How to cite this article:

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Title of article: „Analiza wytrzymałościowa belki opryskiwacza z wykorzystaniem systemów CAD/CAE" ("Strength analysis of a boom sprayer with the use of CAD/CAE systems")

Mechanik, Vol. 91, No. 7 (2018): pages 549–551

DOI: https://doi.org/10.17814/mechanik.2018.7.80

Strength analysis of a boom sprayer with the use of CAD/CAE systems

Analiza wytrzymałościowa belki opryskiwacza z wykorzystaniem systemów CAD/CAE

WALDEMAR DUDDA*

Presented are the results of strength analysis of the Pilmet boom sprayer. After creating the numerical model of the boom, a static analysis was carried out. Stresses and displacements were determined using the finite element method for different variants of the folding boom position.
KEYWORDS: boom sprayer, stress, displacements

One of the main sprayer assemblies is the support (field) beam. It serves to fasten the equipment for spraying liquids, which includes pipes, nozzles and nozzle heads.

The beam span may reach up to 50 m. Such wide beams are exposed to large fluctuations, and thus to significant dynamic loads, caused by movement on unevenly shaped land surface.

Already slight fluctuations in the central part of the beam cause high accelerations of its ends, which on one hand may lead to the fact that some of the plants will not be covered with liquid [1], and on the other – may cause cracking of welded joints and profiles.

Therefore, to limit beam variations, various stabilization systems are used [2, 3]. It is required that the construction of the beam in such working conditions be characterized by relatively high stiffness and, at the same time, the lowest mass.

The purpose of the works described in this article is strength analysis of the field boom of the Pilmet sprayer.

Subject of study

The subject of the analysis is the field boom of a mounted sprayer (fig. 1) from Pilmet.

The beam is made up of eight segments connected to each other articulated with bolts. Segments are folded and unfolded electro-hydraulically using actuators. The working width of the beam assembly is 18 m. The individual segments are made of pipes with a rectangular and square profile. The entire beam structure is mounted on a trapezoidal suspension system.

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Fig. 1. Sprayer with boom

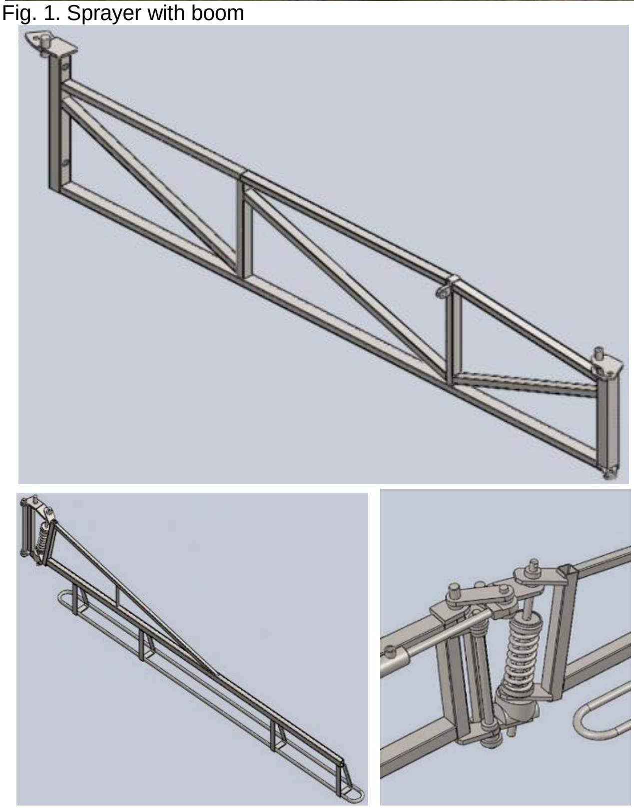

Fig. 2. Examples of modeled beam segments and their joining

The beam's numerical model was created in the SolidWorks program. The necessary dimensions were determined based on measurements of the actual structure and the operating instructions. Examples of modeled beam segments and connection methods are shown in fig. 2, while the entire beam structure – fig. 3.

