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FEM ANALYSIS OF PROTECTIVE FRAME ON ORCHARD TRACTORS IN ROLLOVER CASE

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Abstract: This paper describes a design of the protective frame orchard tractors and tractor power up to 65kW for use in fruit production on sloping ground for mechanical harvesting (shaking) of stone fruits. Shown protective frame can be mounted on existing models of tractors, primarily domestic production. This paper presents an analysis of the stress state of the observed protective frame mode unwanted case overturning tractor. A common practice in the examination and approval of protective frames to be loaded twice the force of gravity of the tractor. Analysis of the protective frame was done using the software package SolidWorks gain and methods of FEM analysis. Ram is loaded with a horizontal and vertical force of 38,2 kN on the side and from above. The results obtained show a satisfactory security.

Key words: *tractor, protective frame, rollover, FEM analysis, load.*

INTRODUCTION

Agricultural tractors are required to have roll-over protective structures (ROPS) for use on European roads. To that end, the ROPS must conform to a series of strength tests in accordance with the Organization for Economic and Co-operation Development (OECD) Standard Codes or the relevant European Community (EC) Directives. Within these Codes, ROPS force and energy absorption test requirements are typically defined in terms of a 'reference mass'. This mass, along with mass values for 'unladen',

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'ballast', and 'maximum laden', required for the homologation documentation, is given by the tractor manufacturer. Recent international interest in operator safety has questioned the appropriateness of the mass definitions and specifically the use of the currently defined reference mass as the basis for ROPS testing.

Tractor roll-overs continue to be one of the most common causes of death and injuries on farms. Tractor operators are most at risk of injury when [1-8]:

- their tractor does not have ROPS,
- the operator does not wear fitted seatbelts,
- equipment is poorly maintained,
- working on sloping terrain,
- working on rough, slick or muddy surfaces,
- towing or pulling objects or loads,
- travelling through pastures where high vegetation can obscure stumps and/or pot holes,
- working near dams, ditches, irrigation channels, embankments or over hanging structures.

So far, risk monitoring indicate the occurrence of different hazards when working with certain types of machines. In order to take preventive measures, it is important to have complete information about the machine and operating conditions. Since tractors working on uneven terrain (fields with canals for irrigation, etc.), the occurrence of rollover accidents are very common.

In accordance with standards and EU directives for machinery, defines three main objectives to protect machine operators in the event of a rollover of the same [9]:

- maintain the required floor space,
- able to prevent the operator runs out of space and the necessary contact with the vehicle structure;
- elements inside the cabin causing minimal injury to the operator, (if there is opportunity to come into contact).

Upon completion of homologation the tractor is required to be fitted with a roll-over protective structure (ROPS). This structure, whose purpose is to provide a survival volume in the event of a rollover, is statically tested according to international standard procedures for the particular tractor type. These tests comprise a series of energy (force–displacement) and force requirements whilst ensuring that the survival volume has not been encroached. Official ROPS tests are performed within Europe according to the Codes of the Organization for Economic and Co-operation Development (OECD) or the equivalent EC Directive. These tests are typically based on the tractor's reference mass, with the only requisite being that it must be greater than or equal to the unladen mass in running order without the driver onboard [10].

MATERIAL AND METHODS

The study was conducted according to the requirements set by the standard ISO 5700 and SAE J 1194, which established a method of static testing and acceptance requirements for cab protective and security frames wheel tractor. In this study, to prescribe standards for the category of tractors with a mass of 800 to 15000 kg and minimum wheel track width greater than 1150 mm was made:

Measurement of the maximum horizontal load means follow:

Examination of the horizontal force acting on the front frame in a plane parallel

the longitudinal axis of the tractor. The offensive power point is located on 170 mm or 116 total width of protective cover. The requirement that the protective frame must satisfy is that the protective frame at overload of the power absorbed energy of E1 = 1666 J while at the same security space operator remain unscathed.

Examination of the horizontal force acting on the side of the upper part of the frame with respect it is certain that he will first touch the ground when the tractor rollover. When the load protective frame has to absorb the energy of E2 = 2082 J while at the same security space operator remain unscathed.

Measurement of the maximum vertical load means examination of the vertical force acting on the front and rear frame without having security operator space remain unscathed.

