Research Article

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.

Introduction

Masts are metal supports with a regular 8-sided or 12-sided sections. They are characterized by a head diameter, a base diameter, a height and a thickness [6].

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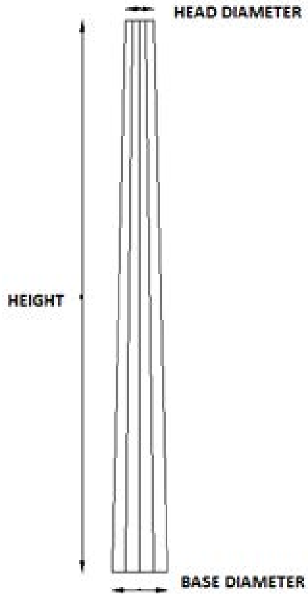

Figure 1.8-sided mast drafting

They are used for stadium lighting (figure 2), port lighting, airport lighting (figure 3), telecommunication (figure 4) and power transmission line (figure 5).

Figure 2.Stadium lighting

Figure 3.Airport lighting

Figure 4.Telecommunication

Figure 5.Power transmission line

The use of this exact number of sides offers equal resistance in all directions. Masts with less than 12 m height are manufactured in one piece. Those beyond 12 m, are manufactured in two parts assembled on site by nesting. The effective nesting length achieved at the site must be greater than 1.35 times the diameter of the female section [1].

The manufacturing of masts goes through several stages. The raw material is in the form of a coil sheet which after unwinding and shearing is cut into two trapeziums by means of reflowing roller. Then, the openings on the trapezoids are made by plasma cutting. Next, the sheet is folded using folding machine. The two trapezoids are then welded and pass to the finishing phase.

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[1]- [4], [6]..

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 (Figure 6), the stiffeners have a square section. The second solution consist to add V-shaped plies to the each sides of the mast (Figure 7). This V-shaped plies was added to increase the resistance of the masts.

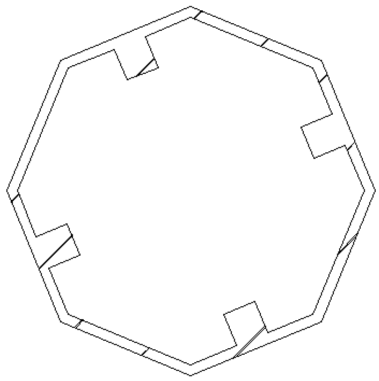

Figure 6.Cross section of mast with stiffeners

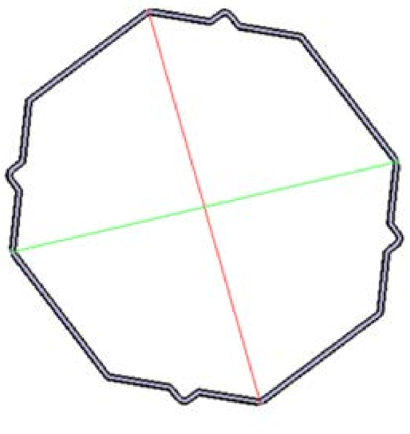

Figure 7.Cross section of mast with V-Shaped plies

A deflection test will be done to determine the influence of adding stiffeners on the resistance masts [7]. 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 [5]. 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.

Deflection tests

Deflection test principle

The purpose of mechanical bending tests is to determine the limit load of metal poles [8].

During the tests, the masts was fixed from their basis. The load was applied from 0.25 m from the top. The load was applied step by step to avoid the dynamic loading, in every step the load value is shown by dynamometer and the displacement was measured using a laser distometer. The loading protocol is described by the standard [8] and it was representing in Figure 8. Before the test a numerical simulation was done to determine the nominal load supporting by the masts using Robot Structural Analysis [3] [4]. We consider that the nominal load represent 100% of test load. In our case we will continue the test until the ruin by adding 10% of the nominal load in every step. When the masts will be brocket the final load will be record. The load recorded is the limit load of the masts.

