Analele Universităţii din Craiova, seria Agricultură – Montanologie – Cadastru (Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series) Vol. XLVII 2017

CONSIDERATIONS ON STATIC NONLINEAR ANALYSIS OF COUPLING DEVICES - NONLINEAR CURVE STRESSES

MIRCEA I.D.[1)], MAICAN E.[1)], VLĂDUŢ V.[2)], DUMITRU I.[2)], IUGA D.[3)], GĂGEANU I.[2)], VOICEA I.[2)], SORICĂ C.[2)], UNGUREANU N.[1)], GHEORGHE G.[2)], MARIN E.[2)], CUJBESCU D.[2)], BORUZ S.[4)]

[1)]University "POLITEHNICA" Bucharest / Romania; [2)]INMA Bucharest / Romania; [3)]SC METROUL SA / Romania; [4)]University of Craiova

Keywords: aggregate, couple, analysis, stresses, forces

ABSTRACT

Coupling devices are the elements ensuring the connection between the power source (tractor) and the towed machine, which must be checked in terms of their safety on the public roads by means of different methods. One of these methods is represented by non-linear static analysis through nonlinear curve stresses, which can in some cases replace verification by endurance testing. The paper presents such an analysis as well as the results obtained from this analysis.

INTRODUCTION

The analysis on the operation of coupling devices of mobile agricultural aggregates (tractor – agricultural machinery), in the view of identifying an "optimum" coupling device, respectively of determining the manner in which it operates adequately, in the case of normal and/or critical stresses, was performed through simulated and accelerated tests, respectively during exploitation on uneven fields, identifying its critical areas (analysis using finite element method – FEM).

Based on these results, an optimization of the coupling device will be achieved, leading to the optimum operation and to an increase of lifetime, in safety conditions for the operator, but especially for other participants in traffic.

Technical conditions for the development of new coupling systems for tractors, trailers and agricultural machinery are harmonized to European regulations, in order to increase the degree of interchangeability and safety in circulation, one of the main reasons why is necessary to study these devices being caused by the multitude of accidents both during operation and in traffic due to the use of inadequate coupling systems (on tractors or trailers, respectively between tractors and agricultural machinery), which are not produced in accordance with certain traffic safety and security specifications [7].

The analysis of the distribution of stresses and strains in the lower rods of the linkage of the tractor, was conducted using triangular type CST finite elements [2]. This study serves to optimize the geometry and shape of the lateral rod by increasing the thickness of the rod in the areas where the stresses are very high, respectively by decreasing the thickness of the rod in areas where the tensions are too small.

Currently, the largest spread is that of carried agricultural machinery, placed behind tractors, the coupling between the machine and the tractor being made by means of the suspension mechanism. The most common suspension mechanisms are those with three-point linkage, currently equipping all agricultural tractors.

The lateral rods (fig. 1) are the basic components of the suspension mechanisms, having different stresses depending on the type of agricultural machine carried and on the work performed. Thus, in the lifting or transporting position, the main stress on the lateral rods is represented by bending, and during the working position, the main stress is tensile.

MATERIALS AND METHOD

The experimental researches for testing the resistance of a coupling device from U650M tractor were conducted using a drawbar (fig. 1), which was previously tested in static and dynamic regimes, through static nonlinear analysis, verifying the situation: nonlinear curve stress.

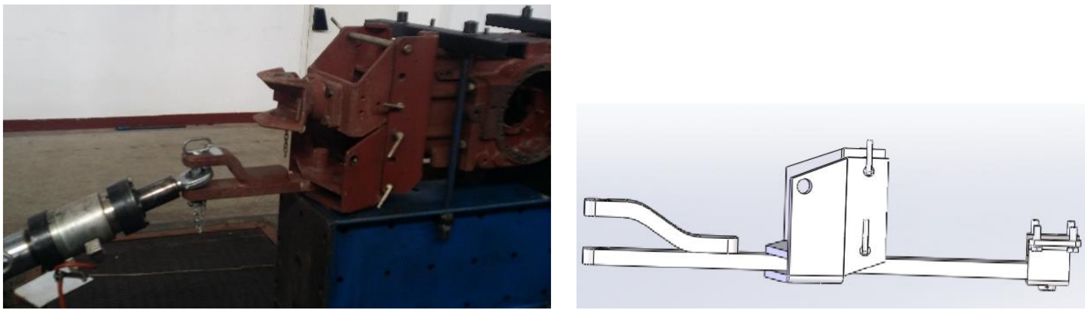


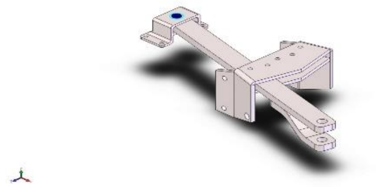
Fig. 1 – Drawbar mounted for experiments