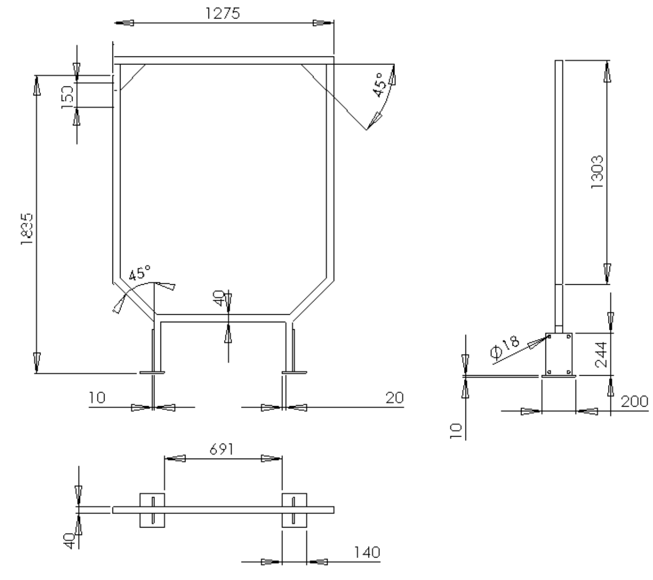

Figure 1. Dimensions of researched protective frame

This paper was carried out examination of the protective frame whose dimensions are shown in Figure 1 Profile dimensions are 40x40x3mm. The frame is hot-rolled steel E235 (EN 10297 - 1 : 2003 Seamless circular steel tubes for mechanical and general engineering purposes. Non-alloy and alloy steel tubes). Crashing force is 38,2 kN.

To simulate the prescribed static testing procedures for ROPS using finite element method Radioss Bulk was used. To create the model Hyper Mesh was used and Radioss Bulk was selected as the phenomena to be simulated involved material deformation beyond its yield strength as well as contact boundary conditions at the point of application of loads Deflection and crushing of beams and poles includes the geometric nonlinearity. Deflection rate was static so no inertia forces were involved. The problem can be model into nonlinear static analysis. The application of load or displacement was applied in steps and at each step the equilibrium should be satisfied. Thus problem can be defined as nonlinear quasi-static analysis [11].

RESULTS AND DISCUSSION

In this crashing test, load was acceptance criteria and acceptance value was crashing force 38,2 kN.

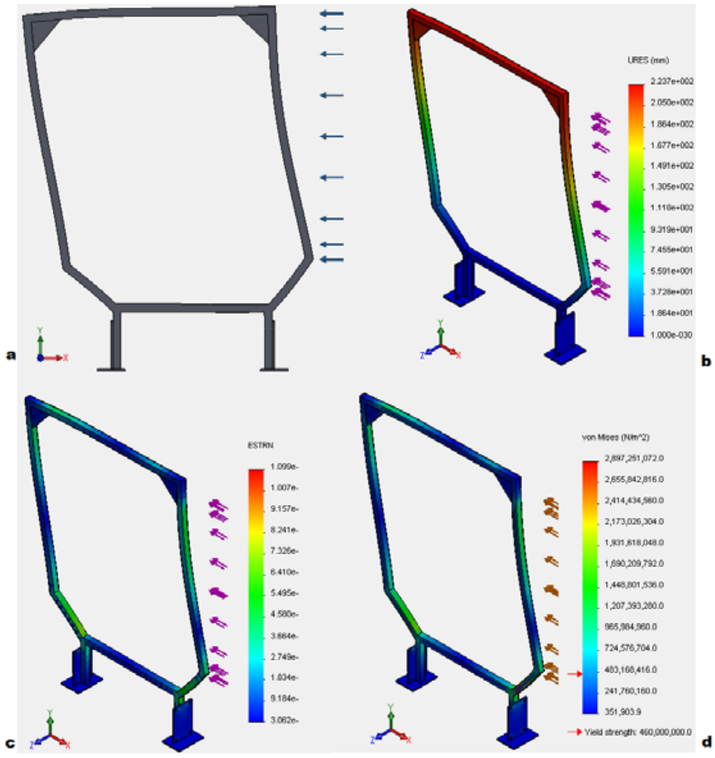

Figure 2. The effect of horizontal load on protective frame (a), view of displacement (b), strain (c) and stress (d)

Fig. 2 shows the result of the horizontal side load test for protective frame. Fig. 3 shows the result of the vertical side load test for protective frame. It is important to note that each load was applied in the sequence shown in Tab. 1 and that subsequent loads were applied following any deformations and stresses sustained during the application of the previous load(s) in the sequence. Once the required energy/load was reached, it was necessary to verify that this was significantly less than the breaking strength of the various structural elements and that no part of the protective frame, while deformed, lead to the infringement of the operator clearance zone or to its invasion by the simulated ground plane. For both side loads depicted in Fig. 2, the maximum stress recovered was significantly lower than the material's breaking strength value, and the operator clearance zone was always protected.

