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Study Two-Dimensional and Three-Dimensional of the Stress Concentration of the Traction Arm of the NEW HOLLAND TT75 Tractor in Service in CHAD

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Abstract

The New Holland TT75 tractors currently in service in Chad use a tractor arm with three holes, the middle one of which has recurrent failures due to traction. The purpose of this work is to use a finite element model to provide an improvement by modifying the geometric parameters to avoid premature failure of the tractor arms of the New Holland TT75. The ultimate force formula of Eurocode 3 was used to determine the maximum pressure to be applied and. A comparative traction study between the current arm and the proposed arm was performed, taking into account the variation in hole size, arm width and applied pressure for the determination of the stress concentration factor Kt. With the determination of Kt and for the arm width (w) less than or equal to 85 mm; the results showed that the proposed arm geometry is better.

Keywords

Tractor, Stress Concentration Factor, Hole Diameter, Arm Width and Pressure

1. Introduction

For food self-sufficiency, tractors are indispensable for large-scale production. The arm of traction is one of the essential elements of the mechanical organs (of the coupling) which undergoes overloads by coming into contact with the ground and without which the tractor would not be able to carry out any field work.

The traction arm of the New Holland TT75 tractor was represented as shown in **Figure 1**.

This study has the objective of increasing the service life of these traction arms and static loads were applied.

The pressure P along the horizontal axis was applied for the determination of stresses and stress concentration factors.

Stress concentration is an indispensable factor to be taken into account when solving the mechanical problems of crack initiation and propagation in part designs. The phenomenon of stress concentration was first treated by [1] [2] for a problem of stress concentration around a hole. Then, analytical solutions were progressively found by different researchers for more and more complex part geometries. H. Neuber [3] and R.E. Peterson [4] have contributed a lot to the knowledge in this field by doing a systematic analysis for the main geometries and mechanical stresses encountered in design [5]. Although the research listed above has been conducted on similar cases as in the cases of the hole plates, no literature concerning the concentration of stresses specific to the tractor arms of the New Holland TT75 tractor in service in Chad has been studied before, and to date, no arms corresponding to the geometry of the proposed arm have been used on the tractors sold in Chad.

2. Materials and Methods

The numerical simulation is done by the ABAQUS/CAE 2017 calculation code. Mechanical loading of pressure $P = 75$ MPa ($P_{\max} = 158.01$ MPa for S235) and a length $L = 800$ mm ($L > 2W$). A mesh consists of C3D8R elements (eight-node element of parametric ISO types). Approximate global mesh size equal to 0.2 was chosen for the structure. Characteristic of the selected steel: Young's modulus 200 GPa, fish coefficient 0.3. Currently, design offices have only Eurocode3 to check the fatigue resistance of their structures [6].

The geometric parameters of the current tension arm were used to calculate the force to be applied. The resistance of the net section was calculated by the ultimate force formula of Eurocode3 [7] given by:

$$N_{uRD} = \frac{0.9 f_u A_{net}}{\Upsilon_{M2}} \tag{1}$$

f_u: ultimate traction resistance of the steel S235 ($f_u = 360$ MPa) [8];

A_{net}: net section area;

Υ_{M2}: resistance factor for the verification of assemblies ($\Upsilon_{M2} = 1.25$).

Equation (2) was used to determine the force (for the pressure calculation) to be applied [7]:

For the calculation of the applied pressure [7], Equation (2) was used to determine the force to be applied:

$$F \le \frac{N_{uRD}}{\Upsilon_R}. \tag{2}$$

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(a) (b)

Figure 1. Presentation of the traction arm of the New Holland TT75 tractor. (a) Current arm shown by ABAQUS/CAE 2017; (b) Photo taken at the sales plant of tractors in Chad.

Υ_R: resistance factor ($\Upsilon_R = 1.1$).

For the current arm dimensions (BA): d = 28 mm, W = 85 mm and t = 16 mm; the application would be:

$$A_{net} = (w - d) \times t = 912 \text{ mm}^2$$

$$N_{uRD} = \frac{0.9 \times 360 \times 912}{1.25} = 236.39 \text{ kN}$$

We find:

$$F \le \frac{236.39}{1.1} = 214.90 \text{ kN}.$$

Hence the value of the maximum force F that the tractor's traction arms can safely support for S235 steel is: F_{maxap} = 214.90 kN.

Pression maximale à appliquer:

$$P_{\text{maxap}} = \frac{F_{\text{maxap}}}{w \times t} = 158.01 \text{ MPa}.$$

For the pressure P = 75 MPa we have F = 102 kN.

Hole spacing according to Eurocode 3 [7]: $P_1 = 2.2d_0$; with $P_1 \ge 2.2d_0$ or proposed hole spacing: P_1 = 68 mm.

d_0: diameter of the hole.

