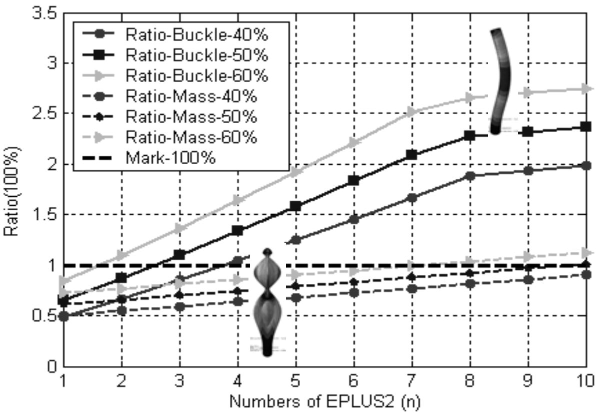

Fig. 4 Buckling load and mass ratio of part1+2

Buckling loads of MALECON part1+part2+part3 with 40%, 50%, 60% of steel layer thickness (5.2,6.5,7.8 mm) of bottom diameter of part1(26mm) ,(4,5,6 mm)of bottom diameter of part2(20mm) and (3.2,4,4.8mm) of bottom diameter of part3(16mm) cannot reach that of steel tower even though the number of EPLUS2 reaches to 10. Mass of MALECON models are above mono-steel tower when the number of the EPLUS2 is 7 for 60% case and 9 for 50% case. MALECON shows less efficient contribution in buckling load case. The mode shapes of structure are typical column buckling, shown as Fig.5.

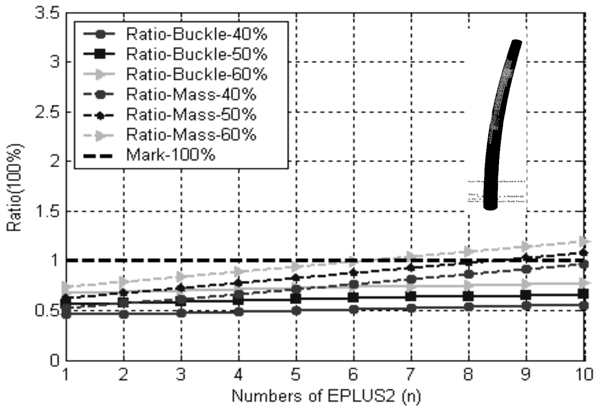

Fig. 5 Buckling load and mass ratio of part1+2+3

Conclusion

Study shows that alternative to a steel tower part to MALECON hybrid material can be mechanical and weight efficiency for the bottom part of tower of offshore wind energy converter. Optimum analysis should be done for the locations of MALECON in parts of tower structures. Mode shapes should be taken into consideration also when assessing the efficiency of the hybrid material because MALECON contribute a little for typical column buckling.

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