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STRENGTH VERIFICATION OF A BOOM LOADER MODULE

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ABSTRACT: This paper demonstrates the necessity of a thorough strength analysis of a mobile work machine module already in its design phase in order to avoid the subsequent damage during its operation. A specific case of a boom loader working device under extreme unilateral load is considered to investigate the creation of permanent deformations. It is shown that these can be prevented by an appropriate use of predictive methods of dimensioning.
KEYWORDS: strength analysis, predictive design, boom, loader, permanent deformation, maximum stress

INTRODUCTION

Currently, the global competition requires rapid introduction of new and innovative products to the market, as well as reduction of the total cost of the products while ensuring their quality and thus competitiveness. Meeting these three basic requirements of competitiveness can only be effective with the use of CAE systems and tools that enable in the process of pre-production and product design stages the solutions that lower the cost of testing real products, and also enable to acquire complex knowledge about the characteristics, performance and behaviour of the future product [3].

So far they have been used as autonomous products only by a limited number of highly qualified specialists in the final stages of the development cycle. Rational use of CAE with a positive impact on the new product development assumes its employment already in the early stages of the design process, which decides on the choice of correct and effective solutions from a number of possible alternatives.

This fact requires an easy-to-use and integrated CAD / CAE environment not only for the process of analyses and calculations, but also for design and engineering purposes.

PROBLEM ANALYSIS

The phase of a realistic simulation of future product/machine behaviour is the essential part in the process of life-cycle management (PLM) of the future product/machine. Strength analysis of the stressed parts of the designed construction, as a significant part of the predictive design, is a part of the development process. The practice, however, clearly shows that the common routines often do not reveal hidden construction defects, which are only detected during the actual operation of the machine. This could result in the limited operation, revision and repair of the machinery, or other warranty interventions and subsequent removal of design errors. To avoid such situations, it is necessary to pay attention to a thorough strength analysis already in the design process of a particular type of machine.

Therefore, it is important to design predictively, i.e. possible extreme operational conditions have to be taken into account in the design process of the machine. The justification for this claim is confirmed by the following case study investigating the possible creation of permanent deformations under extreme loads unilaterally acting on the boom working device of the loader. This was the case in a specific real operation while inserting one edge of the loading tool of the loader into a loose material, ladling it into shovel and lifting it (see Fig. 1). This situation occurred in few special cases of operation with subsequent damage to the construction of the boom as a result of insufficient prediction in the design phase of the working device.

SOLUTION PROCEDURE

The analysis of the described case was preceded by creating a 3D model of the machine with defined material properties, kinematic joints in the nodes, deactivating the parts that do not affect the calculation and defining the extreme load in the critical position (push force of the loader and weight of material in the shovel - combined load) (Fig. 2) [1, 2]. The parameters of the performed calculation were as follows: mesh type - linear tetrahedron elements (135 181), parabolic tetrahedron *elements (56 956), translational elements (30), fixed elements (15), sliding elements (1 769), what makes in total 193 521 elements, 142 521 nodal points, with calculation error of 5.907%.*