The center distance chosen for the simulations is shown in **Figure 2**.

Equation (3) was used to obtain the stress concentration factor K_t [9]:

$$K_t = \frac{\sigma_{\max}}{\sigma_N}. \tag{3}$$

$\sigma_{\max}$: Maximum stress obtained from the traction simulation (S11max) and σ_N: Nominal stress is determined by the following relation:

$$\sigma_N = \frac{F}{(w - d) \times t}. \tag{4}$$

The rupture hole being the center one; Considering only the center hole we can reduce the study in 2D and use a quarter of the section as in **Figure 3**.

The different geometries of the arms (current arm and the proposed arm) are presented by **Figure 4**.

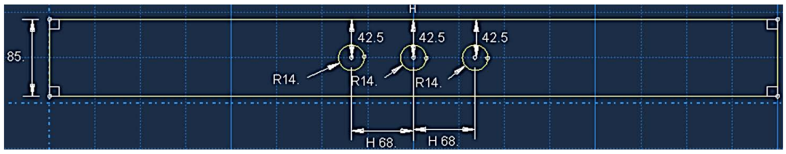


Figure 2. Selected center distance for the actual model.

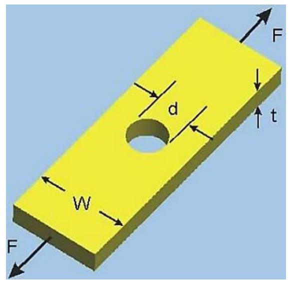
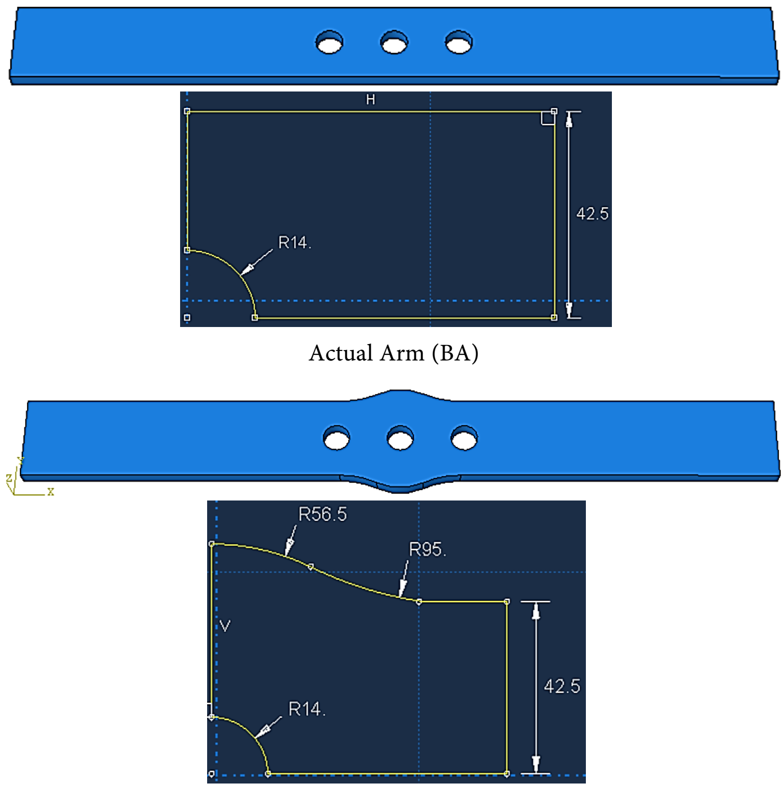


Figure 3. Different variable dimensions of a plate with holes [2].



Proposed Arm (BP):

Figure 4. Traction arm models.

3. Results and Discussions

3.1. Effect of Variation in Traction Arm Diameter

The simulation results obtained due to the variation of the hole diameter are shown in Figure 5 and Figure 6, and that of the stress concentration are indicated in Figure 7.