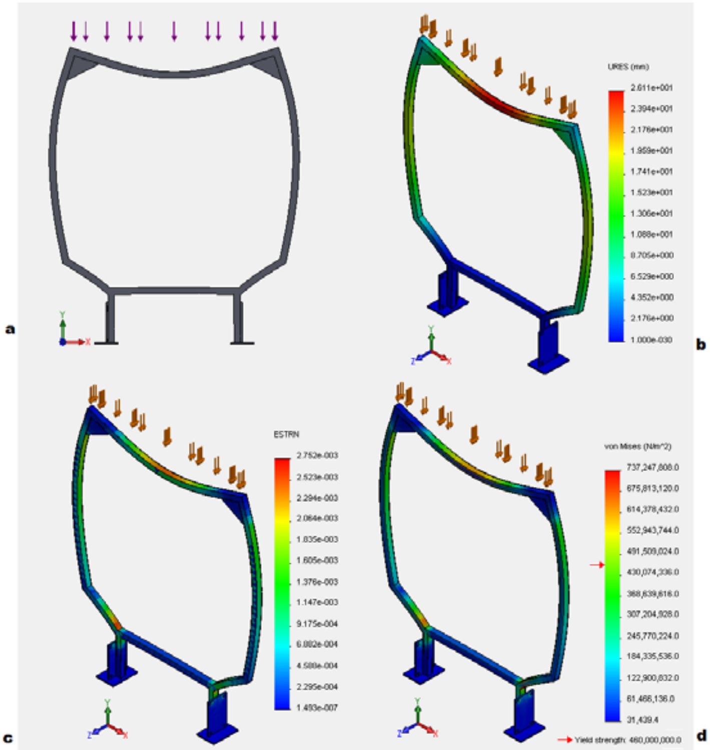

Figure 3. The effect of vertical load on protective frame (a), view of displacement (b), strain (c) and stress (d)

The shown protective frame design process resulted in a permanently fixed roll over protective structure which should provide an adequate level of protection to tractor drivers in the case of a roll over. Moreover, the particular shape of the structure renders working under trees an easier activity and reduces the likelihood of branches being damaged. This has led to an increase in the level of roll over protection offered to drivers of narrow track wheeled agricultural tractors.

The virtual prototyping process and finite element analysis allowed a significant reduction in design costs. Furthermore, the computer aided design (CAD) virtual model helped to take the ergonomic features of the structure into account and the finite element analysis enabled streamlining of the structure, improving its mechanical strength and optimizing the machine production process. Thus, the costly experimental tests have only been carried out on the prototypes which had virtual models that successfully passed the structural analysis. The success factors of the shown protective frame itself can be summarized as follows: reduced tractor overall height; improvement of roll-over protective structure shape, suitable for working under trees or in greenhouses; non-foldable roll-over protective structure.

CONCLUSIONS

Accidents and accidents with farm machinery and tractors are now very common in Serbia, since there is no ongoing training, supporting vocational courses for the proper use and maintenance of these machines.

There are also significant gaps in the knowledge and application of the warp traffic regulations in tractor drivers, as well as irresponsible and undisciplined in the use

tractors and other mobile agricultural machines.

In the future, it is necessary to reduce the number of accidents and accidents at work agricultural machinery and tractors to the smallest possible number. This primarily means providing course of business in agriculture, with the largest

compliance with all prescribed measures and laws pertaining to the protective of machines, and in particular the Law on Road Traffic Safety, when these machines are found in the transport process in public transport areas.

Applying FEM analysis, conducted research and testing protective frame, shows that the requirements defined standards for the protection of the cab or operator with a possible rollover.

Particular focus was given to the appropriateness of using a 'reference' mass associated to the unladen mass as the basis for ROPS strength calculation. A more representative safety criterion may be obtained by linking the energy and force requirements for the ROPS with the maximum laden mass of the tractor. However the mass distribution in working condition can influence the stability/rollover behaviour of the tractor in both positively (increased safety) or negatively (reduced safety). To determine the appropriate energy–mass relationship(s) for ROPS testing additional dedicated research is required.

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MKE ANALIZA SIGURNOSNOG RAMA VOĆARSKOG TRAKTORA PRI PREVRTANJU

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Sažetak: U ovom radu prikazano je jedno konstruktivno rešenje sigurnosnog rama za voćarske traktore i traktore snage do 65 kW koji se koriste u voćarskoj proizvodnji na nagnutim terenima za mašinsko ubiranje (trešenje) koštičavog voća. Prikazani sigurnosni ram može se montirati na postojeće modele traktora, pre svega domaće proizvodnje. U radu je izvršena analiza naponskih stanja posmatranog sigurnosnog rama u režimu neželjenog slučaja prevrtanja traktora. Uobičajena praksa pri ispitivanju i homologaciji sigurnosnih ramova je da se opterete dvostruko većom silom od težine samog traktora. Analiza sigurnosnog rama vršena je pomoću softverskog paketa SolidWorks korišćenjem metode MKE analize. Ram je opterećen silom od 38,2 kN sa bočne strane i sa gornje strane. Dobijeni rezultati ispitivanja ukazuju na zadovoljavajuću bezbednost.

Ključne reči: *traktor, sigurnosni ram, prevrtanje, analiza naponskog stanja, opterećenje.*

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