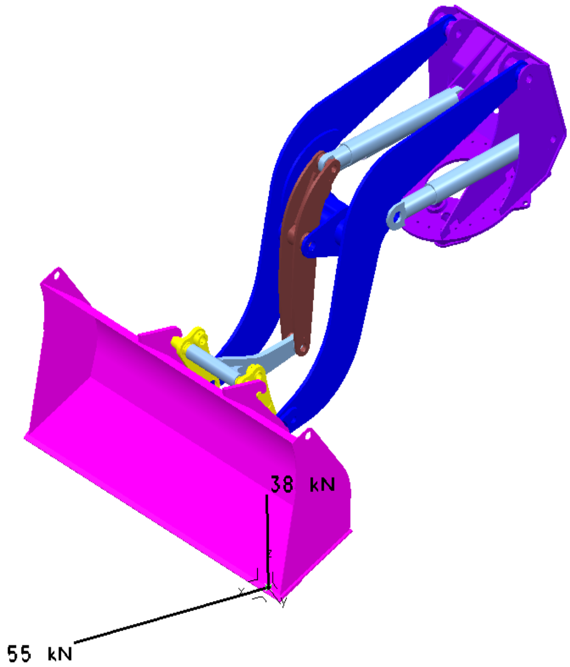


Figure 1. Load Status

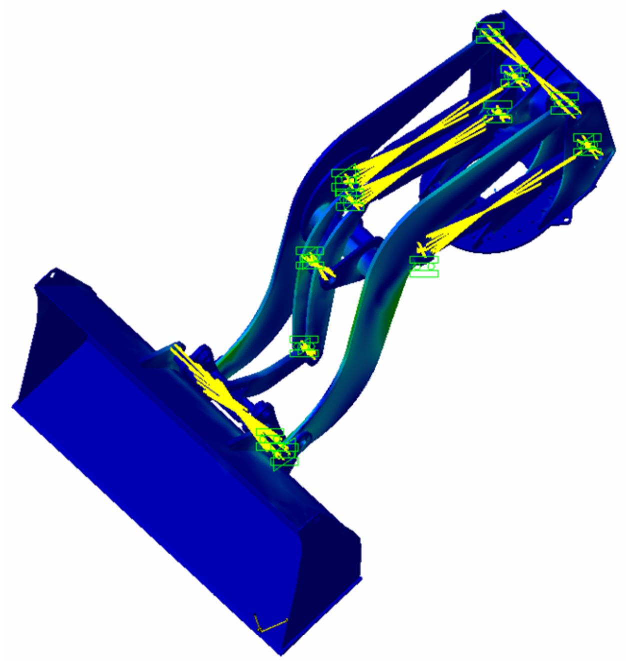


Figure 2. Kinematic Joints In The Nodes

The strength calculation was carried out by the use of Elfini Solver module of CATIA V5R20.The calculation was defined as the strength analysis of the assembly with identification of particular links between the parts of the assembly. Elements that do not affect the accuracy of calculation were excluded from the analysis (pins, retaining rings, etc.). The obtained results of the strength and deformation analysis are shown in Fig. 3 and 4.