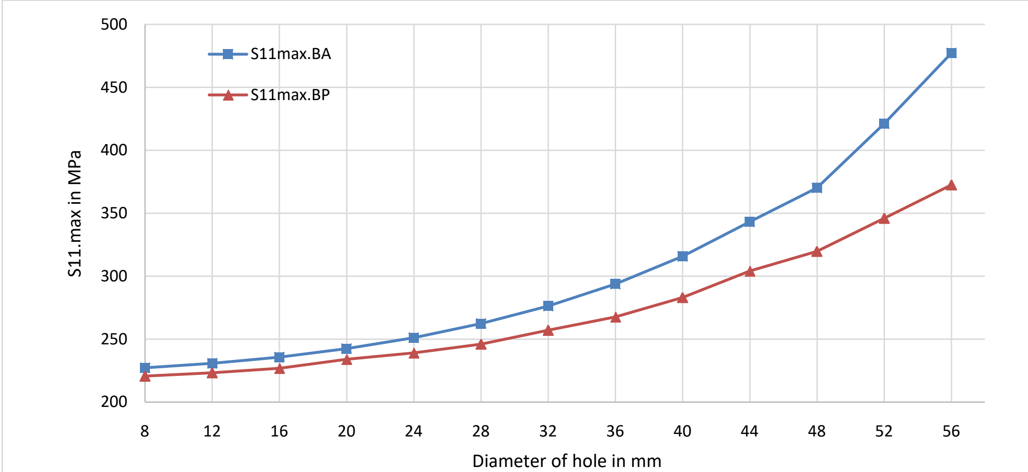


Figure 5. Variation of the normal traction stress (S11max) in function of the hole diameter of the actual arm (BA) and the proposed arm (BP) of New Holland TT75 tractor. W = 85 mm.

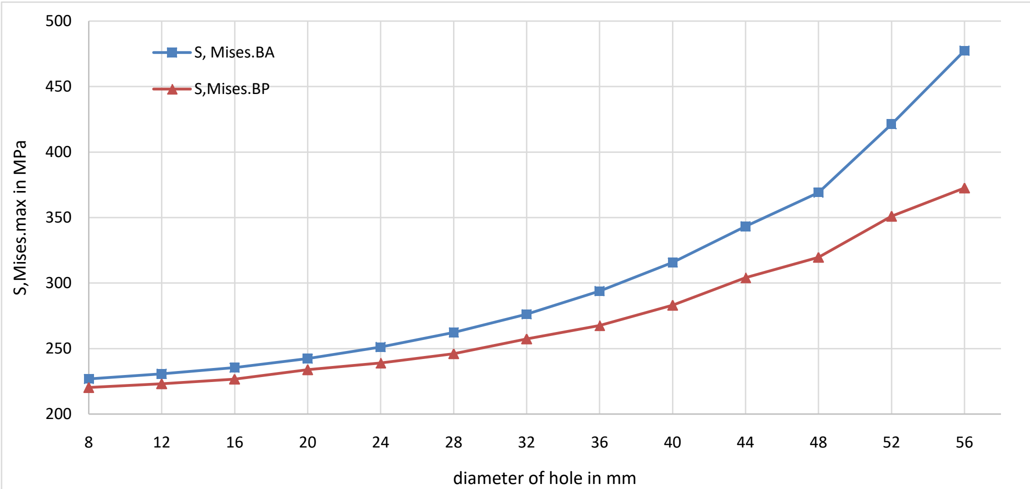


Figure 6. Variation of the Von Mises stress (S, Mises.max) in function of the diameter of the actual arm (BA) and the proposed arm (BP) of New Holland TT75 tractor. W = 85 mm.

