Simulation of 15 Meter Mitas REV3

Date: donderdag 23 april 2020
Designer: Mark Koopman
Study name: Static 1
Analysis type: Static

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Omschrijving

Statische berekening van een 15 meter mast voor een Bestwatt 10Kw MKII windturbine.

Technische gegevens

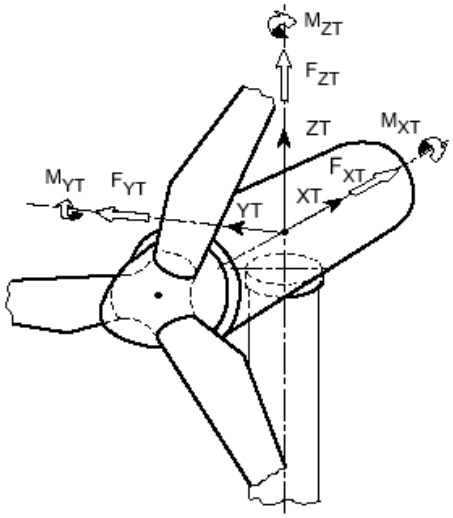
Type turbine:	Bestwatt 10Kw MKII
Vermogensregeling:	Overtrek
Nominaal vermogen:	10Kw
Maximaal vermogen:	15Kw
Aantal wieken:	3
Nominaal toerental:	Variabel 70-85 RPM
Maximaal toerental:	95 RPM
Rem:	Passief remsysteem normaal gesloten.
Over toeren beveiliging:	Centrifugaal rem door middel van wiek tip veren.
Startwindsnelheid:	2,5 m/s
Windsnelheid vollast:	9 m/s
Uitschakel windsnelheid:	25 m/s
Temperatuurbereik:	-20°C ... +30°C

Ontwerp voor IEC windklasse 2:

- Naafhoogte: 15 m
- Gewicht gondel: 1014 Kg
- Eigen frequentie Gondel:
  - 1p bij nominaal toeren: 1,16 - 1,41Hz
  - 3p bij nominaal toeren: 3,48 - 4,25Hz
- Hart afstand naaf tot bovenzijde mast: 374 mm
- Totale hoogte mast: 14626 mm
- Fundering: Buisfundering; lengte op basis van sondering.

Toren berekening

De richting van de krachten word hieronder weergegeven volgens het Turbine Coordinate system torentoplasten.



As X word aangeduid als de hartlijn vanuit de naaf. Dit coördinaat vertegenwoordigt de kracht die optreed in horizontale richting.
As Y word aangeduid als de horizontale lijn haaks op de rotor as. Dit coördinaat vertegenwoordigt de kracht die optreed in zijdelingse richting.
As Z word aangeduid als de hartlijn van de toren. Dit coördinaat vertegenwoordigt de kracht die optreed in verticale richting.
My word aangeduid als het koppel wat optreed om as Y, dit is het kiepmoment van de gondel.
Mx word aangeduid als het koppel wat optreed om as X, dit is het aandrijfmoment van de gondel.

Uitgangspunten

De toren van de turbine is berekend volgens de torentoplasten uit onderstaand rapport. De toren is hier berekend in het belastinggeval Extreem parkeren bij een windsnelheid op ashoogte van V_e50 =59,5 m/s (IEC klasse 2). De rotor volgt de wind, het frontaal oppervlak van de rotor geeft dan de maximale bijdrage aan het voetmoment.
Voor het simuleren van de optredende krachten in de torentop is gekozen voor het gebruik van de resultante:

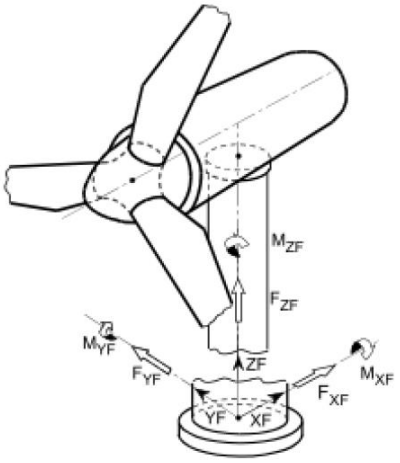
Fxy:	24,12kN
Fz:	9,9kN
Mxy:	14.81kNm 200