RESULTS

Static nonlinear analysis of the drawbar

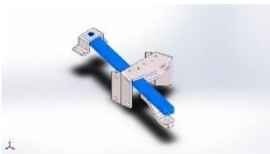
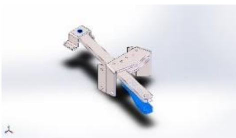
Nonlinear curve stresses

Model Information



Model name: Rel-1.0

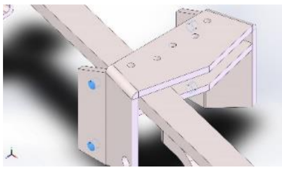
Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Cut-Extrude1 	Solid Body	Mass:15.1715 kg Volume:0.00197032 m^3 Density:7700 kg/m^3 Weight:148.681 N	C:\Temp\Carlig_tractor_poz_2\Rel-1.1.SLDPRT Jul 01 10:03:30 2017
Cut-Extrude1 	Solid Body	Mass:5.02876 kg Volume:0.000653085 m^3 Density:7700 kg/m^3 Weight:49.2818 N	C:\Temp\Carlig_tractor_poz_2\Rel-1.2.SLDPRT Jul 01 10:03:30 2017
Fillet2 	Solid Body	Mass:2.95203 kg Volume:0.000383381 m^3 Density:7700 kg/m^3 Weight:28.9299 N	C:\Temp\Carlig_tractor_poz_2\Rel-1.3.SLDPRT Jul 01 13:31:31 2017
Cut-Extrude4 	Solid Body	Mass:18.0411 kg Volume:0.002343 m^3 Density:7700 kg/m^3 Weight:176.803 N	C:\Temp\Carlig_tractor_poz_2\Rel-1.4.SLDPRT Jul 02 10:41:55 2017

Material Properties

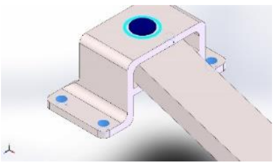
Model Reference	Properties	Components
	Name: Alloy Steel Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 6.20422e+008 N/m^2 Tensile strength: 7.23826e+008 N/m^2 Elastic modulus: 2.1e+011 N/m^2 Poisson's ratio: 0.28 Mass density: 7700 kg/m^3 Shear modulus: 7.9e+010 N/m^2 Thermal expansion coefficient: 1.3e-005 /Kelvin	SolidBody 1(Cut-Extrude1)(Rel-1.1-1), SolidBody 1(Cut-Extrude1)(Rel-1.2-1), SolidBody 1(Fillet2)(Rel-1.3-1), SolidBody 1(Cut-Extrude4)(Rel-1.4-1)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-6		Entities: 6 face(s) Type: Fixed Geometry

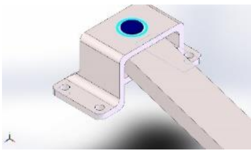
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-73.9722	-0.720269	-22.7045	77.3815
Reaction Moment(N.m)	0	0	0	0

Fixture name	Fixture Image	Fixture Details
Fixed-2		Entities: 4 face(s) Type: Fixed Geometry

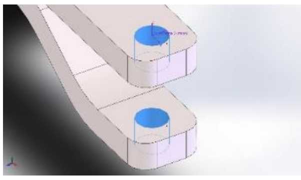
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-169.022	-1.08008	-36.0664	172.83
Reaction Moment (N.m)	0	0	0	0

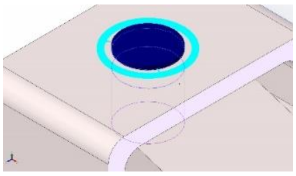
Fixture name	Fixture Image	Fixture Details
On Flat Faces-1		Entities: 2 face(s) Type: On Flat Faces Translation: ---, ---, -0 Units: mm

Resultant Forces

Components	X	Y	Z
Reaction force(N)	-8.77142	1.82251	-1.74966
Reaction Moment(N.m)	0	0	0