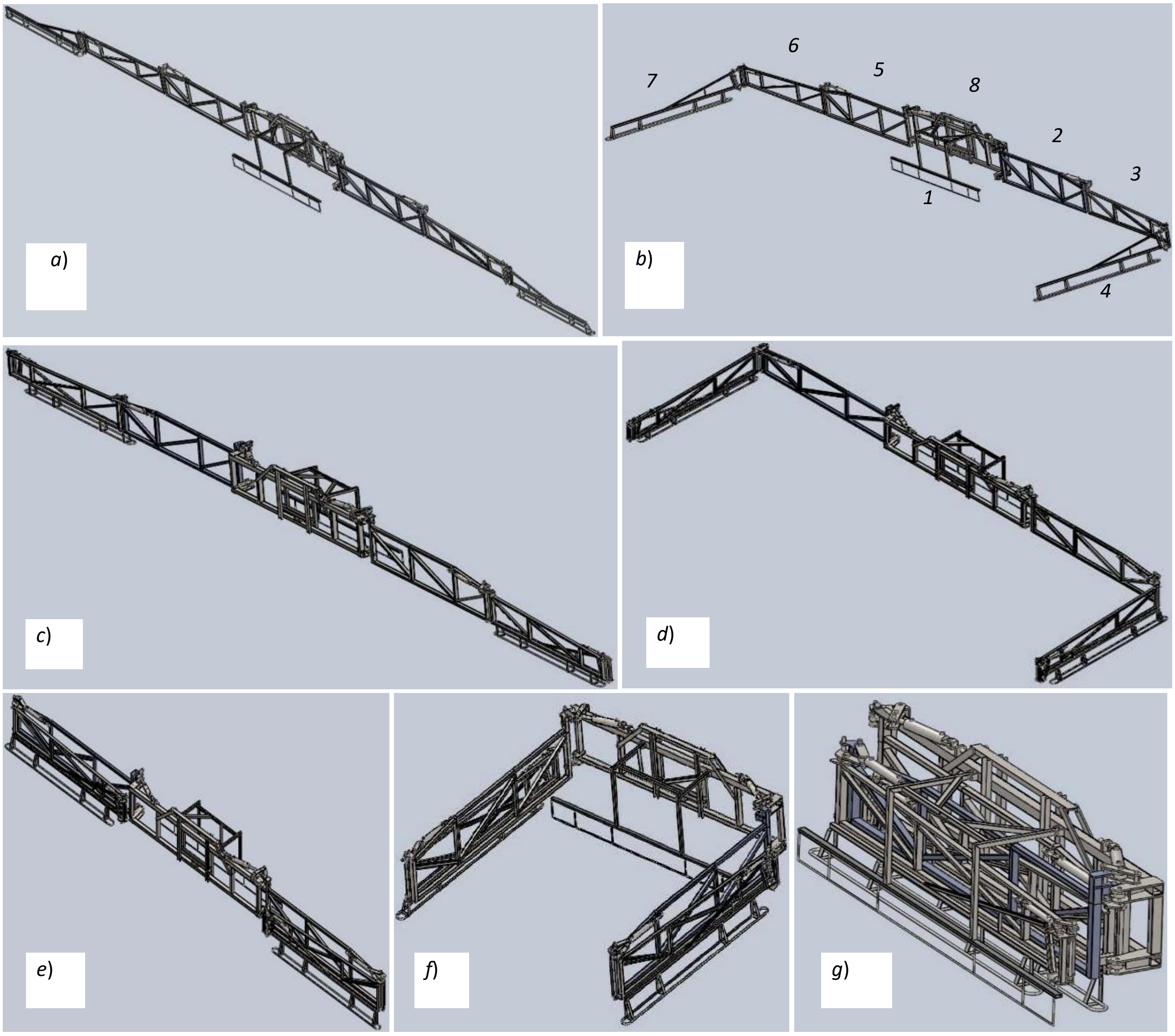

Fig. 3. Variants of distribution/assembly of beam segments (segment numbers – *b*)

Variants of strength analysis of a beam

The influence of the self-weight of the structure on its strength and stiffness was considered depending on the variants of the individual segments of the beam:

- A – beam completely folded in working position (fig. 3*a*),
- B – extreme segments set at an angle of 90º to the plane of the beam (fig. 3*b*),
- C – extreme beam segments completely complex (fig. 3*c*),
- D – segments 4 and 7 folded into segments 3 and 6, which are laid at an angle of 90º to the working plane of the beam (fig. 3*d*),
- E – segments 4 and 7 and 3 and 6 folded into segments 2 and 5 (fig. 3*e*),
- F – segments 2 and 5 laid out at an angle of 90° with folded remaining segments (fig. 3*f*),
- G – segments folded to the transport position (fig. 3*g*).

Results of strength analysis

A static analysis (FEM) was performed using CAD/CAE tools (SolidWorks Simulation) for each of the seven variants of setting the beam structure segments (figs. 3a-g). In all cases, the load was the self-weight. According to the instruction manual, the material properties corresponding to the structural steel S235JR were assigned to the model (former St3S designation). The fastening elements of the structure were fixed using fixed geometry constraints (fig. 4). The model was digitized by a three-dimensional (solid) grid based on curvature; tetrahedral elements (finite element type) were used.

In particular variants, the stresses reduced according to the Huber-Mises-Hencky hypothesis and displacement were determined. For variant A the maximum stress was 193.2 MPa and was located in segment 2 (fig. 5*a*), while the maximum displacement was 34.5 mm and took place in the extreme beam segment (fig. 5*b*).

In variant B, the maximum reduced stress was 205 MPa (fig. 6*a*) and took place in segment 2, while the maximum displacement amounted to approx. 139 mm (fig. 6*b*) and occurred in the extreme beam segment.

