NUMERICAL SIMULATION OF THE IMPACT BEHAVIOR OF AN ENGINE MOUNTING / *SIMULAREA NUMERICA A COMPORTARII LA IMPACT PENTRU UN SUPPORT MOTOR*

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Abstract: *The paper refers to the study of the impact behavior of a motor mounting, but at the same time the calculus method can be used also for the cast parts used in agricultural machines. The objective of the work was to simulate the impact behavior of the part, to highlight its breaking areas. There were performed several numerical simulations which results were compared with the experimental measurements performed on test stands. We used FEM for calculation and the PAMCRASH application.*

Keywords: *impact, engine mounting, breaking, Finit Element Method*

Rezumat: *Lucrarea se refera la studiul privind comportarea la impact a unui suport motor, dar in acelasi timp metoda de calcul poate fi utilizata si pentru piesele turnate utilizate la masinile agricole. Obiectivul lucrarii a fost sa se simuleze comportarea la impact a piesei, pentru a pune in evidenta zonele de rupere ale acesteia. Au fost realizate mai multe simulari numerice ale caror rezultate au fost comparate cu determinarile experimentale realizate pe standurile de incercare. Ca metoda de calcul s-a folosit metoda elementelor finite, iar ca aplicatie s-a utilizat PAMCRASH.*

Cuvinte cheie: *impact, suport motor, rupere, metoda elementelor finite*

INTRODUCTION

Currently, the validation of automotive components parts but also of agricultural machinery components are made using physical tests and model calculations. Numerical simulations are performed over several phases of design, allowing confirmation of the results of physical tests and turning them in pre-valid results during one part design.

Engine mountings (Fig. 1) belong to the engine and gearbox suspension system and transmission system respectively. Because they are weight-bearing for the engine and the gearbox, the brackets have a robust shape and a significant weight. They are undergoing to severe and complex stresses such as successive turns, more or less tight, and various types of shock (frontal impact, side impact). These stresses can determine immediate or gradual deterioration of the structure.

A shock is a collision during which the kinetic energy of the bodies which collide is wholly or partially converted into internal energy of at least one of the bodies. This phenomenon occurs in a very short time, around 100ms.

In numerical models, fracture zones are accurately correlated with the results of physical experiments only if the items are as accurately discretized by boundary conditions [4].

The objective of this paper is to correlate the results of the impact virtual simulations with the experimental measurements done in the laboratories.

Meanwhile, will be used more fracture laws associated with several features of materials and will be integrated in the calculation of assembled parts, aiming to determine the law as representative simulating rupture identified in experimental trials.

INTRODUCERE

In prezent, validarea pieselor pentru componentele auto dar si a componentelor masinilor agricole, se face cu ajutorul incercarilor fizice si a modelelor de calcul. Simularile numerice se realizeaza de-a lungul a mai multor faze de proiectare, permitand confirmarea rezultatelor incercarilor fizice si transformarea acestora in prevalidari pe perioada de proiectare a unei piese.

Suportii motor (fig. 1) apartin sistemului de fixare şi suspensie al motorului si cutiei de viteze, respectiv al sistemului de transmisie. Datorită faptului că suportă greutatea motorului si a cutiei de viteze, suportii au o formă robustă si o greutate semnificativă. Suportii, sunt supusi solicitarilor complexe si severe cum ar fi virajele succesive, mai mult sau mai putin stranse, dar si diverselor tipuri de soc (impact frontal, impact lateral). Aceste solicitari pot produce deteriorari imediate sau progresive ale structurii.

Un soc este o coliziune in timpul careia energia cinetica a corpurilor care se lovesc este transformata total sau partial in energie interna a cel putin unuia dintre corpuri. Acest fenomen se produce intr-un moment foarte scurt, in jur de 100ms.

In modelele numerice, zonele de rupere sunt corelate cat mai exact cu rezultatele experimentelor fizice doar daca elementele sunt discretizate cat mai exact in functie de conditiile la limita si fixarile utilizate [4].

Obiectivul acestei lucrari este de a corela rezultatele simularilor virtuale pentru soc cu masuratorile experimentale facute in laboratoarele de specialitate.