Extreme Loads Calculation Tower

General inputs — Date: 15-04-20

Wind turbine			BW 10/15 15m tower				Wind regime	61400-2{ed1.0} Safety	
Load case			Extreme tower bending moment					small wind turbines.p	
Filename:			T20m-BW10.xls				NEN	1	
Consequence of failure			1.00						
Load factor wind gFa			1.35 (NVN/IEC)						
Load factor gravity			1.35 force	0.9 moment (IEC)					
Material factor gM			1.00 (IEC/NVN)						
Re_16			355 MPa	S235J2G3					
Re_40			355 MPa	S235J2G3					
dH_torent	0.614			2nd mode	Maak alle CD's 0			7.96E-08	
Inputs for extreme loads calculation				routine	Maak MYGH 0			1.26E+07	
14.81	24.12	FXYaHtemp	6.19	MYGHtemp	Maak FXYH 0				
V_Hub	59.5	m/s	A_hub+nac	0.6	m2 (0.87m diam.)	Maak MYXH = .001 (1 N)			
H_hub	15.1	m	Cd_hub+nac	1.2	-	Maak uflex 0 met solver op FXYa			
FXYa_H	24.12	kN	G_nac	4.2	kN (pos)	dan is K_2nd = 1/alfa_flx (waarde plakken)		m_generat	440
FZR_H	9.9	kN	L_nac	0.42	m	maak grafiek van alfa en u over de hoogte		helft rotor	helft nac
MXYa_H	14.81	kNm	G_rot	5.75	kN (pos)				
H_high	14.460	m	L_rot	0.77	m	tower top moment 23.16 [kNm]	14.5 [m]		
H_low	0.000	m	MYg_H	6.19	kNm	tower half moment 227.15 [kNm]	7.2 [m]		
D_high	0.400	m	A_blades	7.02	m2	tower foot moment 497.64 [kNm]	0.0 [m]		
D_low	0.775	m	CD_blades	1.45	-	Polynom const1: 0.636			
M0	0.026	m/m	CD_tower	1.2	-	Polynom const2: -42.01			
M1	0.026	m/m	rho_Fe	8500	kg/m3	Polynom const3: 498			
M2	0.026	m/m	z_0	0.03	m	15 m voetdiameter			
step	0.201	m				schaalft: 25.83 775		X is hori	
Extreme loads calculation (stresses include load factor but no material factor)							Mininum SRF	Y is hoog	1.46

Het moment op de voet van de toren is in onderstaande tabel weergegeven, voor het berekenen van de funderingsbuis hanteert fa. Fubo consult de onderstaande tabel met het daarbij horende Coordinate system torenvoet.



XF horizontal
ZF vertically upwards in direction of the tower axis
YF horizontally sideways, so that XF, YF, ZF rotate clockwise

Fig. 4.A.6 Tower bottom coordinate system

	Ashoogte 15m			Ashoogte 20 m			Ashoogte 25m		
Windklasse	Fx kN	Fz kN	My kNm	Fx kN	Fz kN	My kNm	Fx kN	Fz kN	My kNm
IEC class 2	41.7	-27.9	498.0	51.07	-29.7	741.0	58.9	-43	1026.0
IEC class 3	32.5	-27.9	389.0	39.8	-29.7	579.0	45.8	-43	515.0
IEC class 4	20.8	-27.9	252.0	25.5	-29.7	374.0	29.3	-43	515.0

Model Informatie

Model name: 15 Meter Mitas REV3
Current Configuration: Default

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Funderingsbuis L=6000mm.SLDPRT 	Solid Body	**Mass:2.060,52 kg** **Volume:0,26417 m^3** **Density:7.800 kg/m^3** **Weight:20.193,1 N**	**C:\Users\mk\Documents\BESTwind\Tekeningen Solidworks\Berekening Mitas 15 meter Definitief\Mast Tekening en Simulatie REV2\Onderdelen\Funderingsbuis L=6000mm.SLDPRT** Apr 22 14:35:48 2020