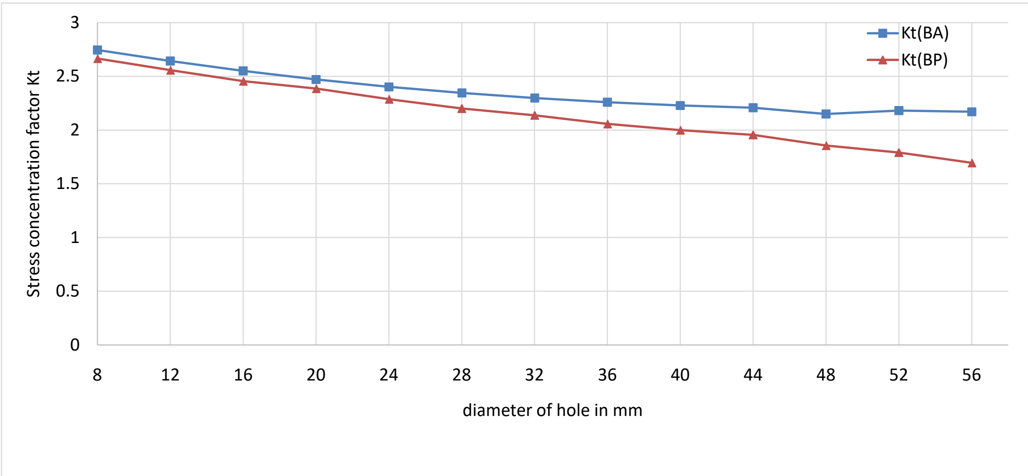
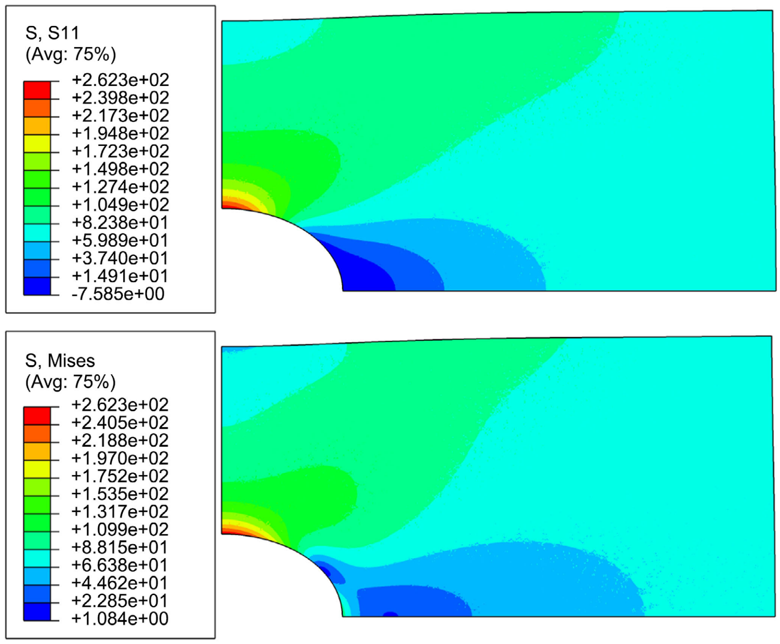
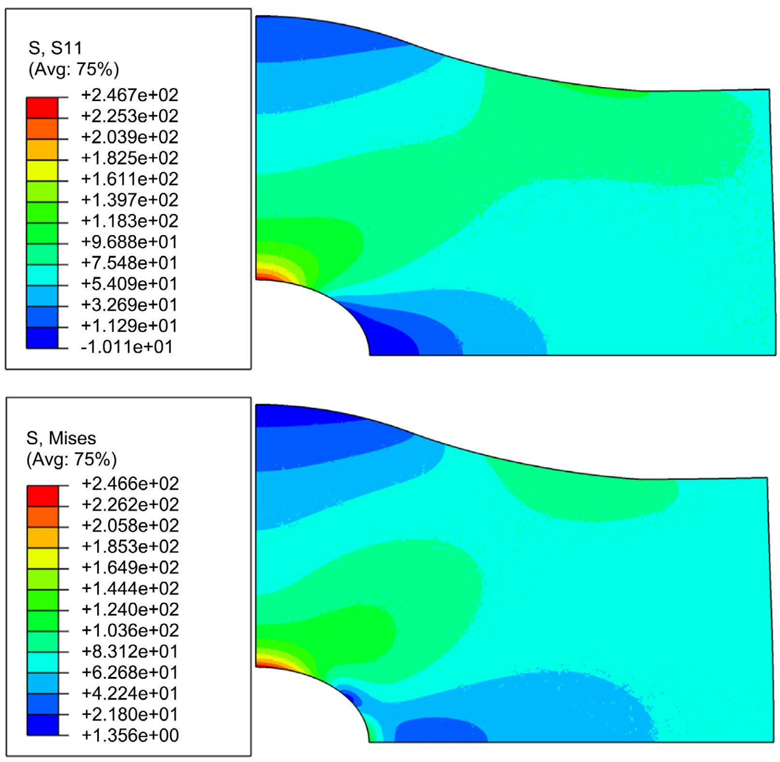


Figure 7. Stress concentration factor in function of hole diameter.

For the same applied pressure of 75 MPa, the same diameter d = 28 mm, the same width W = 85 mm and the same thickness t = 16 mm; these results of the simulation in S, Mises and S, S11 in **Figure 8** show that the maximum stresses of the proposed arm are lower than that of the current arm.



Actual Arm (BA)



Proposed arm (BP)

Figure 8. 2D model of the traction arm.

It is observed on the variation of hole diameters that, the Von Mises equivalent stress values (S, Mises.max) and the normal tensile stress values (S11.max) of the proposed arm are lower than those of the actual arm. As the diameter increases, the stress intensities increase and the difference between the stress intensities increases. Between the holes of diameters: 8, 20, 40 and 56; the stresses are respectively for the actual and proposed arm as follows: 227.2 and 220.6 MPa; 242.4 and 234 MPa; 315.8 and 283.1 MPa and 477.3 and 372.6 MPa. These different variations are due to the added material and the geometry of the proposed arm.

For the determination of the stress concentration factors, the two extreme holes were used (small net sections) for the nominal stress calculations.

The values of the stress concentration factors decrease with increasing diameters and the difference between the two factors increases. The graph of the proposed arm is below that of the actual arm; this signifies that there will be less risk of crack initiation and propagation with the proposed arm.

3.2. Effect of Variation in the Width of the 2D Traction Arm

The simulation results obtained due to the variation of the width of the arms are presented in **Figure 9** and **Figure 10**, and that of the stress concentration are indicated in **Figure 11**.