In acelasi timp, se vor utiliza mai multe legi de rupere asociate cu mai multe caracteristici de materiale urmand sa fie integrate in calculul pieselor asamblate, avand ca scop determinarea legii care simuleaza cat mai reprezentativ ruptura identificata in incercarile experimentale.

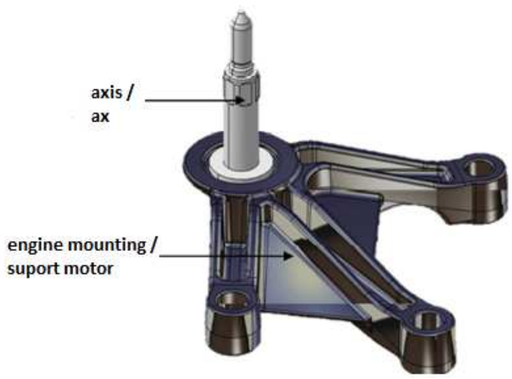

Fig. 1 – The 3D model of the engine mounting / *Modelul 3D al suportului motor*

MATERIAL AND METHOD

The traction tests (Fig. 2) are made with a hydraulic cylinder and a rod placed on the tested part. The test is done with an uniaxial speed and aimed to assess the breaking area and the composite breaking force for parts such as gearbox brackets or engine mountings [1].

MATERIAL ŞI METODĂ

Incercarile de tip tractiune (fig. 2) sunt realizate cu un cilindru hidraulic si o bieleta asezate pe piesa testata. Se realizeaza cu o viteza de deplasare uniaxiala si au ca scop evaluarea zonei de rupere si a efortului de rupere compus pentru piese cum ar fi suportii cutiei de viteze sau suportii motorului [1].

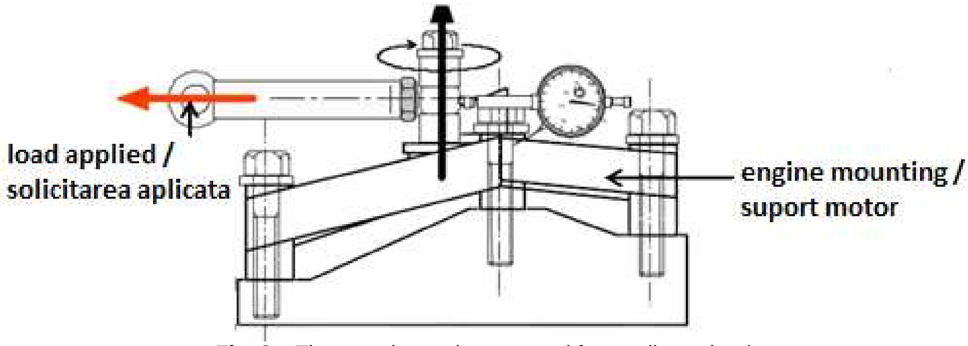

Fig. 2 – The experimental setup used for tensile testing /
Montajul experimental folosit pentru incercarea la tractiune

During the experiments there were performed two tensile testings: one on the OX-axis (Fig. 3) and the second one on the OZ-axis (Fig. 4). The engine mounting is fixed on the bench by 3 screws. An impactor was positioned at the mounting level, so that the center of application of the force to be coaxial with the center of the base. The impactor and the acting hydraulic cylinder are connected by a connecting rod. This rod allows to protect the cylinder, to prevent the apparition of a cutting moment during installation.

In cadrul experimentelor au fost realizate doua incercari la tractiune: o incercare dupa axa OX (fig. 3), iar cea de a doua incercare dupa axa OZ (fig. 4). Suportul motor este fixat pe banc cu ajutorul a 3 suruburi. A fost pozitionat un impactor la nivelul suportului, astfel incat centrul de aplicare al fortei sa fie coaxial cu centrul bazei. Impactorul si cilindrul hidraulic de actionare sunt conectate cu ajutorul unei bielete. Aceasta bieleta permite protejarea cilindrului, pentru a evita aparitia unui moment taietor la montaj.

Fig. 3 – The experimental setup for testing on OX axis /
Montajul experimental folosit pentru incercarea pe axa OX

Fig. 4 –The experimental setup for testing on OZ axis/
Montajul experimental folosit pentru incercarea pe axa OZ

Realization of virtual simulations

We used ANSA for preprocessing, PAMCRASH for analysis and the post-processing was done with METAPOST application.