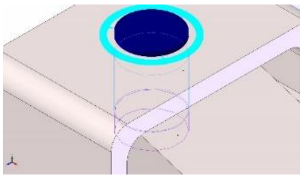
Load name	Load Image	Load Details
BearingLoads-1		Entities: 2 face(s) Coordinate System: Coordinate System1 Force Values: 25000 0 0 N

Connector Definitions
Pin/Bolt/Bearing Connector

Model Reference	Connector Details	Strength Details
 Pin Connector-3	Entities: 2 face(s) Type: Pin Connection type: With key (No rotation) Connection type: With retaining ring (No translation)	No Data

Connector Forces

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	8.3391e-006	3.365	5.9063e-007	3.365
Shear Force (N)	-76.365	0.00018896	1.6274	76.382
Torque (N.m)	-6.7109e-007	-0.2708	-4.7531e-008	-0.2708
Bending moment (N.m)	0.076376	-1.4576e-006	7.2261	7.2265

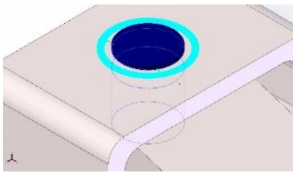
Model Reference	Connector Details	Strength Details
 Pin Connector-4	Entities: 2 face(s) Type: Pin Connection type: With key (No rotation) Connection type: With retaining ring (No translation)	No Data

Connector Forces

Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	-3.7343e-006	-1.4478	-3.1799e-007	1.4478
Shear Force (N)	92.657	-0.00024726	37.694	100.03
Torque (N.m)	7.5959e-007	0.2945	6.4683e-008	-0.2945
Bending moment (N.m)	0.12208	-3.8765e-007	0.33131	0.35308

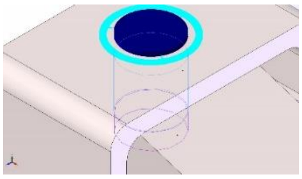
Connector Definitions

Pin/Bolt/Bearing Connector

Model Reference	Connector Details	Strength Details
 Pin Connector-3	Entities:2 face(s) Type: Pin Connection type: With key (No rotation) Connection type: With retaining ring (No translation)	No Data

Connector Forces

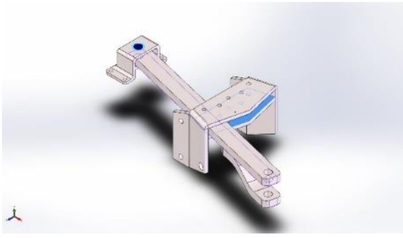
Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	8.3391e-006	3.365	5.9063e-007	3.365
Shear Force (N)	-76.365	0.00018896	1.6274	76.382
Torque (N.m)	-6.7109e-007	-0.2708	-4.7531e-008	-0.2708
Bending moment (N.m)	0.076376	-1.4576e-006	7.2261	7.2265

Model Reference	Connector Details	Strength Details
 Pin Connector-4	Entities: 2 face(s) Type: Pin Connection type: With key (No rotation) Connection type: With retaining ring (No translation)	No Data

Connector Forces

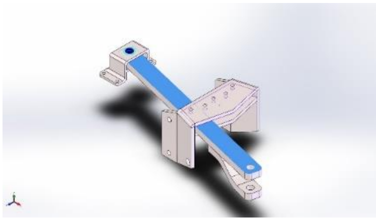
Type	X-Component	Y-Component	Z-Component	Resultant
Axial Force (N)	-3.7343e-006	-1.4478	-3.1799e-007	1.4478
Shear Force (N)	92.657	-0.00024726	37.694	100.03
Torque (N.m)	7.5959e-007	0.2945	6.4683e-008	-0.2945
Bending moment (N.m)	0.12208	-3.8765e-007	0.33131	0.35308

Contact Information

Contact	Contact Image	Contact Properties
Contact Set-4		Type: **No Penetration contact pair** Entites: **2 face(s)** Friction Value: **0.5** Advanced: **Node to surface**

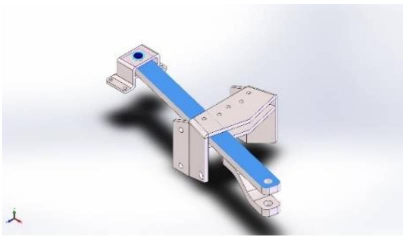
Contact/Friction force

Components	X	Y	Z	Resultant
Contact Force(N)	**9.8392**	**0.0021283**	**-40.681**	**41.854**
Friction Force(N)	**3.8076E-012**	**-1.5354E-015**	**-2.1294E-013**	**3.8136E-012**

