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STUDY OF IMPACT LOADS ON AGRICULTURAL MACHINE ELEMENTS BASED ON FINITE ELEMENT ANALYSIS.

Alex Tenicota García [1] , Cristian David Redrobán Dillon [1], Luis Felipe Contreras Vásquez [2], Javier Renato Moyano Arévalo [3], Julio Cajamarca Villa [1], Alex Fernando Barrionuevo Remache [4], Mayra Viscaíno-Cuzco [5], César Daniel Arregui Toro [5], Danielita Borja [6].
[1]Escuela Superior Politécnica de Chimborazo (ESPOCH), Grupo de investigación del Mantenimiento GIMAN, Riobamba, 060155, Ecuador.
[2]Universidad Técnica de Ambato, Docente Investigador DIDE-FICM.
[3]Docente-Investigador, Universidad Politécnica Salesiana
[4]Universidad estatal de Bolívar, Docente investigador
[5]Universidad Técnica de Ambato - Facultad de Ingeniería Civil y Mecánica - Carrera de Ingeniería Civil
[6]Faculty of Food Science and Engineering and Biotechnology, Universidad Técnica de Ambato (UTA), Ambato, 180104, Ecuador

Abstract
The circumstances that give rise to overloads in agricultural machinery and implements are increased in any territory due to demanding soil conditions and heavy soil characteristics. In agriculture, it is common to find examples of machines and implements, both domestic and imported, that suffer deformations in their structure or frequent breakages in their working parts. The determination of dynamic load coefficients that make it possible to obtain, with an acceptable degree of accuracy, the stress and deformation states in parts and structures subjected to impact loads, presents a high level of difficulty, especially when the elements subjected to the action of these loads have a configuration that is not simple, making it necessary to implement other methods that simplify the calculation and make it possible to deal with cases not considered typical. The paper presents a case study in which finite element analysis is applied as a tool during the determination of stresses and deformations in a structural element subjected to impact loads, compared with the calculation by traditional methods. As a result, it is found that during the calculation of structural elements by traditional methods, the dynamic load coefficients obtained give higher values of stresses and deformations than those obtained by finite element impact analysis.
Keywords: Finite elements; agricultural machinery; element design; ABACUS software; impact loads; agriculture.

1. Introduction

The circumstances that give rise to overloads in agricultural machinery and implements are increased in agriculture due to demanding soil conditions and heavy soil characteristics, being common in agriculture in any territory, the examples of machines and implements, both domestic and imported, that suffer deformations in their structure or frequent breakages in their working parts. working parts.

Generally, during the calculation of the stress and deformation state of elements subjected to dynamic impact actions by traditional methods, the calculation is initially carried out assuming that the actions are of a static nature, determining the deflections caused by this type of load, from which the so-called dynamic load coefficients are determined, aided by the application of the principle of work and energy (Pisarenko, 1979). Then the results obtained under static loads are affected by these coefficients, finally determining the stresses and deformations resulting from the application of dynamic loads (Goitizolo et al., 2007).

The determination of dynamic load coefficients that make it possible to obtain, with an acceptable degree of accuracy, the stress and deformation states in parts and structures subjected to impact loads, presents a high level of difficulty, especially when the elements subjected to the action of these loads present a configuration that is not simple, making it necessary to implement other methods that simplify the calculation and allow cases not contemplated as typical to be addressed. as typical.

In modern times, the finite element method has been successfully used in the analysis of structures subjected to dynamic loads and in particular impact loads. Zhongping et al. (2001), study the deformation of an elastic beam with free ends subjected to an impulsive transverse load (rectangular pulse) at one end using finite element analysis, obtaining the displacement, velocity, and acceleration at various points along the beam, as well as the deformation of the beam as a function of time. Melo et al. (2003), using a pseudo-dynamic procedure, perform the simulation of impact loads acting on beam-type structures, proposing an alternative method for the analysis of beams with solid cross-sections subjected to transverse impact loads.

Ruijun et al. (2008), study the flexural strength of a concrete bar under dynamic loads using the finite element method, obtaining the stress-strain curve of the specimens experimentally, agreeing the experimental results with those obtained by numerical simulation. Lu Xin-zheng et al. (2007), perform a non-linear simulation using the finite element method of the impact between the top of a heavy truck and a bridge structure, using MSC.MARC 2005 software. They apply four levels of load impact velocity and obtain displacement curves as a function of time for the impacted points of the truck and the bridge, as well as the simulation of the way in which the deformations are produced, although they do not report experimental test results with which to compare the results obtained from the simulation. the simulation.