It is observed that on these various values of widths that; the values of the equivalent stress of Von mises and the values of the normal stress in traction of the proposed arm are lower than those of the actual arm on an interval going from 75 mm to 95 mm. From 100 mm onwards the stress values of the proposed arm are higher than those of the current arm; as the width increases the difference between the stress intensities increases. These different deviations are also due to the added material and the geometry of the proposed arm.

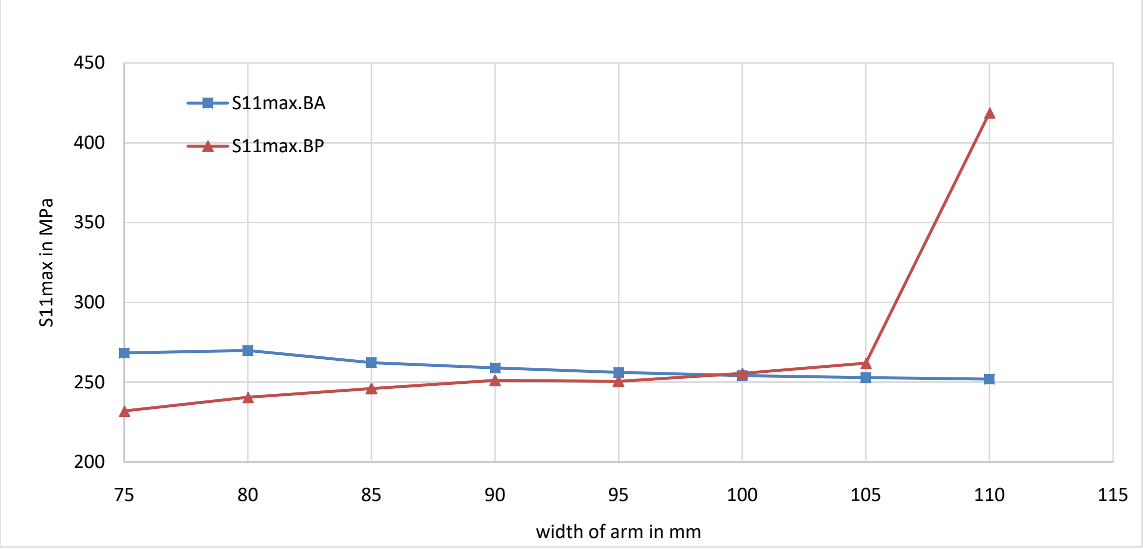


Figure 9. Variation of traction stress (S11.max) in function of the widths W of the current New Holland TT75 tractor arm (BA) and the proposed arm (BP).

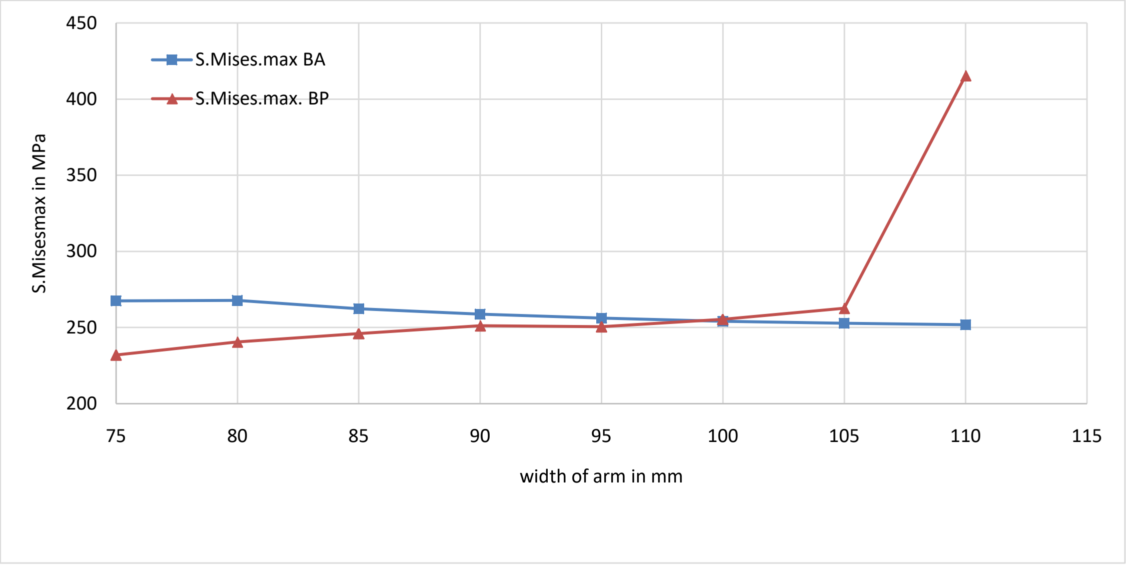


Figure 10. Variation of traction stress (S11.max) in function of width W of the actual New Holland TT75 tractor arm (BA) and the proposed arm (BP).

