Elastoplastic Analysis of a Metallic Mast with Stiffeners. Experimentation and Numerical Simulation

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***Abstract*—This work entitled - Elastoplastic Analysis of a Metallic Mast with Stiffeners - is devoted to optimize the weight of masts. These masts are made of steel and have a conical geometry with constant thickness. The masts are considered clamped at their lower basis in soil. The masts should resist to the applied loads which are self weight, wind and equipments. Firstly, two types of design have been proposed to pursue this study; Type A consists of adding longitudinal stiffeners and type B consists of changing the whole shape of the masts section. Deflection tests will be applied to the type A of masts according to the metallic standards, these same tests will be applied also on normal masts. The test results will be analyzed to study the effects of the stiffeners on the mechanical behavior of the masts. Many computational cycles are realized by a numerical software to prove that we have the same results on the type A masts either by experimental tests or numerical simulation, hence, we will analyze the mechanical behavior of type B by using only the mumerical simulation method. The results have shown that both type A and type B allow a considerable weight optimization. Finally, an analysis of the two solutions proposed will be done in order to determine the advantages and disadvantages of each one of them.**

Keywords— Material Behavior, Masts deflection tests, numerical simulation , Optimization, Masts, Metallic Standards.

1. Introduction

Masts are metal supports with a regular 8-sided or 12-sided section. They are characterized by a head diameter, a base diameter, a height and a thickness.

They are used for stadium lighting, port lighting, airport lighting, telecommunication and power transmission line.

Recently, there is a fierce competition in the mast manufacturing industry, which makes the development of innovative optimization solutions a necessity. This solutions must respect the standards recommendations.

It is for this reason that this work has been initiated. The main objective of this work is to find new geometric shapes of the masts sections. This geometric shapes must ensure better resistance to the forces applied to the masts with the use of minimum material.

Two solution was proposed in this work. The first solution consist to add stiffeners to the masts, the stiffeners have a square section. The second solution consist to add V-shaped plies to the each sides of the mast. This V-shaped plies was added to increase the resistance of the masts.

A deflection test will be done to determine the influence of adding stiffeners on the resistance masts. Three masts will be subjected to deflection test to study their behavior. The three masts have the same height, head diameter and base diameter. The difference between the masts is that two of them have the same thickness, but the first one is without stiffeners and we add the stiffeners for the second. The third one have no stiffeners but have a higher thickness.

After the tests, an elastoplastic analysis will be done using NASTRAN to validate the finite element model. This analysis will be done to the three masts. The three masts subjected to the elastoplastic analysis have the same geometric characteristic as those subjected to the deflection test.

The finite element model validate by the elastoplastic analysis will be used to study the behavior of the mast with the V-Shaped plies.

A comparison between the two types of masts proposed will be discussed in the end of this work and some perspectives will be proposed.

2. Deflection tests

2.1. *Masts without stiffeners*

The bending tests were carried out according to the loading protocol defined in the previous section in order to determine the load which causes the appearance of the first plastic ball joint. Throughout the test, the displacement of the mast corresponding to each load is noted down to the point of ruin.

The geometric characteristics of the mast without stiffeners subjected to the deflection tests is given by the table below:

Table 1 : Geometric characteristics of the mast without reinforcement

Head Diameter	120 mm
Base diameter	300 mm
Height	10 m
Thickness of the sheet	3 mm

The results of the test are summarized in the table below:

Table 2. Tests results for the mast without stiffener

Load (daN)	Displacement (mm)
0	0
264	232
0	16
264	238
398	390
476	506

530	611

The limit load supported by the mast without stiffeners is 530 daN as we seen in table 2. The displacement is 611 mm at the limit load.

2.2. Masts with stiffeners

The geometric characteristics of the mast without stiffeners subjected to the deflection tests is given by the table below:

Table 3: Geometric characteristics of the mast with reinforcement

Head Diameter	120 mm
Base diameter	300 mm
Height	10 m
Thickness of the sheet	3 mm
reinforcements	10x10 mm

The mast with the stiffeners has undergone the same tests and the results obtained are in the table below:

Table 4. Tests results for the mast with stiffeners

Load (daN)	Displacement (mm)
0	0
266	156
0	6
264	156
398	241
478	297
530	335
582	377
636	423
688	476
742	534
792	601
847	738

The limit load supported by the mast without stiffeners is 847 daN as we seen in table 4. The displacement is 738 mm at the limit load.

2.3. Masts with higher thickness

The geometric characteristics of the mast with higher thickness subjected to the deflection tests is given by the table below:

Table 5 : Geometric characteristics of the mast without reinforcement

Head Diameter	120 mm
Base diameter	300 mm
Height	10 m
Thickness of the sheet	4 mm

The results of the test are summarized in the table below:

Table 6. Tests results for the mast with higher thickness

Load (daN)	Displacement (mm)
0	0
334	188
2	15
334	191
500	321
602	429
670	533
736	707

The limit load supported by the mast without stiffeners is 736 daN as we seen in table 6. The displacement is 707 mm at the limit load.

3. Modeling of the elastoplastic problem of masts

3.1. Masts without stiffeners

The mast studied is an octagonal mast whose geometrical characteristics are given in the table 1.