Mastdeel 2.SLDPRT 	Solid Body	**Mass:473,017 kg Volume:0,0606432 m^3 Density:7.800 kg/m^3 Weight:4.635,57 N**	**C:\Users\mk\Documents\BESTwind\Tekeningen Solidworks\Berekening Mitas 15 meter Definitief\Mast Tekening en Simulatie REV2\Onderdelen\Mastdeel 2.SLDPRT** Apr 22 20:52:05 2020
Mastdeel3.SLDPRT 	Solid Body	**Mass:335,724 kg Volume:0,0430415 m^3 Density:7.800 kg/m^3 Weight:3.290,09 N**	**C:\Users\mk\Documents\BESTwind\Tekeningen Solidworks\Berekening Mitas 15 meter Definitief\Mast Tekening en Simulatie REV2\Onderdelen\Mastdeel3.SLDPRT** Apr 22 20:52:43 2020
Ondermast.SLDPRT 	Solid Body	**Mass:870,153 kg Volume:0,111558 m^3 Density:7.800 kg/m^3 Weight:8.527,5 N**	**C:\Users\mk\Documents\BESTwind\Tekeningen Solidworks\Berekening Mitas 15 meter Definitief\Mast Tekening en Simulatie REV2\Onderdelen\Ondermast.SLDPRT** Apr 23 13:15:53 2020
Topmast.SLDPRT 	Solid Body	**Mass:256,142 kg Volume:0,0328387 m^3 Density:7.800 kg/m^3 Weight:2.510,19 N**	**C:\Users\mk\Documents\BESTwind\Tekeningen Solidworks\Berekening Mitas 15 meter Definitief\Mast Tekening en Simulatie REV2\Onderdelen\Topmast.SLDPRT** Apr 22 20:52:35 2020

Studie Eigenschappen

Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	25 Celsius
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\mk\Documents\BESTwind\Tekeningen Solidworks\Berekening Mitas 15 meter Definitief\Mast Tekening en Simulatie REV3\Simulation Results)

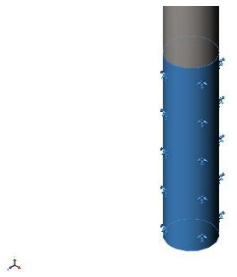
Eenheden

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Celsius
Angular velocity	Hertz
Pressure/Stress	N/mm^2 (MPa)

Materiaal eigenschappen

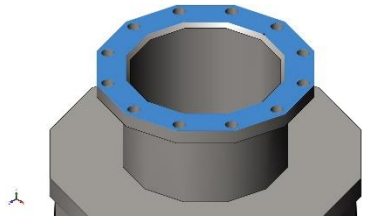
Model Reference	Properties		Components
	**Name:** **Model type:** **Default failure criterion:** **Yield strength:** **Tensile strength:** **Elastic modulus:** **Poisson's ratio:** **Mass density:** **Shear modulus:** **Thermal expansion coefficient:**	1.0545 (S355N) Linear Elastic Isotropic Max von Mises Stress 275 N/mm^2 450 N/mm^2 210.000 N/mm^2 0,28 7,8 g/cm^3 79.000 N/mm^2 1,1e-05 /Kelvin	SolidBody 1(Split Line1)(Funderingsbuis L=6000mm-1), SolidBody 1(Cut-Extrude2)(Mastdeel 2-1), SolidBody 1(Cut-Extrude2)(Mastdeel3-1), SolidBody 1(Split Line1)(Ondermast-1), SolidBody 1(Chamfer3)(Topmast-1)
Curve Data:N/A			