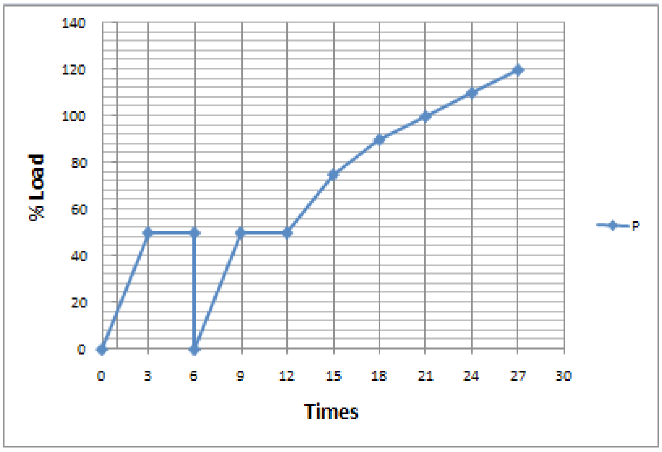

Figure 8.Loading protocol

Bending tests were carried out on three types of 8-sided octagonal masts which have the same diameters and height. The first type of masts that have been tested has 3mm as thickness, the second type has the same thickness with the addition of longitudinal reinforcement, the third one has 4 mm as thickness. The bending tests were carried out on the three variants in order to determine the influence of the addition of the stiffeners on the limit load of the metal poles.

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:

The results of the test are summarized in 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

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.

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.

Masts with higher thickness

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

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.

Modeling of the elastoplastic problem of masts

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.

The results of the numerical simulation are shown in figure 9.

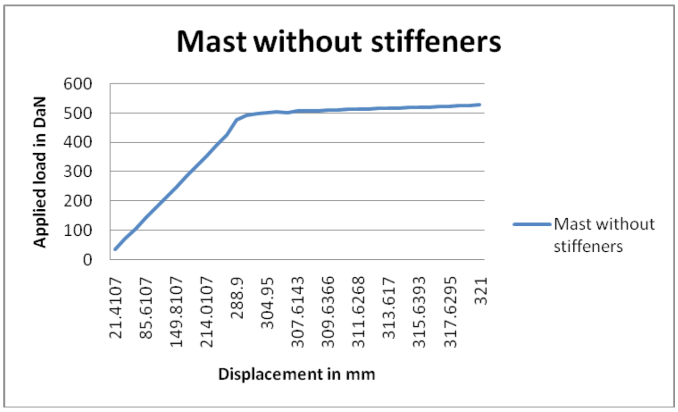

Figure 9.Numerical simulation result of mast without stiffeners

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.

The results of the numerical simulation are shown in Figure 10.

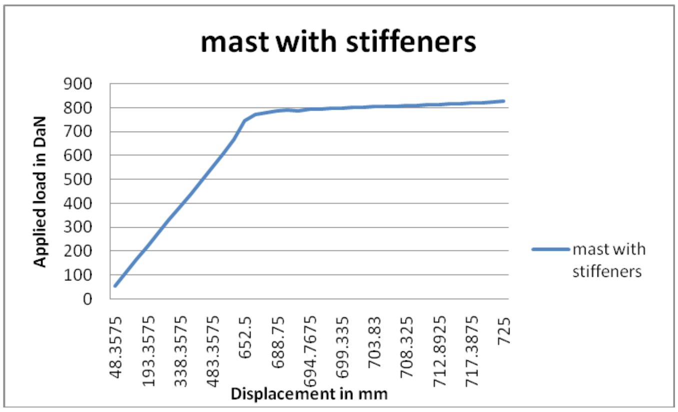

Figure 10.Numerical simulation result of mast with stiffeners

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.

The results of the numerical simulation are shown in figure 11.

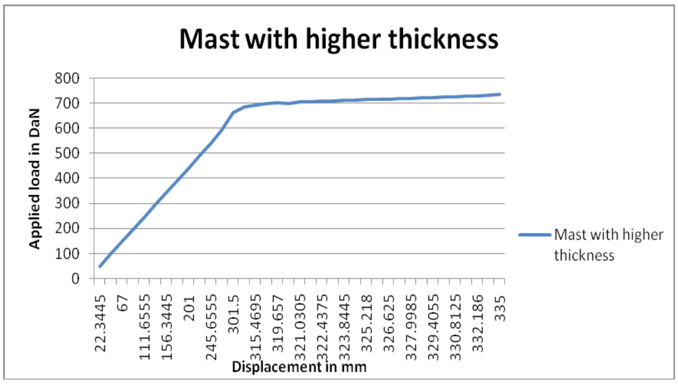

Figure 11.Numerical simulation result of mast with higher thickness

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 12.