Contact Set-5		Type: **No Penetration contact pair** Entites: **2 face(s)** Friction Value: **0.5** Advanced: **Node to surface**

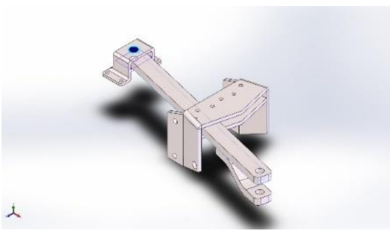
Contact/Friction force

Components	X	Y	Z	Resultant
Contact Force(N)	**0**	**-702.81**	**0**	**702.81**
Friction Force(N)	**5.064E-013**	**-8.0366E-030**	**-6.7828E-015**	**5.0645E-013**

Contact Set-9		Type: **No Penetration contact pair** Entites: **2 face(s)** Advanced: **Node to surface**

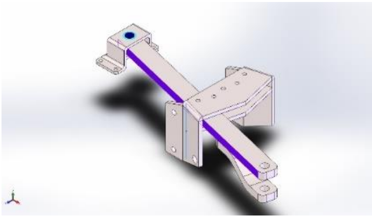
Contact/Friction force

Components	X	Y	Z	Resultant
Contact Force(N)	**0**	**-11491**	**0**	**11491**
Friction Force(N)	**-636.33**	**7.1696E-015**	**-228.23**	**676.02**

Contact Set-10		Type: **No Penetration contact pair** Entites: **2 face(s)** Advanced: **Node to surface**

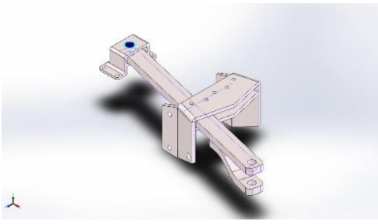
Contact/Friction force

Components	X	Y	Z	Resultant
Contact Force(N)	**28.519**	**11428**	**-117.92**	**11429**
Friction Force(N)	**-1870.1**	**4.9893**	**-457.32**	**1925.2**

Contact Set-13		Type: **No Penetration contact pair** Entites: **2 face(s)** Advanced: **Node to surface**

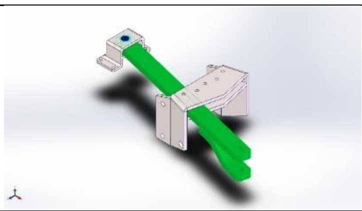
Contact/Friction force

Components	X	Y	Z	Resultant
Contact Force(N)	**-3.2474E-015**	**-1128.9**	**-3.0032E-014**	**1128.9**
Friction Force(N)	**-549.21**	**1.7304**	**-171.36**	**575.33**

Contact Set-14		Type: **No Penetration contact pair** Entites: **1 edge(s), 1 face(s)** Advanced: **Node to surface**

Contact/Friction force

Components	X	Y	Z	Resultant
Contact Force(N)	**26.924**	**11074**	**-111.32**	**11075**
Friction Force(N)	**-1805.7**	**4.0373**	**-440.56**	**1858.7**

Component Contact-4		Type: **Bonded** Components: **2 Solid Body (s)** Options: **Compatible mesh**

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Curvature-based mesh
Jacobian points	16 Points
Maximum element size	19.2419 mm
Minimum element size	3.84838 mm
Mesh Quality Plot	High
Remesh failed parts with incompatible mesh	Off

Resultant Forces

Reaction forces

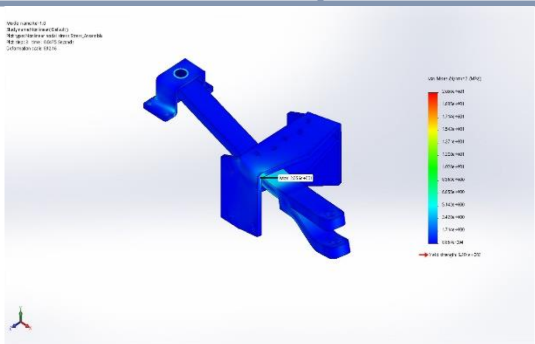
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-242.994	6.87689e-006	-58.7709	250