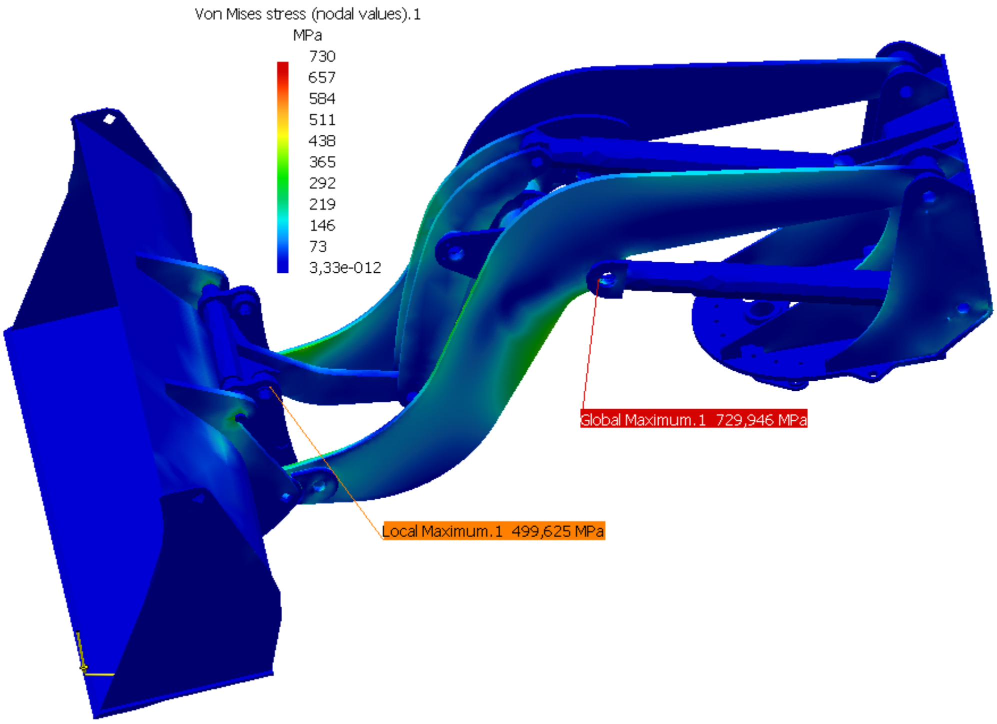
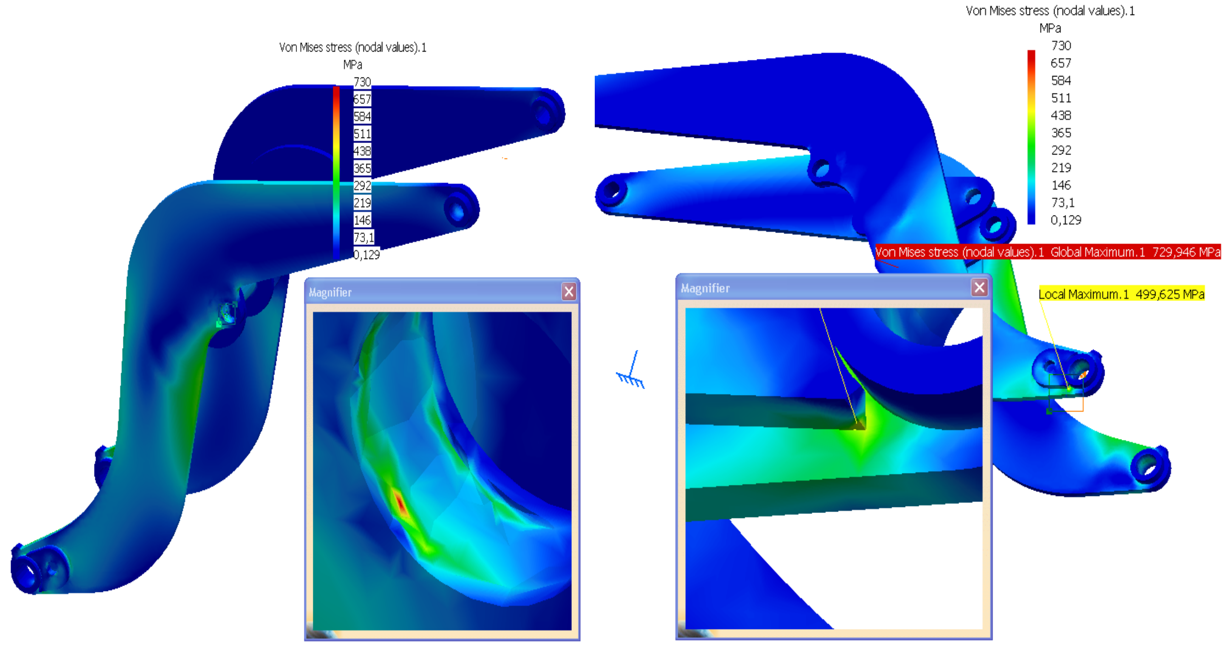