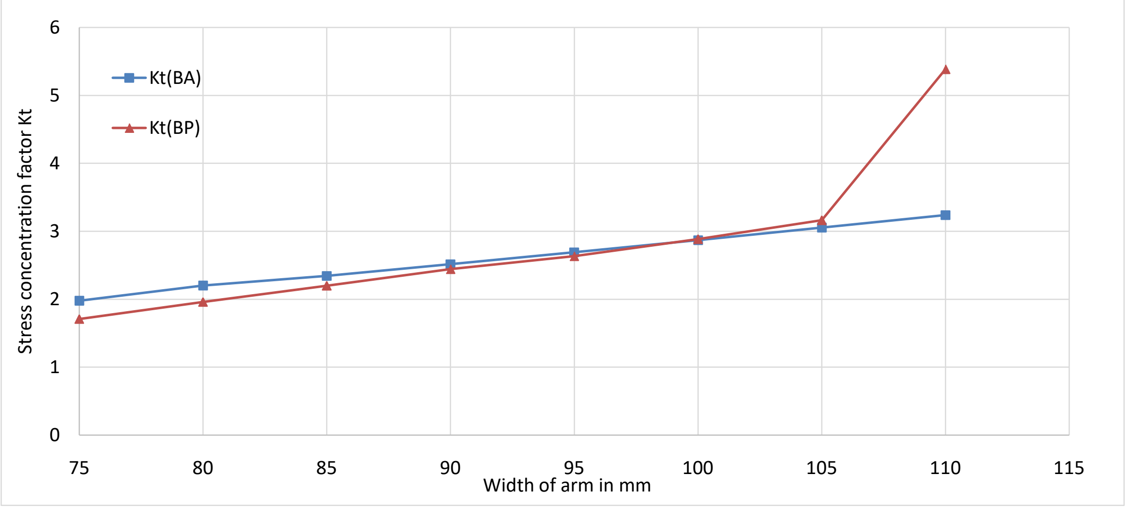


Figure 11. Stress concentration factor in function of width. P = 75 MPa and d = 28 mm.

As for the variation of the stresses; the values of the equivalent Von mises stress and the values of the normal traction stress of the proposed arm are lower than those of the actual arm only over a range from 75 mm to 95 mm. From 100 mm onwards the stress values of the proposed arm are higher than those of the actual arm; as the width increases the difference between the stress intensities increases. These different differences are also due to the added material and the geometry of the proposed arm.

3.3. Effect of Variation of the Pressure of the Traction Arm

The simulation results obtained due to the variation of the pressure applied to the traction arm are presented in **Figure 12** and **Figure 13**, and that of the stress concentration are indicated in Figure 14. Approximate global mesh size equal to 2 was chosen for the structure.

Similarly to Figure 8, for an applied pressure of 75 MPa, same diameter d = 28 mm, same width W = 85 mm and same thickness t = 16 mm; these simulation results in S, Mises and S, S11 of Figure 15 show that the maximum stresses of the proposed arm are lower than the current one.

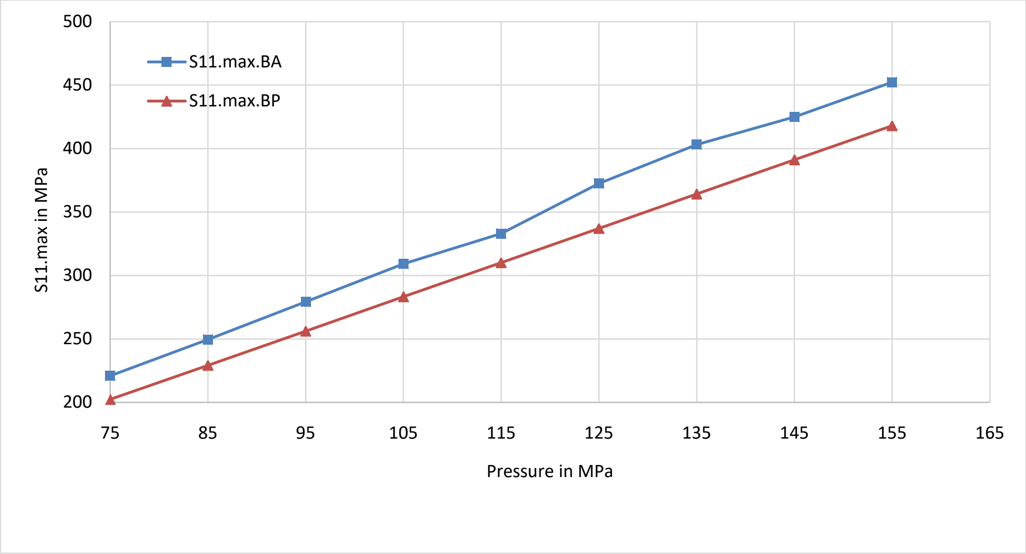


Figure 12. Variation of traction stress (S11.max) in function of pressures for the actual New Holland TT75 tractor arm (BA) and the proposed arm (BP).