Loads and Fixtures

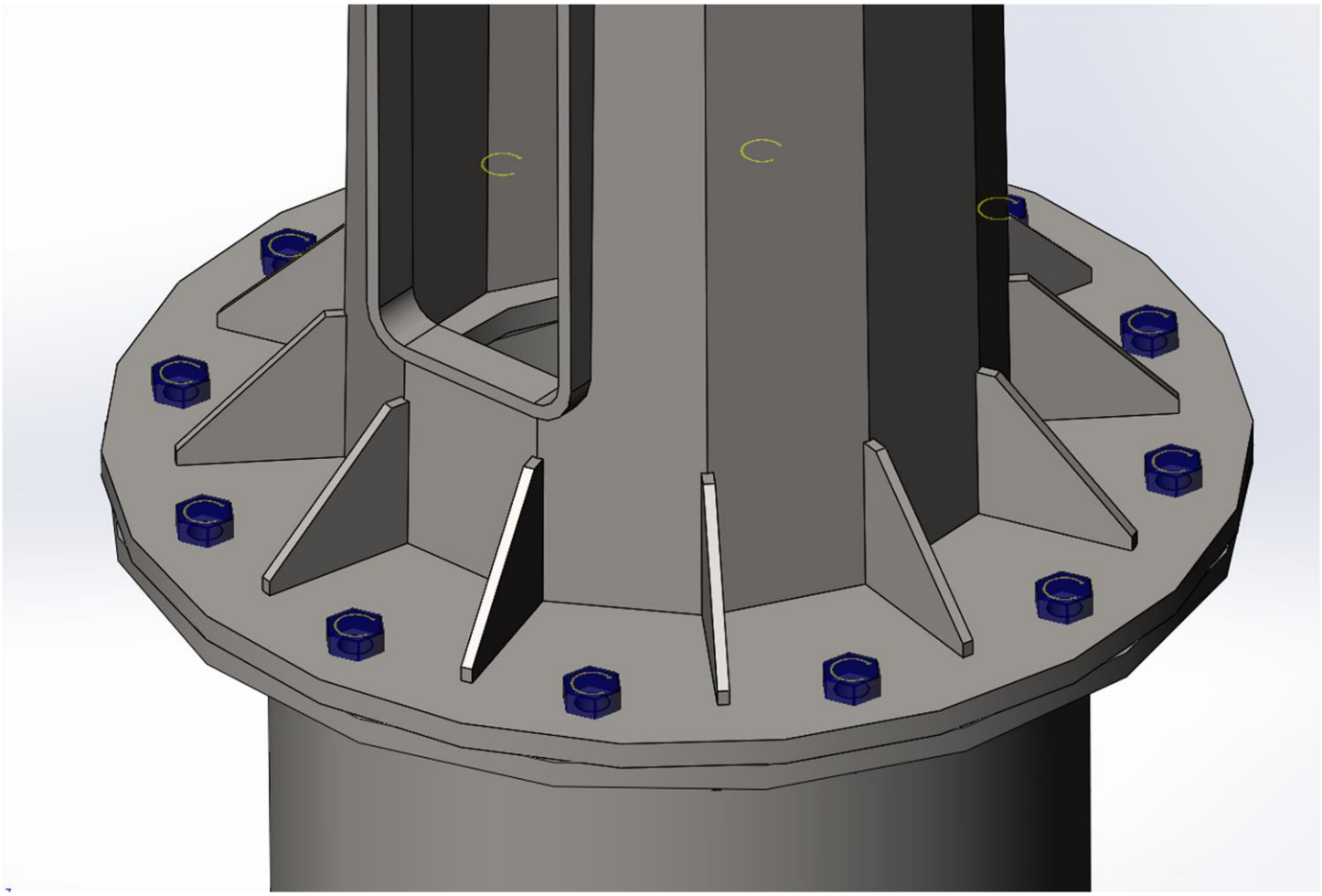
Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry

Resultant Forces

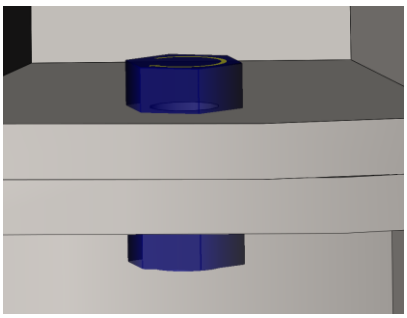
Components	X	Y	Z	Resultant
Reaction force(N)	-24.120,1	-9.900,01	-0,000722656	26.072,7
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Remote Load (Distributed connection)-1		**Entities:** 1 face(s) **Connection Type:** Distributed **Weighting Factor:** Default (Constant) **Coordinate System:** Coordinate System1 **Translational Components:** 24.120 N;---;9.900 N **Rotational Components:** ---;14.810 N.m;--- **Reference coordinates:** 0 0 0 cm

Connector Definities



Pin/Bolt/Bearing Connector

Model Reference	Connector Details	Strength Details
 Counterbore with Nut-1	Entities: 2 edge(s) Type: Bolt(Head/Nut diameter)(Counterbore) Head diameter: 65 mm Nut diameter: 65 mm Nominal shank diameter: 42 mm Preload (Torque): 3.000 Young's modulus: 2,1e+11 Poisson's ratio: 0,28 Preload units: N.m	No Data

Connector Forces Counterbore with Nut-1

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,5803e+05	0	3,5803e+05
Shear Force (N)	-518,27	0	-909,61	1.046,9
Bending moment (N.m)	12,929	0	-26,517	29,501

Connector Forces Counterbore with Nut-2

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,6582e+05	0	3,6582e+05
Shear Force (N)	-891,65	0	-433,36	991,39
Bending moment (N.m)	-42,023	0	27,787	50,379

Connector Forces Counterbore with Nut-3

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,7639e+05	0	3,7639e+05
Shear Force (N)	-838,5	0	-418,19	937
Bending moment (N.m)	-32,223	0	109,17	113,83

Connector Forces Counterbore with Nut-4

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,7638e+05	0	3,7638e+05
Shear Force (N)	-661,94	0	-718,67	977,06
Bending moment (N.m)	78,02	0	122,68	145,39