Meshing the motor mounting is a very imporatant phase and can greatly influence the results. As the element size is larger, the results are far from reality. By clearing fine elements greatly increase the computation time. It must then found a compromise between computation time and the size of the element in order to achieve optimal effectiveness. [5]

Materials underlying principle fracture modeling. They contain all the data needed to create the calculation of fracture. In fact, in addition to applying a material part, each material characteristics should be introduced,, such as density, Poisson's ratio, elastic resistance. The properties of the material used in the calculation are shown in Table 1.

Realizarea modelelor virtuale

Pentru preprocesare s-a utilizat aplicatia ANSA, pentru analiza s-a utilizat aplicatia PAMCRASH, postprocesarea rezultatelor s-a facut cu aplicatia METAPOST.

Discretizarea suportului motor este o faza foarte importanta si poate influenta enorm rezultatele. Cu cat marimea elementului este mai mare, rezultatele se indeparteaza de realitate. Prin compensare, elementele foarte fine maresc timpul de calcul foarte mult. Trebuie deci gasita o varianta de compromis intre timpul de calcul si marimea elementului in scopul de a obtine eficacitatea optima. [5]

Materialele stau la baza modelarii principiului de rupere. Ele contin toate datele necesare crearii calculului de rupere. De fapt, pe langa aplicarea materialului pe o piesa, trebuiesc introduse si caracteristicile proprii fiecarui material, cum ar fi densitatea, coeficientul Poisson, rezistenta elastica. Proprietatile de material utilizate in calcul sunt redate in tabelul 1.

Table 1 / *Tabelul 1*

The properties of the material used in the calculations / *Proprietatile de material utilizate in calcul*

Symbol / *Simbol*	Characteristics / *Caracteristici*	Value / *Valoare*	Measurement units / *Unitati de masura*
E	Young modulus / *Modulul lui Young*	75000	MPa
µ	Poisson coefficient / *Coeficientul Poisson*	0.3 / *0,3*	
ρ	Density / *Densitatea*	2700	Kg/m^3
Rp0.2	Elastic limit / *Limita de elasticitate*	170	MPa
Rm	Breaking limit / *Limita de rupere*	250	Mpa

But if we want to integrate a fracture law in models then we must add a certain number of coefficients according to laws which are determined experimentally and are recovered as a result of tensile tests on samples of material.

Breaking laws studied:

- EPSILONpmax: 16 type material – used to describe the deformation of metal parts during numerical simulations; this law provides a full range of: elastic criteria and fracture models. Behavior will result in a deterioration in the level of isotropic plastic deformation in relation to the maximum plastical deformation. [2]
- GURSON: material type 26 - isotropic deterioration of Gurson type is based on the wall thickening and joining the parts wall porosity.[2];
- FLECK: material type 35 - works well for polyurethane and polystyrene [2];
- KOLMOGOROV-DELL: material type 52 - to this law shall be 2 different types of fracture: ductile fracture associated with increased micro-cavities, fracture by shear;
- EWK (ESI Wilkins Kamoulakos) : Material Type 7 - the criterion for ductile cast materials, which is calculated according to the thickness of porosity, starting from plastic deformation and two functions representing the state of tension [2].

After achieving the numerical discretization, the model preparation is just as important. In fact, our goal is to realize a simple model easely to modify , allowing simulation of real phenomena recorded on the test bench. For this reason, the impact simulation programs provide a wide range of database functions, that can be incorporated in each analysis to improve the probability of the calculation – test correlation.

The engine mounting is fixed on the bench by screws. So, beside applying the force, the mounting will slide up to come into contact with the screw because the hole is much larger than the bolt diameters. Therefore, we performed the modeling of the screw and of the tightening, because simple use of the rigids will not be representative and will not simulate the tests. The tightening is modeled by applying an axial tension on the screw head and, ideally, an opposite axial tension to simulate the screw elongation (Figure 5).

Dar daca dorim sa integram si o lege de rupere in modele, trebuie atunci sa adaugam un anumit numar de coeficienti in functie de legi, care sunt determinati experimental si care sunt recuperate in urma unor incercari la tractiune pe esantioane de material.

