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FEA of NSW structure to predict deflection during a large assembly

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Abstract. The article describes the application of FE analysis as a prediction of deflection, and a survey of measurement methods to control the real deflections during the assembly steps of New Small Wheel (NSW) support structure. The FEA method of additive mass and stiffness was used to simulate assembly steps and was therefore the important tool for planning the whole assembly procedure. To achieve the required detector performance, the geometry is controlled, the deflections are measured using survey techniques and after that compensated in specific assembly steps.

Introduction

The project of the NSWs consists of the replacement of the forward regions of the ATLAS detector and is part of the muon system upgrade due to the increase of the instantaneous luminosity in the next upgrades, [1], [2]. The ATLAS detector is one of the four major experiments of the LHC (Large Hadron Collider) at CERN (European Organization for Nuclear Research), and with the dimensions at 46 m long, 25 m in diameter and 7000 tons in weight is the largest particle detector, as seen in Figure 1.

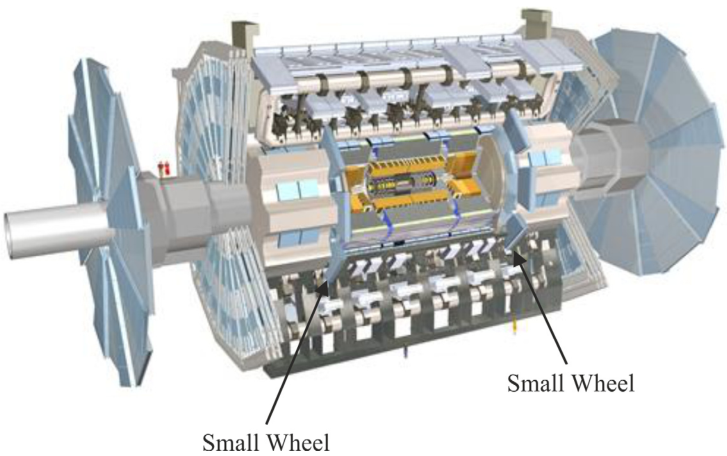

Fig. 1: ATLAS detector

The design of the NSWs and the choice of material was done to achieve optimal weight and strength of the NSW support structure to meet physics requirements. Because of the size, shape and weight of the structure, great attention is given to the assembly procedure of the NSW. In general, the analysis of structures using different methods is crucial in CERN, example can be found in [3].

Method

The mechanical study was used for dimensioning and calculating of the final deflection shape of the structure. The rigidity of the structure is permanently changing during each assembly step. Therefore, it was of interest to predict the influence of each assembly step on the final deformation so that it could be stepwise compensated. The compensation is done based on the analysis of the results from FE and measurement by lifting up the extremity of the hub with the crane while the feet spokes are used for the shimming.

Investigated structure. The analysis and measurement was carried out on two support structures of New Small Wheel. The NSW is a disk-shape configuration of two detector technologies, i.e. sectors, placed on the support structure that consist of the shielding disc (NJD), hub, spokes and alignment system. The whole NSW is approximately 11 m in diameter and 100 tons in weight.

NSW structure assembly procedure. The first step of the NSW assembly procedure is the assembly of NJD, i.e. shielding disc, that consists of internal and external segments joined together by means of pined and bolted connections. The second step consists of the assembly of the shielding hub which is the main supporting structure of the spokes. Then the spokes are assembled on the hub. Each detection chamber is attached to the spokes by means of adjustable kinematics mounts. The last steps of the assembly are the installation of the A-plate and hub extension. The main assembly steps are shown in Figure 2.