Connector Forces Counterbore with Nut-5

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,6679e+05	0	3,6679e+05
Shear Force (N)	-106,7	0	769,44	776,81
Bending moment (N.m)	33,686	0	62,967	71,412

Connector Forces Counterbore with Nut-6

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,5764e+05	0	3,5764e+05
Shear Force (N)	103,05	0	2.068,1	2.070,6
Bending moment (N.m)	-48,792	0	1,7825	48,824

Connector Forces Counterbore with Nut-7

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,5674e+05	0	3,5674e+05
Shear Force (N)	1.287	0	2.998,8	3.263,3
Bending moment (N.m)	-97,086	0	55,955	112,06

Connector Forces Counterbore with Nut-8

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,5693e+05	0	3,5693e+05
Shear Force (N)	4.726,3	0	2.877,6	5.533,3
Bending moment (N.m)	-105,35	0	188,38	215,84

Connector Forces Counterbore with Nut-9

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,5666e+05	0	3,5666e+05

Shear Force (N)	7.206,3	0	601,72	7.231,3
Bending moment (N.m)	-13,136	0	243,13	243,48

Connector Forces Counterbore with Nut-10

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,5663e+05	0	3,5663e+05
Shear Force (N)	7.131	0	-1.575,5	7.303
Bending moment (N.m)	47,713	0	244,11	248,73

Connector Forces Counterbore with Nut-11

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,5703e+05	0	3,5703e+05
Shear Force (N)	5.084,3	0	-2.832,1	5.819,9
Bending moment (N.m)	102,88	0	192,52	218,29

Connector Forces Counterbore with Nut-12

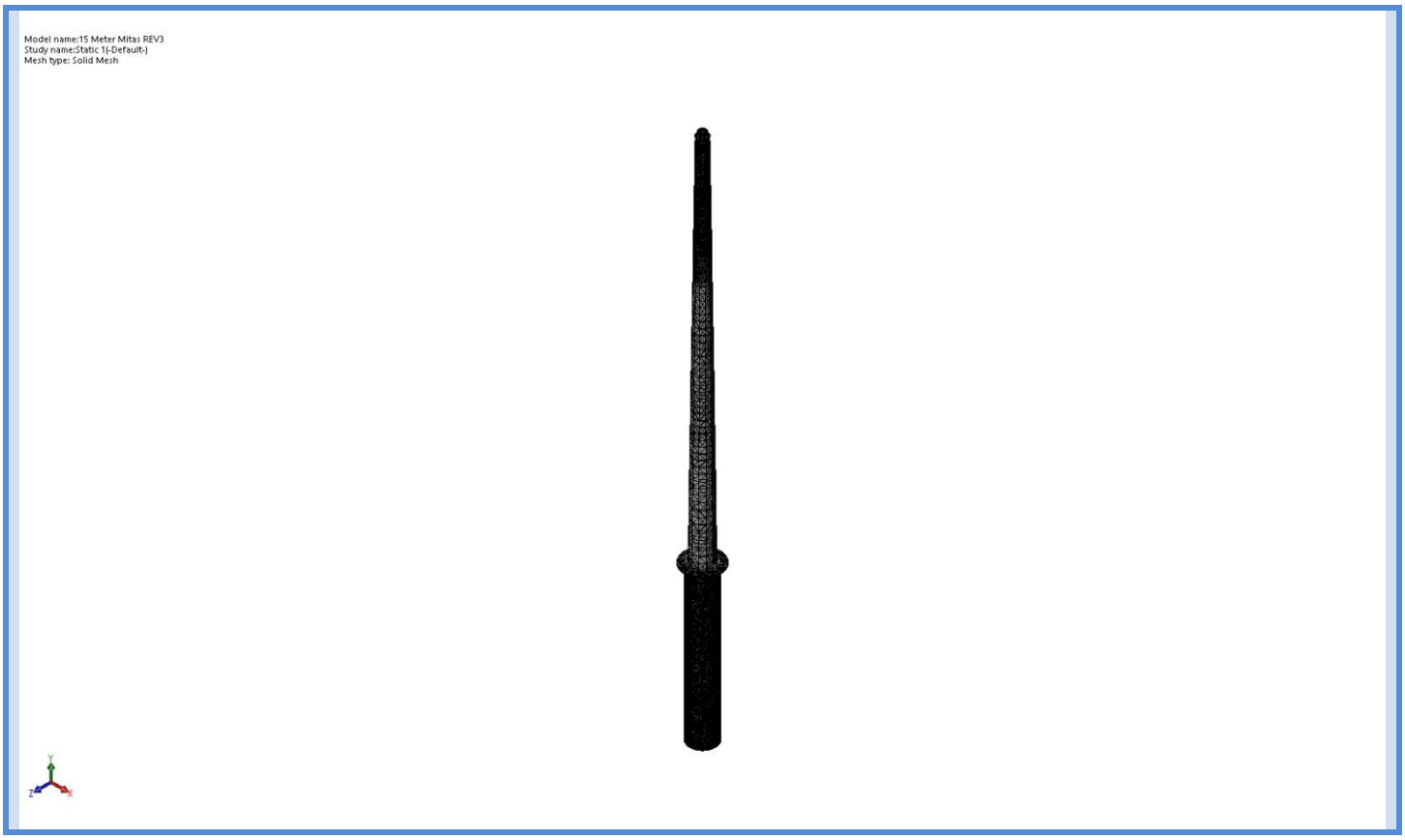
Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	0	3,5697e+05	0	3,5697e+05
Shear Force (N)	1.599,2	0	-2.428,1	2.907,5
Bending moment (N.m)	77,365	0	66,412	101,96