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

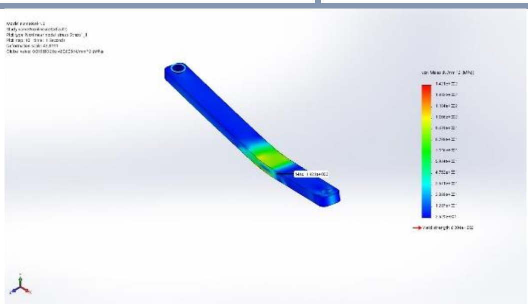
Study Results

Name	Type	Min	Max
Stress_Ansamblu	VON: von Mises Stress at Step No: 3(0.0475 Seconds)	8.867e-004N/mm^2 (MPa) Node: 49337	2.056e+001N/mm^2 (MPa) Node: 62193



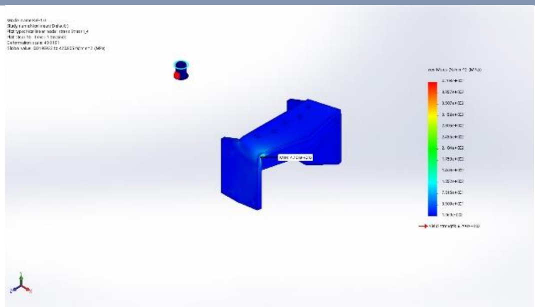
Rel-1.0-Nonlinear-Stress-Stress_Ansamblu

Name	Type	Min	Max
Stress1_1	VON: von Mises Stress at Step No: 10(1 Seconds)	1.969e-002N/mm^2 (MPa) Node: 49337	4.208e+002N/mm^2 (MPa) Node: 62193



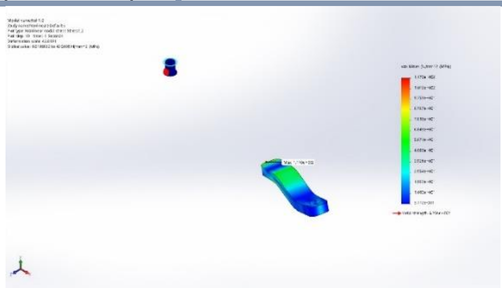
Rel-1.0-Nonlinear-Stress-Stress1_1

Name	Type	Min	Max
Stress1_4	VON: von Mises Stress at Step No: 10(1 Seconds)	1.969e-002N/mm^2 (MPa) Node: 49337	4.208e+002N/mm^2 (MPa) Node: 62193



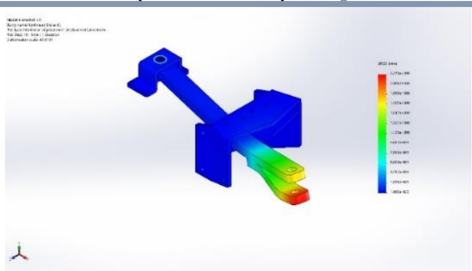
Rel-1.0-Nonlinear-Stress-Stress1_4

Name	Type	Min	Max
Stress1_2	VON: von Mises Stress at Step No: 10(1 Seconds)	1.969e-002N/mm^2 (MPa) Node: 49337	4.208e+002N/mm^2 (MPa) Node: 62193



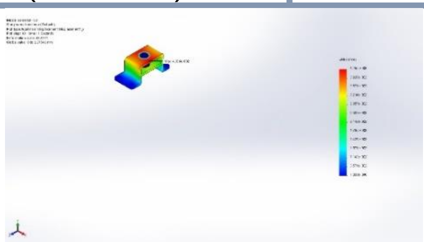
Rel-1.0-Nonlinear-Stress-Stress1_2

Name	Type	Min	Max
Displacement_Ansamblu	URES: Resultant Displacement at Step No: 10(1 Seconds)	0.000e+000mm Node: 12176	2.275e+000mm Node: 8211



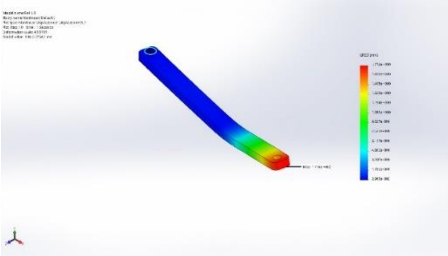
Rel-1.0-Nonlinear-Displacement-Displacement_Ansamblu