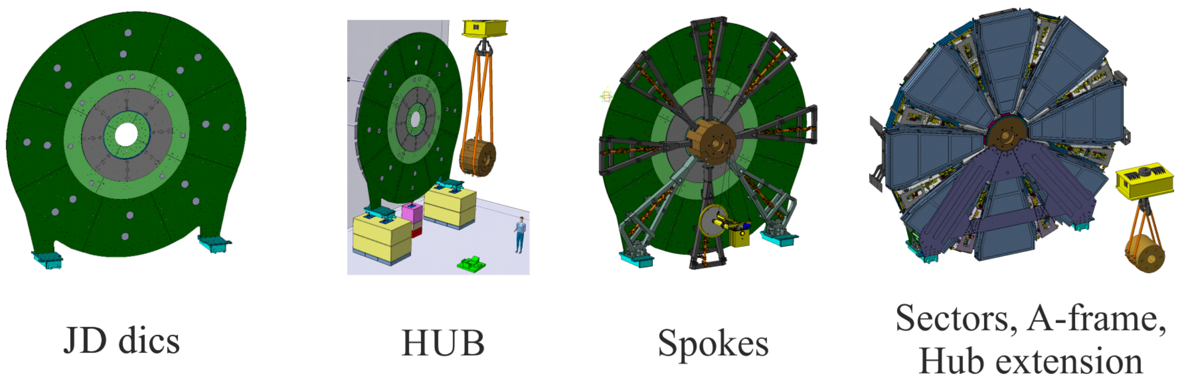

Fig. 2: NSW assembly steps

FE analysis

Specific FEA method was used to achieve the best possible information about the behaviour of the structure. Different loading states corresponding to the assembly steps were used for the simulations and to extract individual deflection contribution of each assembly step. Therefore, only the newly added components maintained the real density while the other components only retained the stiffness properties with a zero density. This method is the only one that can give the deformation and strength information of a structure during the different steps of the construction as its matrix of rigidity is changing at each step. From this method one can extract individual deflection contribution.

Simulation model. Based on the method one simulation model was used for each assembly step. The FE model of NSW was created as a deformable 3D solid model consisting of the components with material properties of steel or aluminium alloys. The example of the simulation model with the meshing and boundary conditions is in the figure 3. The used elements for meshing are 10-node tetrahedrons or 8-node hexahedrons with element size of approximately 50 mm. The boundary conditions are applied in poles that are fixed at the extremities and at the level of JD feet where one is remote displacement with free rotations and fixed translations and the other is longitudinal (vertical) with defined stiffness.

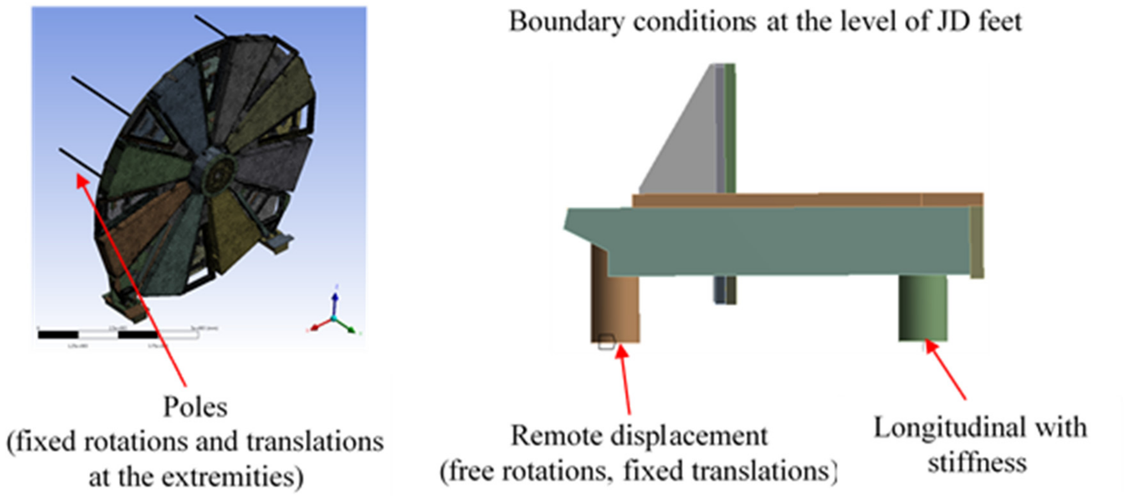

Fig. 3: Simulation model with boundary conditions

FE analysis results. Vertical deformation measured on the specific place on the hub was used for the subsequent analysis of simulation results. This corresponds to the place where the deflections are measured using survey techniques.