The geometry of the mast studied was realized under Catia V5 and was exported to Patran for the mesh and the application of the boundary conditions. The geometry of the mast was discretized into surface elements with four nodes having 50 mm as size, then a thickness of 3 mm is assigned to the surface. The material is defined as ordinary structural steel with an elastic limit of 235 MPa. The mast base was embedded to the ground and a concentrated load was applied at 0.25 m from the top to reproduce the tests conditions. Finally, a nonlinear analysis was launched under NASTRAN to determine the mast ruin load. The limit load of the mast without reinforcement is 530 DaN.

3.2. Masts with stiffeners

The mast studied is an octagonal mast with four reinforcements whose geometrical characteristics are given in the table 3.

The geometry of the mast studied was realized under Catia V5 and was exported to Patran for the mesh and the application of the boundary conditions. The geometry of the mast was discretized into surface elements with four nodes having 50 mm as sides and the stiffeners were discretized into volume elements at 8 knots, then a thickness of 3 mm is assigned to the surface. The material is defined as ordinary structural steel with an elastic limit of 235 MPa. The mast base was embedded to the ground and a concentrated load was applied at 0.25 m from the top to reproduce the test conditions. Finally, a nonlinear analysis was launched under NASTRAN to determine the mast ruin load. The limit load of the mast with four stiffeners is 829 DaN.

3.3. Masts with higher sthickness

The mast studied is an octagonal mast with four reinforcements whose geometrical characteristics are given in the table 5.

The geometry of the mast studied was realized under Catia V5 and was exported to Patran for the mesh and the application of the boundary conditions. The geometry of the mast was discretized into surface elements with four nodes having 50 mm as, then a thickness of 4 mm is assigned to the surface. The material is defined as ordinary structural steel with an elastic limit of 235 MPa. The mast base was embedded to the ground and a concentrated load was applied at 0.25 m from the top to reproduce the test conditions. Finally, a nonlinear analysis was launched under NASTRAN to determine the mast ruin load. The limit load of the mast with four stiffeners is 720 DaN.

4. Masts with v-shaped plies

An elastoplastic analysis using the finit element method of the mast with V-Shaped plies will be presented in this section. The mast will be modeled as we have done in precedent sections.

The geometric characteristic of the mast with V-Shaped plies is given by the table below.

Table 7. Geometric characteristic of the mast with V-Shaped plies

Diamètre de tête	120 mm/plat
Diamètre de base	300 mm/plat
Hauteur	10 m
Le nombre des « Vé »	4
L'ouverture du « Vé »	14 mm
Le bord du « Vé »	20 mm
Le rayon intérieur Ri	3,3 mm

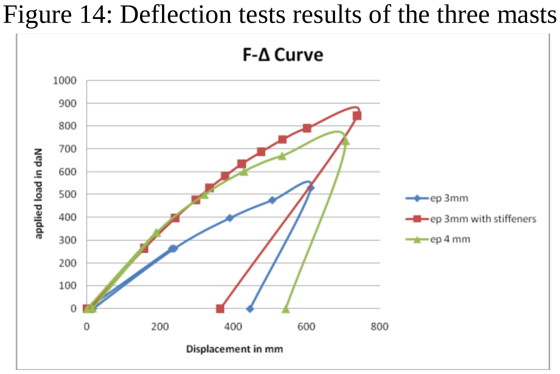
The geometry of the mast studied was realized under Catia V5 respecting the specification in table 7, and was exported to Patran for the mesh and the application of the boundary conditions. The geometry of the mast was discretized into surface elements with four nodes having 50 mm as, then a thickness of 3 mm is assigned to the surface. The material is defined as ordinary structural steel with an elastic limit of 235 MPa. The mast base was embedded to the ground and a concentrated load was applied at 0.25 m from the top to reproduce the test conditions. Finally, a nonlinear analysis was launched under NASTRAN to determine the mast ruin load. The results of the numerical simulation are shown in figure 13.

The limit load of the mast with four stiffeners is 730 DaN.

5. Conclusion

The deflection test show as that the stiffeners add give us a better resistant of the masts. The figure 3 show as the summary of the three masts deflection tests.

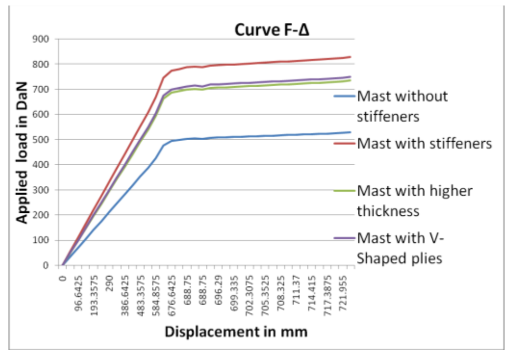
Figure 14: Deflection tests results of the three masts



The mast with stiffeners present a better resistance compared with the two others masts. Also, the mast with stiffeners have a better resistance compared with the mast with higher sheet thickness, and he has a lower weight than it. Then we can conclude that the solution proposed give us a better resistance to the load applied with the lower use of materiel. But the problem with this solution is that needs a higher production cost due to addition of the welding phase in manufacturing.

A comparison between the second solution and the first done was all ready done. The mast with V-Shaped plies has a resistant less than the one with stiffeners. On the other hand he still more resistant than the mast with higher thickness as shown in the figure below.

Figure 15: Elastoplastic analysis result



The mast with V-Shaped plies present a weight reduction of 24%. The problem of this solution that it needs a manufacturing machine to realize the plies.

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