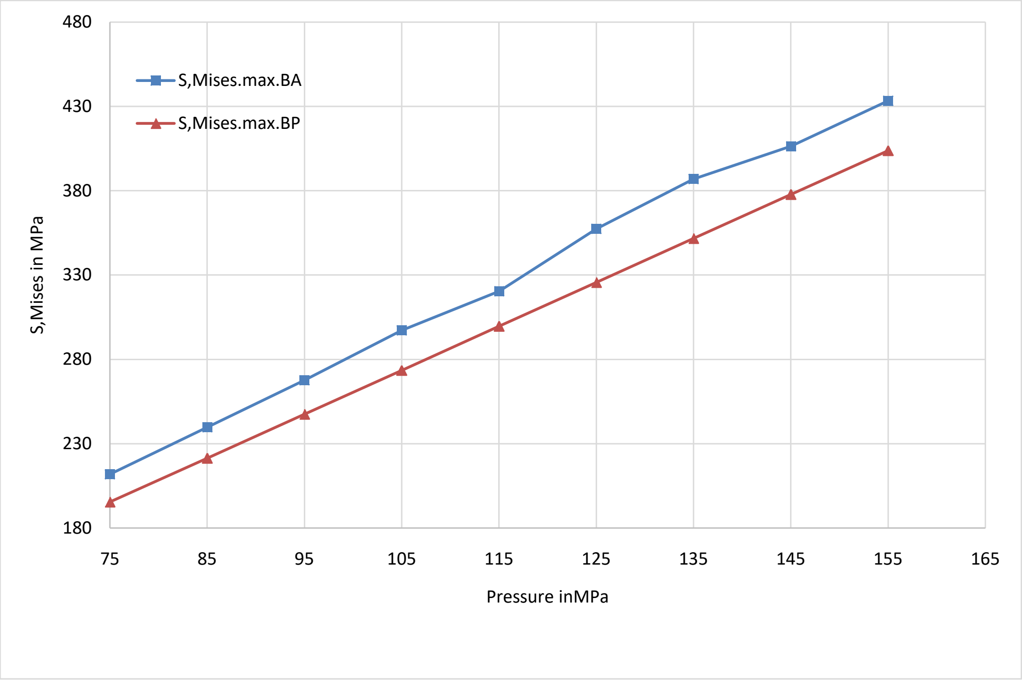


Figure 13. Variation of Von Mises stress (S, Mises.max) in function of pressures for the actual New Holland TT75 tractor arm (BA) and the proposed arm (BP). d = 28 mm.

Although the mesh size is 2, It is observed on these different pressure values that the values of the equivalent Von Mises stress (S, Mises.max) and the values of the normal traction stress (S11.max) of the proposed arm are lower than those of the actual arm and their growths are proportional to the pressure increase. As the pressure increases, the difference between the stress intensities increases (slightly); these differences in the differences are also due to the added material and the geometry of the proposed arm.

The values of the stress concentration factors increase with increasing pressure and the difference between the two factors increases (also slightly). The growth of Kt proportional to the pressure. The curve of the proposed arm is below that of the actual arm; this also means that there will be less risk of crack initiation and propagation with the proposed arm.