Kenny et al. (2002), obtained by modeling using the finite element method, the dynamic buckling response of geometrically imperfect slender beams when subjected to axial impact loads. Sabuwala et al. (2004), perform a finite element analysis of the steel beam-to-column restraint system in building structures, with a view to assessing their resistance to violent loads, such as blasts or earthquake. They use the ABACUS software and apply cyclic loads at the free end of the beams under study in the simulated model in correspondence with experimental tests. As a result, they make recommendations to reinforce these connections and obtain a high correspondence between the results obtained from the numerical simulation and the experimental results. experimental results.

Ben and Sujimoto (2007) perform a finite element numerical analysis of the impact of a body falling vertically onto a beam simply supported in a horizontal position. They use the PAM-CRASH, 2006 software and obtain displacement-load relationships with a good level of correspondence between the results obtained by simulation and experimentally. Marur and S. Srinivas (2007) simulate a crash on the side of a car using reduced-order finite element models, such as bar elements and nonlinear discrete elements. The load cases used are elastic and fully plastic. They obtain results comparable to those obtained with the use of more complex elements. Sawaoto (2008) simulates the impact failure of a notched specimen used in Charpy pendulum tests using LS-DYNA finite element analysis software and validates the use of this method in this type of simulation. this method in this type of simulation.

Norimitsu Kishi (2008) and six other Japanese researchers carried out a comparative analysis between various finite element analysis methods and experimental results during the analysis of the dynamic behavior of a rectangular section beam subjected to the impact of a weight falling from a certain height. The variants employed were: two-dimensional finite element analysis; using bar elements; multilayer shell elements; one- and two-dimensional discrete elements as well as three-dimensional finite elements. It was confirmed that different methods could be used with a good level of accuracy to estimate the impact behavior of the beam as long as the material constitutive law models, damping constants, and boundary conditions were appropriately introduced. and boundary conditions were entered appropriately.

Likewise, different authors Xin-zheng (2002); Isobe (2008); Fukuda et al. (2008), have simulated the impact of an aircraft on the twin towers of the World Trade Center, aimed at clarifying the way in which they collapsed. All these investigations indicate that the finite element method is currently a very useful tool for the analysis of structures subjected to dynamic loads and in particular to dynamic loads of dynamic loads and in particular impact loads.

This international experience can and should be extended to the field of agricultural machinery, with a view to perfecting design methods, bearing in mind that, in almost all cases, the structure and elements used in agricultural work are subjected to dynamic loads and in many cases to impact loads. impact loads.

This paper presents the results of a study carried out on a structural element consisting of a horizontally supported square steel beam with a joint and a simple support at the ends and supporting a load located in the centre of the beam. This system is subjected to a free fall from different heights, and a dynamic stress and deformation study is carried out using the finite element method. A similar case, in which the load is dropped on the beam at different heights, is analysed using traditional methods of calculation of dynamic load coefficients, The results obtained by the different methods applied are compared.

2. Methods and materials.

The study with traditional methods was carried out on the basis of two methods of calculation of dynamic load coefficients proposed by Pisarenko (1989), for the case of a body of mass m impacting on a beam with certain support conditions, from a given height H (see Figure 1).

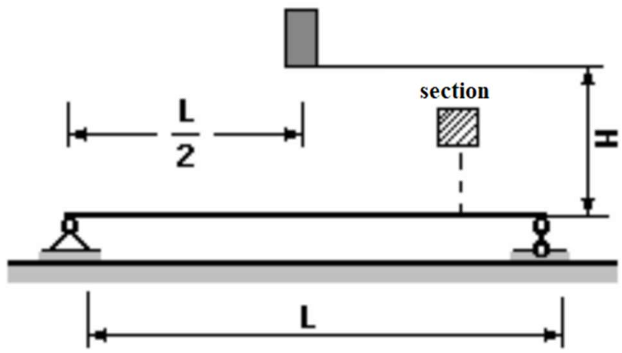

Figure 1. Diagram of the beam under study using traditional calculation methods.

In the first method, in which the mass of the impacted beam is not considered, the dynamic load coefficient is determined by the expression (Pisarenko, 1989). the impacted beam is not considered, the dynamic load coefficient is determined by the expression (Pisarenko, 1989):

$$kd = 1+\sqrt{1+\frac{2H}{\delta_{est}}} \qquad 1$$

where:

kd, is the dynamic load coefficient when the mass of the impacted body is not taken into account;
δest, is the maximum deflection of the beam (impacted body) under the static load (m.g).