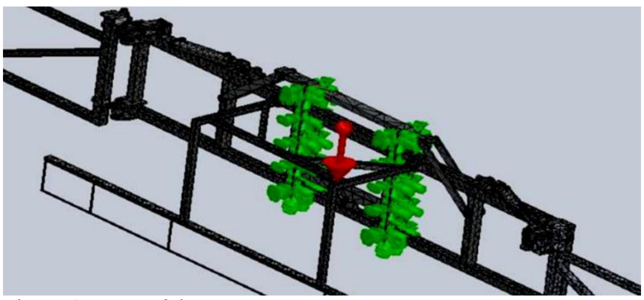

Fig. 4. Support of the structure

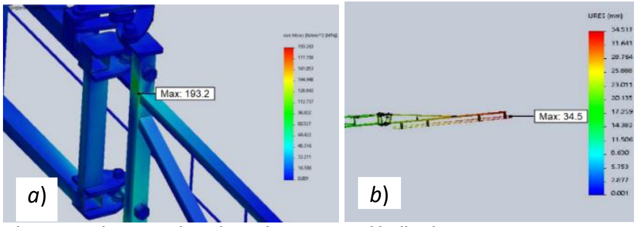

Fig. 5. Variant A: *a*) reduced stresses, *b*) displacements

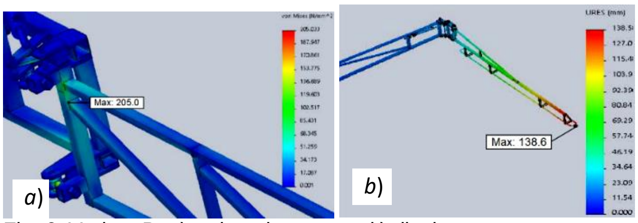

Fig. 6. Variant B: *a*) reduced stresses, *b*) displacements

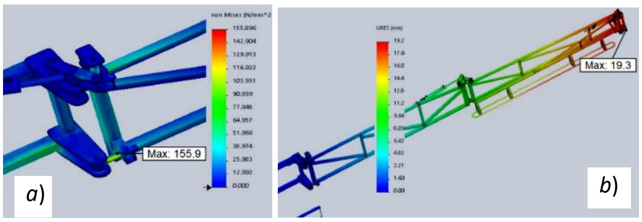

Fig. 7. Variant C: *a*) reduced stress, *b*) displacement

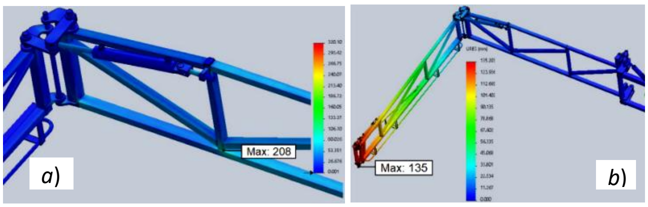

Fig. 8. Variant D: *a*) reduced stress, *b*) displacement

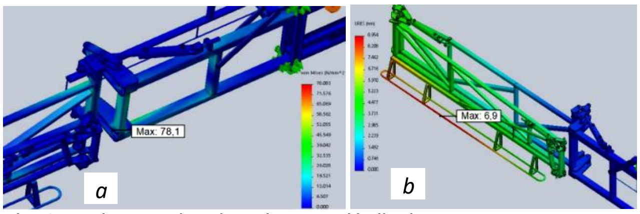

Fig. 9. Variant E: *a*) reduced stress, *b*) displacement

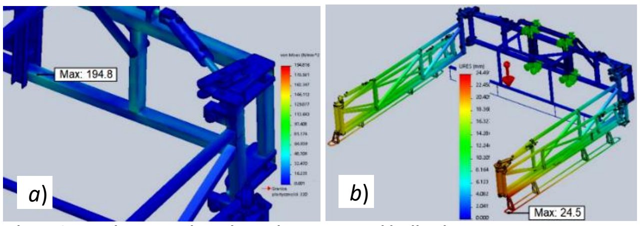

Fig. 10. Variant F: *a*) reduced stresses, *b*) displacements

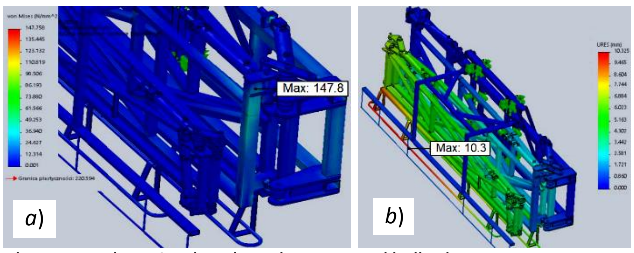

Fig. 11. Variant G: *a*) reduced stresses, *b*) displacements

The maximum tension in variant C was 156 MPa and took place in segment 2 (fig. 7*a*), the maximum displacement was 19.3 mm (fig. 7*b*) and occurred at the end of this segment.

In variant D of the arms' spreading, the maximum stress was 208 MPa and occurred in the central part of segment 5 (fig. 8*a*), the displacement amounted to ca. 135 mm and occurred on the joining of segments 6 and 7 (fig. 8*b*).

In variant E, the maximum stress was 78 MPa and occurred at the extreme pillar of segment 1 (fig. 9*a*), the maximum displacement was 9 mm and took place in the central part of segment 7 (fig. 9*b*).

The maximum stress in the F variant was 195 MPa and occurred in the central segment (fig. 10*a*), whereas the displacement – around 24 mm – occurred in the extreme part of segment 4 (fig. 10*b*).

With a completely folded beam (variant G), the maximum stress was 148 MPa (fig. 11*a*), and the maximum displacement was 10 mm and occurred in the central part of segment 4 (fig. 11*b*).

Conclusions

The analysis of the results shows that the most dangerous variant is D, in which the greatest reduced stresses occurred, amounting to 208 MPa (fig. 8*a*). However, the largest displacement, 138.6 mm, occurred in the B variant (fig. 6*b*). However, in option D (fig. 8*b*), the maximum displacement was slightly smaller than in the B variant and amounted to 135 mm. Both of these positions were characterized by the perpendicular arrangement of the segments in relation to the working plane of the beam.

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Translation of scientific articles, their computer composition and publishing them on the website www.mechanik.media.pl by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.

Ministry of Science and Higher Education
Republic of Poland