The loading states corresponding to the assembly steps are numbered from 1 to 9 are summarized together with the results in table 1. Hub deflection show the individual contribution to the deformation of each assembly step. Cumulative hub deflection gives information of the total increasing deformation during the assembly procedure.

Table 1: Loading states

Loading state	Description of the structure	Hub deflection [mm]	Cumulative hub deflection [mm]
1	JD + Poles	-1.06	-1.06
2	JD + Poles + Hub	-1.27	-2.33
3	JD + Poles + Hub + Small Sector Spokes (SSS)	-0.05	-2.38
4	JD + Poles + Hub + SSS + Small Sectors (SS)	-0.05	-2.44
5	JD + Poles + Hub + SSS + SS + Large Sector Spokes (LSS)	-0.08	-2.52
6	JD + Poles + Hub + SSS + SS + LSS + Large Sectors (LS)	-0.13	-2.65
7	JD + Poles + Hub + SSS + SS + LSS + LS + A-Plate	-0.02	-2.67
8	JD + Poles + Hub + SSS + SS + LSS + LS + A-Plate + Hub Extension	-0.11	-2.78
9	JD + Hub + SSS + SS + LSS + LS + A-Plate + Hub Extension	-0.42	

The results analysis assumes the compensation of both NSWs between the assembly steps 2 and 3. Using the specific FE method of additive mass and stiffness, the contribution of the deformation by the removing the poles (step 8 → step 9) is -0.32 mm and the total cumulative hub deflection is -3.09 mm. In order to achieve the needed value for the compensation of deflections by the hub lifting, the premise is considered that the deformation of the assembled JD disk was compensated with help of poles, i.e. the loading state 1 is used as a reference. Then the total compensation should be approximately 2 mm of hub lifting.

Compensation of the deflections

The schematic procedure of the deflection compensating is shown in figure 4. The main purpose is to eliminate the deformation of the final NSW during the assembly steps in advance. The compensation was conducted by pulling up the extremity of the hub by means of the overhead crane of the building.

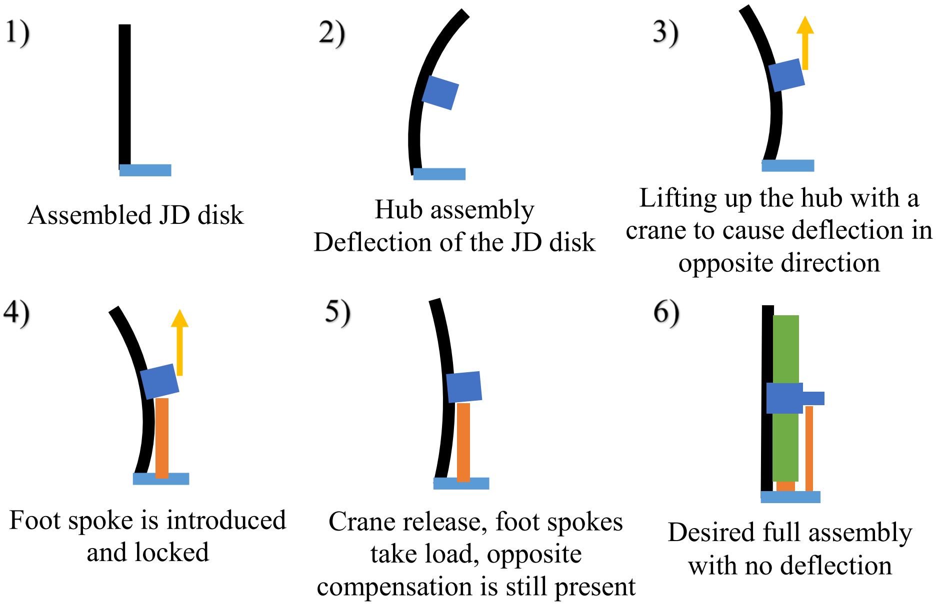

Fig. 4: Compensation of the deflections

Conclusions

The actual results and compensations of the deformation obtained from the ongoing NSW assembly process correspond to the requirements. It concludes that appropriate use of FEA methods together with precise control with survey techniques can be used to predict and deformations compensation during the assembly of large objects.

References

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