Mesh informatie

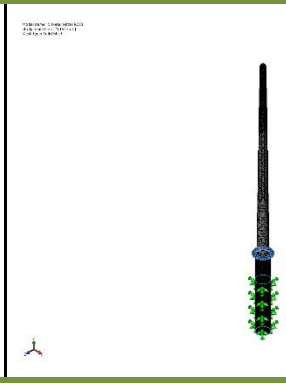
Mesh type	Solid Mesh
Mesher Used:	Curvature-based mesh
Jacobian points	4 Points
Maximum element size	259,041 mm
Minimum element size	51,8083 mm
Mesh Quality Plot	High
Remesh failed parts with incompatible mesh	Off

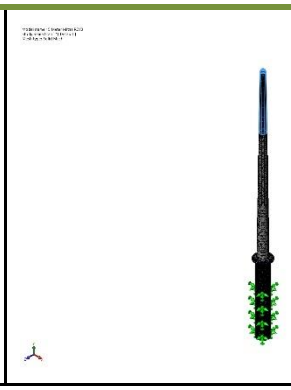
Mesh information - Details

Total Nodes	137654
Total Elements	69577
Maximum Aspect Ratio	444,66
% of elements with Aspect Ratio < 3	12,1
% of elements with Aspect Ratio > 10	27,4
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:19
Computer name:	BETTINK-NB33



Mesh Control Information:

Mesh Control Name	Mesh Control Image	Mesh Control Details
Control-1		**Entities:** 1 Solid Body (s) **Units:** mm **Size:** 54,1281 **Ratio:** 54,1281

Control-2		**Entities:** 1 Solid Body (s) **Units:** mm **Size:** 66,0786 **Ratio:** 66,0786