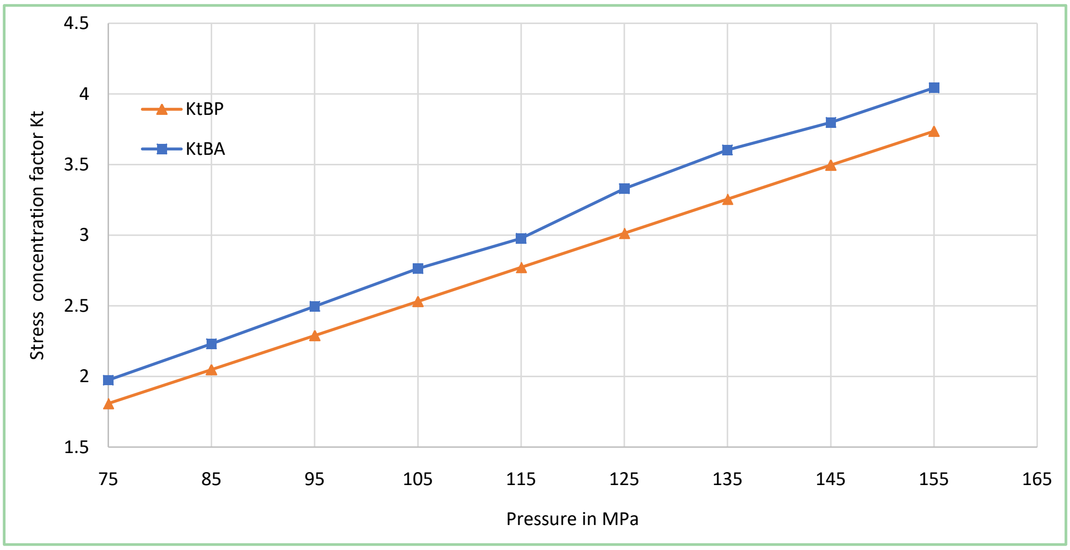
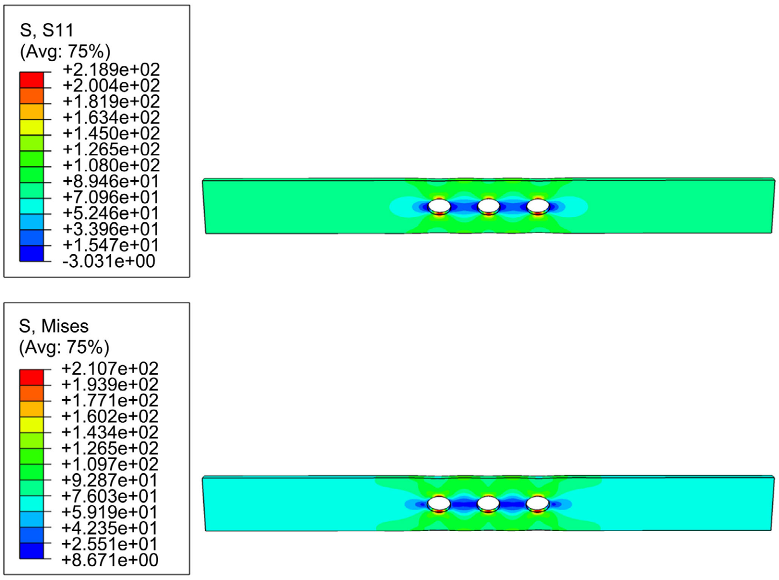
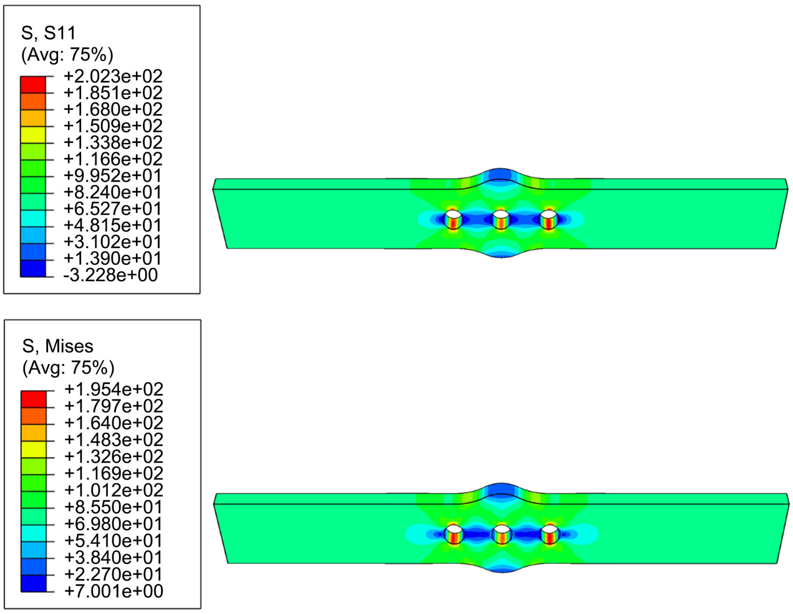


Figure 14. Stress concentration factor in function of applied pressure.



Actual Arm (BA)



Proposed arm (BP)

Figure 15. 3D models with three holes in the traction arm.

4. Conclusions

Hole diameter, width and pressure were the variables for this study. The simulations were done using the finite element method.

By making the comparisons of stresses of S11.max, S, Mises.max and stress concentration factors K_t on the variation of hole diameter and pressure; the results obtained from the geometrical parameters of these two arms, show that, the proposed arm is better.

The variation of the width shows that the proposed arm is better than on a range from 75 mm to 95 mm.

This geometry modification can be useful for all other tractor traction arms.

No diagram of the variation of stress concentration (K_t) as a function of hole diameter corresponding to the proposed arm was found to make a comparison with the current values.

The advantage of the proposed arm geometry is that it does not require any other modification of the form of the mechanical parts in connection with it and that it does not present any major difficulty in assembly and disassembly.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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