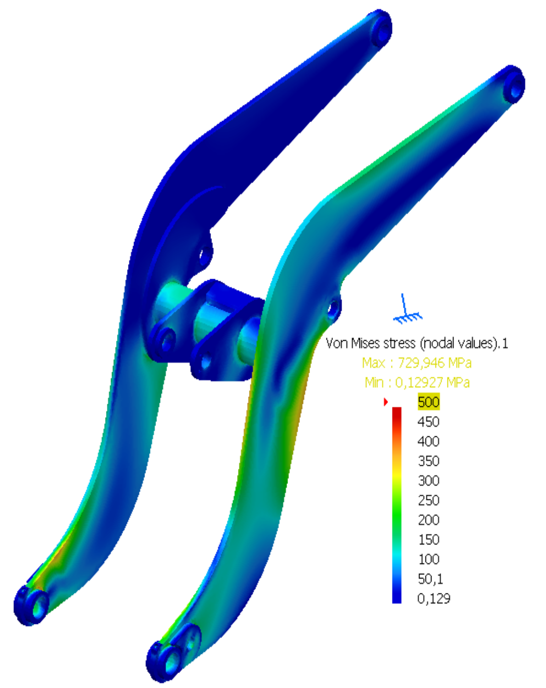
Figure 3. Strength analysis of the assembly

According to these results it can be concluded that the maximum stress occurs in the place where the boom is supported by a straight axis hydraulic motor, and has a value of 730 MPa. At this point there is a groove for the snap ring (small shape changes in terms of geometry), which to some extent causes problems in creating a mesh of the boom (at this point there is a deviation from the terms defined for the whole boom mesh, expressed by a percentage error of 0,0457%), (see Fig. 4a). This error, or the global maximum stress at this point, can be neglected. The second local stress maximum of 500MPa (Fig. 4b) is correct in terms of the mesh and can be considered as the maximum stress of the loader (and in this case also of the entire assembly).



a) b)

Figure 4. Extreme stress in the boom



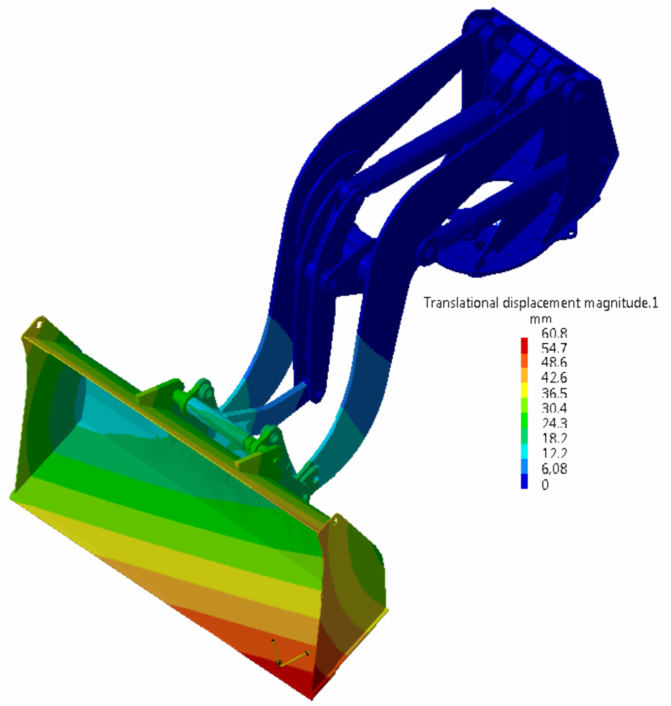


Figure 5. Real stress in the boom Figure 6. Deformation of the assembly

The real stress distribution in the boom is depicted in Fig. 5. A repeated detection of another stress peaks showed that these occurred only in the vicinity of the first local maximum and their value was less than 470 MPa (Fig. 4b). Hence, it follows that the value of the first local maximum could be possibly moved downwards by considering appropriate geometric changes of the shape, e.g. chamfering or rounding of edges, i.e. managing tangential continuity in case of cross-section change, or elimination of elements causing the stress concentration. The course of deformation shows that value of maximum displacement after the modifications is only 20.6 mm, which is with respect to the whole assembly 60,8 mm (Fig. 6).

CONCLUSIONS

The above analysis shows that in the case of an in-depth analysis during the design process, an appropriate shape treatment of incriminated boom sections (rounded edges and removed curvature discontinuities) makes it possible to modify the stress values, and despite a critical type of load in an unfavourable boom position to prevent from permanent deformations that showed up later in the operation of the loader.

ACKNOWLEDGEMENT

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