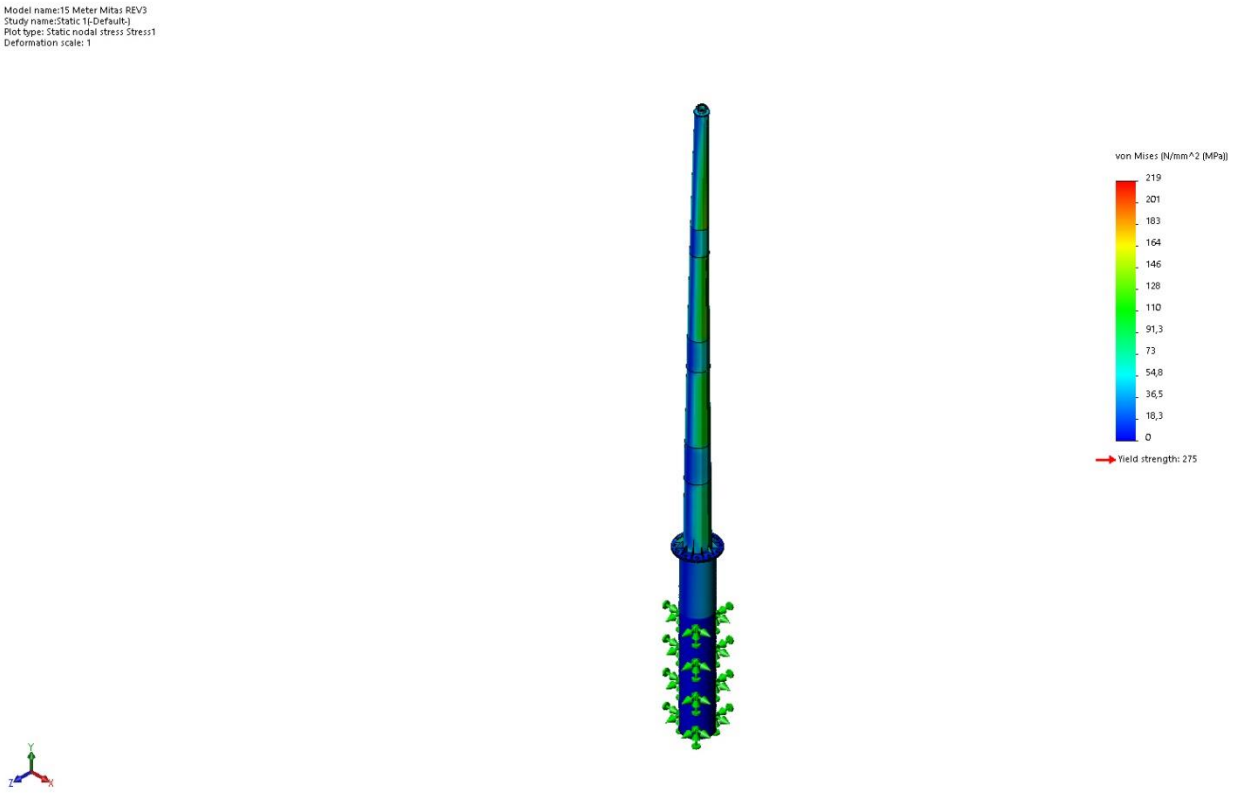
Resultant krachten

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-24.120,1	-9.900,01	-0,000722656	26.072,7

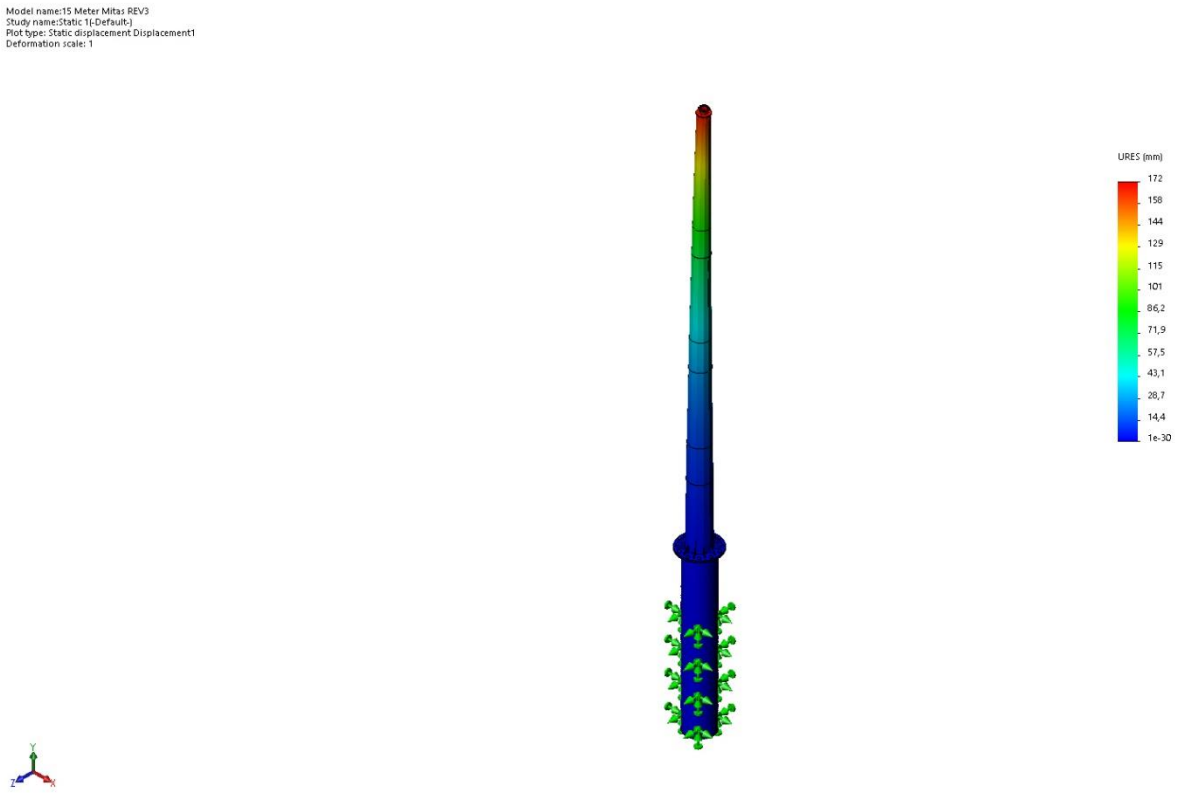
Studie resultaten

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0N/mm^2 (MPa) Node: 330	219N/mm^2 (MPa) Node: 104328