In the second method, where the mass of the impacted beam is taken into account, the maximum deflection of the beam (impacted body) under the static load (m.g.) is of the impacted beam is taken into account, the dynamic load factor is determined by the expression:

$$KD = 1+\sqrt{1+\frac{2\cdot H}{\delta_{est}(1+\alpha\cdot\beta)}} \qquad 2$$

where:

KD: the coefficient of dynamic loads, when the mass of the impacted body is taken into account;
α: is a coefficient that takes into account the mass of the struck element and which depends on the shape, restraints, and type and location of application of the loads. The expressions for its

determination are tabulated only for some typical cases (Roark and Young). typical cases (Roark and Young, 1989; Pisarenko, 1979);

β: is the ratio of the mass of the impacted body to the mass of the impacting body. mass of the impacting body.

Expressions 1 and 2 were evaluated with different variants, as shown in Table 1.

Table 1. Variants used in the evaluation of the models

Variant	Drop height, H, mm.	section of the beam	side, mm	length between supports: L, mm	Load impacting the beam: Q=mg, N
1	20	Square	38	940	98
2	40	Square	38	940	98
3	60	Square	38	940	98
4	80	Square	38	940	98
5	100	Square	38	940	98

For the finite element analysis, the beam was subjected to a non-linear impact analysis simulating the fall of the beam-load system from a height H against a rigid surface, as shown in Figure 2.
The evaluation variants during the finite element impact analysis were matched to those evaluated with traditional methods (Table 1).

A volumetric meshing with tetrahedral elements was used, reaching 32212 elements. The analysis was performed with evaluations every 20 microseconds during the impact time.

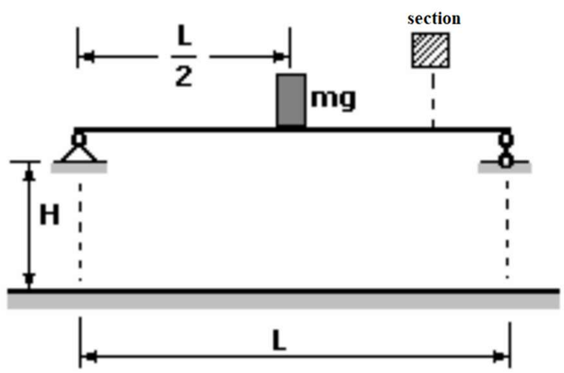

Figure 2. Schematic of the system under study by finite element analysis.

For control purposes, a parallel static finite element analysis was carried out was carried out in parallel, determining the stresses and strains caused on the strains and deformations caused on the beam by the statically applied load Q were determined.

The values of stresses and strains obtained in the dynamic finite element analysis at certain representative points were compared with those obtained in the static analysis, as well as with those obtained by traditional calculation methods (Pisarenko, 1989). calculation methods (Pisarenko, 1989).

3. Results and discussions.

The results of the application of the traditional calculation methods on the basis of expressions 1 and 2 were processed in specially developed software, which provides the results both in tabular and graphical form. Fig. 3 shows, as an example, one of the software output graphs, where the dynamic load coefficients (kd and KD) obtained by the traditional methods (according to expressions 1 and 2) can be seen as a function of the impact height. As can be seen, the dynamic coefficient increases as the impact height increases, and lower values are obtained when the mass of the impacted element is considered.

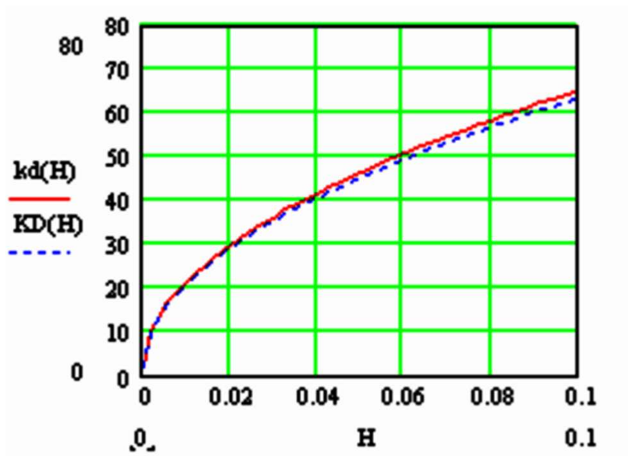

Figure 3. Dynamic load factor calculated by traditional methods.

Figure 4 shows one of the output plots resulting from running the finite element program when performing the static analysis, showing the results of the beam deflection on the vertical axis. of the deflection of the beam in the vertical axis.

Figure 5 shows one of the output plots obtained by the finite element impact analysis, which corresponds to the equivalent dynamic stresses (Von Mises) for a drop height of 2 cm. (Von Mises) for a drop height of 2 cm.