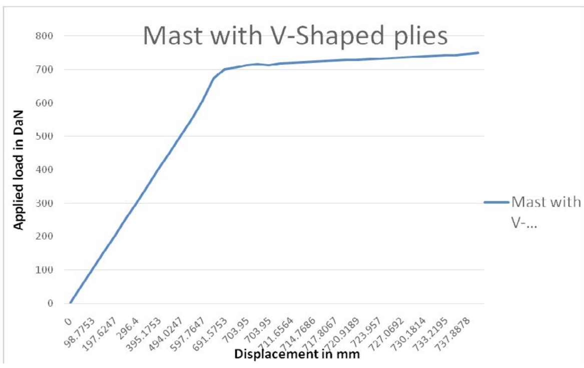

Figure 12.Numerical simulation result of mast with V-Shaped plies

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

Coclusion

The deflection test show as that the stiffeners add give us a better resistant of the masts. The figure 13 show as the summary of the three masts deflection tests.

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.

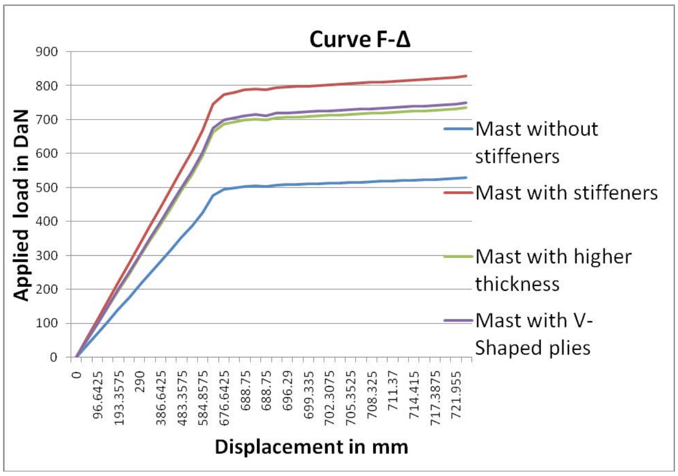

Figure 13.Deflection tests results of the three masts

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.

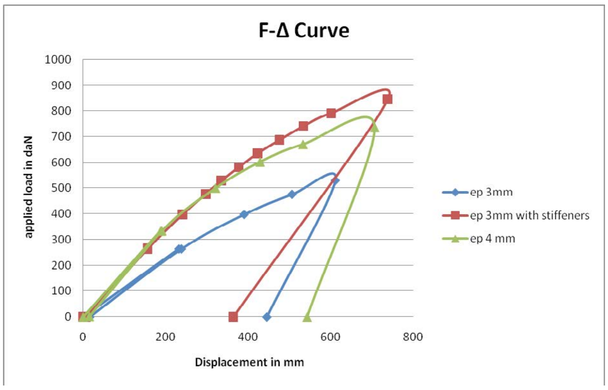

Figure 14.Elastoplastic analysis result

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.

References

1. Règles CM66 et additif 80: Règles de calcul des constructions en acier, Eyrolles.
2. Règles NV65 et N84 modifiées 95: Règles définissant les effets de la neige et du vent sur les constructions et annexes, Douzième édition, Eyrolles.
3. NF EN 1993-3-1. Eurocode 3: Calcul des structures en acier. Partie 3-1: Tours, mâts et cheminées - Pylones et mâts haubanés. AFNOR 2007; 1-82.
4. NF EN 1991-1-4. Eurocode 1: Actions sur les structures. Partie 1-4: Actions générales - Actions du vent. AFNOR 2005; 1-125.
5. Save MA, Massonnet CE, De Saxce G. Plastic limit analysis of plates, shells and disks. 2nd Ed. The Netherlands: Elsevier Sciences B. V, 1997.
6. EN40-2. Candélabre d'éclairage public. Partie 2: Prescriptions générales et dimensions. AFNOR 2005; 1-24.
7. Rahui S, Dirhar MA, Jalal SE, Bousshine L, El Maskaoui Z, Mechanical strength of public lighting masts, ACMA 2014; 1-4.
8. EN40-3-2. Candélabre d'éclairage public. Partie 3-2: Conception et vérification: vérification par essais. AFNOR 2000; 1-16.