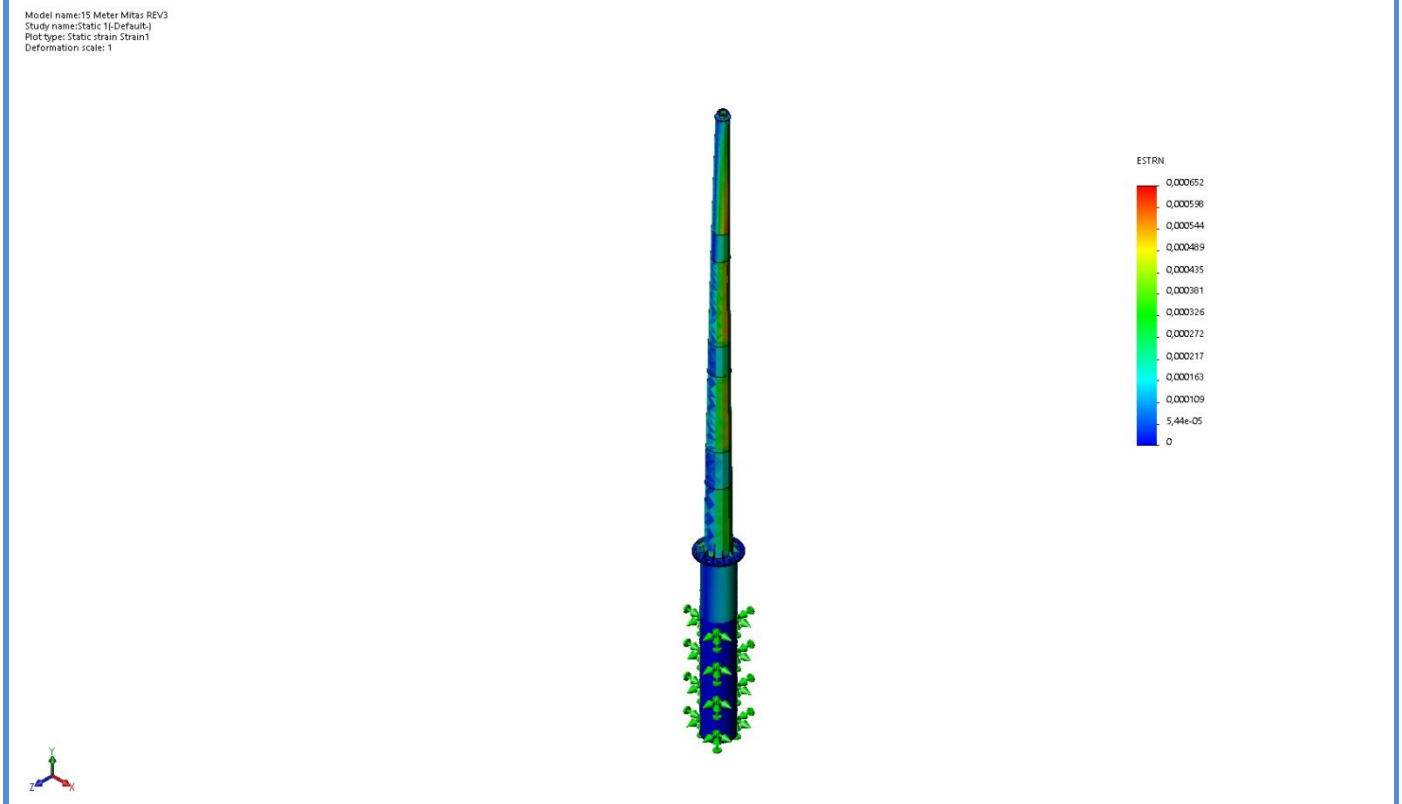
15 Meter Mitas REV3-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0mm Node: 1	172mm Node: 117007



15 Meter Mitas REV3-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0 Element: 1	0,000652 Element: 53382



15 Meter Mitas REV3-Static 1-Strain-Strain1

Conclusie

De spanningsreserve is gelijk aan de rekgrens/(gF*Sigma) = 355/(1.35*219) = 1,20.

Deze is groter dan 1 dus de toren is statisch goedgekeurd.