The integrated results of the different methods studied are shown in Table 2, where the deflections and stresses at the center of the beam can be seen, as well as the dynamic load coefficients obtained. dynamic load coefficients obtained.

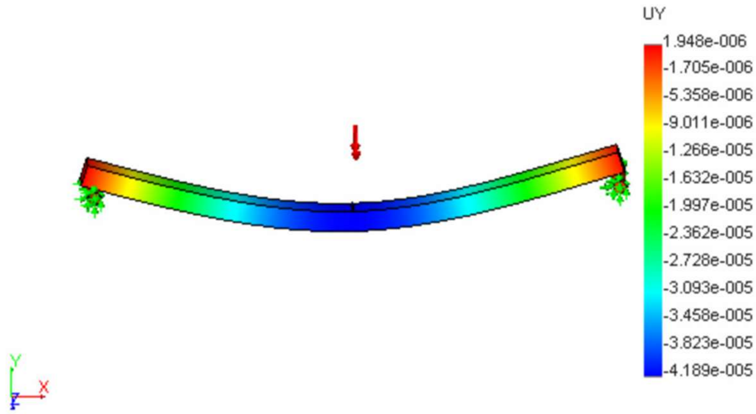

Figure 4. Deflection of the beam in the vertical direction obtained by static finite element analysis.

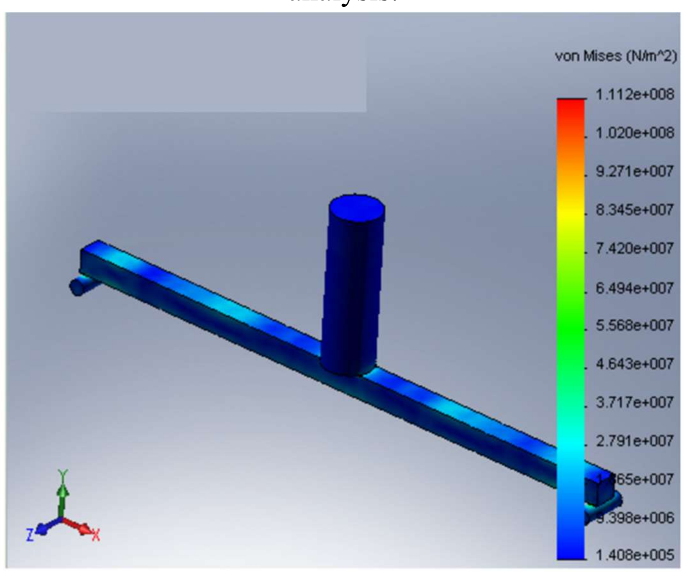

Figure 5. Dynamic stresses obtained by finite element impact analysis.

Table 2. Integration of the results obtained by the different methods

Height of body drop (cm)	Studies	Deflection, mm	Stress (MPa)	Dynamic load factor
0	Traditional 1	0,098	5,036	2
	Traditional 2	0,098	5,036	2
	Traditional Static	0,049	2,518	-
	Static FEA	0,042	2,337	-

2	Traditional 1	1,447	74,663	29,649
	Traditional 2	1,411	72,821	28,918
	Dynamic FEA	0,576	31,78	13,59
4	Traditional 1	2,025	104,513	41,503
	Traditional 2	1,975	101,91	40,469
	Dynamic FEA	0,576	31,78	13,59
6	Traditional 1	2,469	127,423	50,601
	Traditional 2	2,407	124,234	49,334
	Dynamic FEA	0,7050	38,88	16,64
8	Traditional 1	2,843	146,739	58,271
	Traditional 2	2,772	143,056	56,808
	Dynamic FEA	0,8127	38,10	16,30
10	Traditional 1	3,173	163,757	65,029
	Traditional 2	3,093	159,64	63,394
	Dynamic FEA	0,9092	44,97	19,24

As can be seen from the comparison of the results obtained by the different methods, it can be seen that the dynamic load coefficients obtained by finite element impact analysis are substantially lower than those obtained by traditional methods. In the range evaluated, the values obtained are practically one-third of those obtained by traditional methods. of those obtained by traditional methods.

From this, it can be concluded that the application of the finite element method in the analysis of dynamic stresses makes it possible to avoid over-dimensioning during calculations of structural elements subjected to impact loads.

4. Conclusions.

The results of the impact load analysis during a case study of a structural element show that by applying the finite element method, dynamic load coefficients of the order of 1/3 of those obtained by traditional calculation methods are obtained. obtained by traditional calculation methods.

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