Name	Type	Min	Max
Displacement1_3	URES: Resultant Displacement at Step No: 10(1 Seconds)	0.000e+000mm Node: 12176	2.275e+000mm Node: 8211



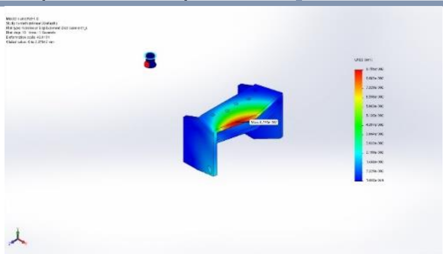
Name	Type	Min	Max
Rel-1.0-Nonlinear-Displacement-Displacement1_3			

Name	Type	Min	Max
Displacement1_1	URES: Resultant Displacement at Step No: 10(1 Seconds)	0.000e+000mm Node: 12176	2.275e+000mm Node: 8211



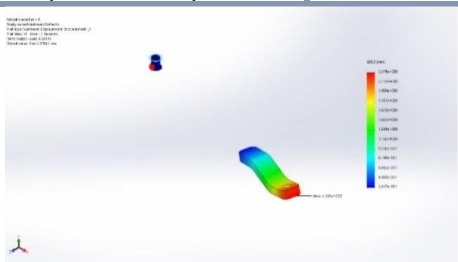
Rel-1.0-Nonlinear-Displacement-Displacement1_1

Name	Type	Min	Max
Displacement1_4	URES: Resultant Displacement at Step No: 10(1 Seconds)	0.000e+000mm Node: 12176	2.275e+000mm Node: 8211



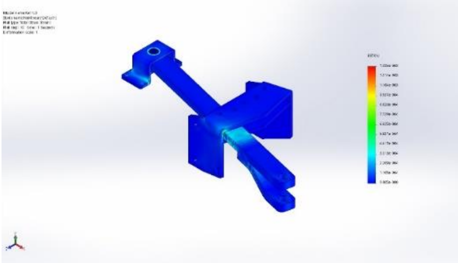
Rel-1.0-Nonlinear-Displacement-Displacement1_4

Name	Type	Min	Max
Displacement1_2	URES: Resultant Displacement at Step No: 10(1 Seconds)	0.000e+000mm Node: 12176	2.275e+000mm Node: 8211



Rel-1.0-Nonlinear-Displacement-Displacement1_2

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain at Step No: 10(1 Seconds)	9.005e-008 Element: 26676	1.325e-003 Element: 30722

Name	Type	Min	Max
	 **Rel-1.0-Nonlinear-Strain-Strain1**		

CONCLUSIONS

The highest stresses occur, as in case of longitudinal stresses, in the hinge areas of the engine chassis, respectively in the coupling pin between tractor and trailer, but higher in the first hinge pin in the chassis fastening element and the front, respectively the rear part of the bar (in relation to the bolt), which implies a reinforcement (optimization) of this area.

REFERENCES

[1]. **Andrei Ionel, Cârdei Petru, Gângu Vergil, Muraru Vergil, Popa Cristian, Păunescu Dan**, 2006 - *Resistance analysis of the coupling system between tractor and trailer*;

[2]. **Biriş Sorin-Ştefan, Păunescu Dan, Vlăduţ Valentin**, 2001 - *Structural static analysis of lateral rods of the tractor suspension mechanism using finite element method*;

[3]. **Biriş S.**, 1999 – Finite element method - *Applications in the construction of agricultural machinery*, PRINTECH Pub. House, Bucharest;

[4]. **Blumenfeld M.** 1995 - *Introduction to finite element method*, Technical Pub. House, Bucharest;

[5]. **Blumenfeld M. et al.** 1992 - Finite element method – Introductive applications and programs, U.P.B.;

[6]. **Cârdei P., Sfiru R., Ciuperca R., Muraru V.**, 1999 - Structural analysis of the main elements, parts and machine asemblies, used in the construction of agricultural machinery. Verification and optimization of the means of transport structures in the field of agriculture, MCT contract;

[7]. **Ciupercă R, Bodea C., Popa L, Dumitru A, Cândea Ioan**, 2006- *New coupling systems for agricultural and forestry tractors and machinery, harmonized with European standards*, INMATEH Journal- vol. 17, Nr. 2/2006;

[8]. **Sorohan Şt.**, 1996 - *Finite element method in mechanical engineering - Programs and applications*, Part I, U.P.B.