Legile de rupere studiate:

- EPSILONpmax: material de tip 16 – utilizat pentru a descrie deformarile pieselor metalice in timpul simularilor numerice, aceasta lege furnizeaza o intreaga gama de: criterii elastic si modele de rupere. Comportamentul sau se va traduce printr-o deteriorare izotropa in functie de nivelul de deformare plastica in raport cu deformata plastica maxima [2]
- GURSON : material de tip 26 – Deteriorarea izotropa de tip Gurson este bazata pe ingrosarea si unirea porozitatilor peretilor pieselor [2];
- FLECK: material de tip 35 – functioneaza foarte bine pentru poliuretan si polistiren [2];
- KOLMOGOROV-DELL: material de tip 52 – pentru aceasta lege se considera 2 tipuri diferite de rupere: rupere ductila asociata cu cresterea micro-cavitatilor, rupere prin forfecare;
- EWK (ESI Wilkins Kamoulakos): material de tip 7 – criteriu pentru materialele ductile turnate, care se calculeaza in functie de grosimea porozitatilor, plecand de la deformarea plastica si doua functii reprezentative ale starii de tensionare [2].

Dupa realizarea discretizarii numerice, pregatirea modelului este la fel de importanta. De altfel, obiectivul nostru este sa realizam un model simplu, usor de modificat, care sa permita simularea fenomenele reale inregistrate pe bancul de incercari. Din acest motiv, programele de de simulare a impactului furnizeaza o gama larga de functii in baza de date, functii care pot fi incorporate in fiecare analiza pentru a ameliora probabilitatea corelarii calcul – incercari.

Suportul motor este fixat pe bancul de incercari prin suruburi. Asadar, in afara aplicarii fortei, suportul va aluneca pana la intrarea in contact cu surubul deoarece alezajul este mult mai mare decat diametrele suruburilor. De aceea, trebuie realizata modelizarea suruburilor si a unei strangeri, deoarece utilizarea simpla a rigizilor nu va fi reprezentativa si nu va simula incercarile realizate. Strangerea se modeleaza aplicand o tensiune axiala pe capul surubului si, in mod ideal, o tensiune axiala opusa, pentru a simula alungirea surubului (figura 5).

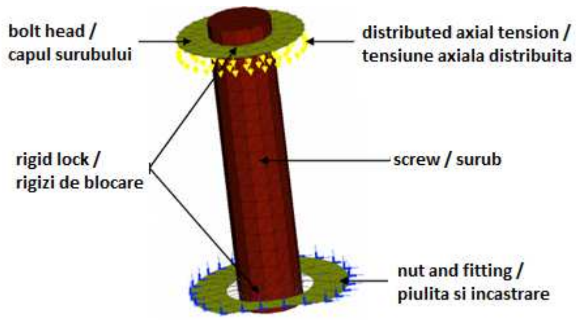

Fig. 5. Screw tightening modelling / *Modelarea surubului cu strangere*

RESULTS

Results for the OX axis

In this test case, we observe that the break occurs in the contact between the shaft and the mounting (Figure 6). In calculations we opted for a "TIED" semi-contact type (soldering in the direction of force application) and a solid-solid contact to manage the controlled breaking of the model elements. Following the virtual simulation, it is observed that the breaking area corresponds to the rupture of the test only for type GURSON law. Other types of fracture laws are not breaking the predictive catch (Figure 7).

REZULTATE

Rezutate dupa axa OX

In cazul acestei incercari se observa ca ruperea apare la nivelul contactului intre ax si suport (figura 6). In calcule am optat pentru un semi-contact de tip «TIED» (lipire in directia de aplicare a fortei) si pentru un contact de tip solid-solid, pentru a gestiona ruperea controlata a elementelor modelului. In urma efectuarii simularii virtuale, se observa ca zona de ruptura obtinuta corespunde cu zona de ruptura de la incercari (figura 7) decat pentru legea de tip GURSON. Celelalte tipuri de legi nu sunt predictive prind zona de rupere.

Fig. 6 – The experimental result on OX axis /
Rezultatul experimental obtinut pe axa OX

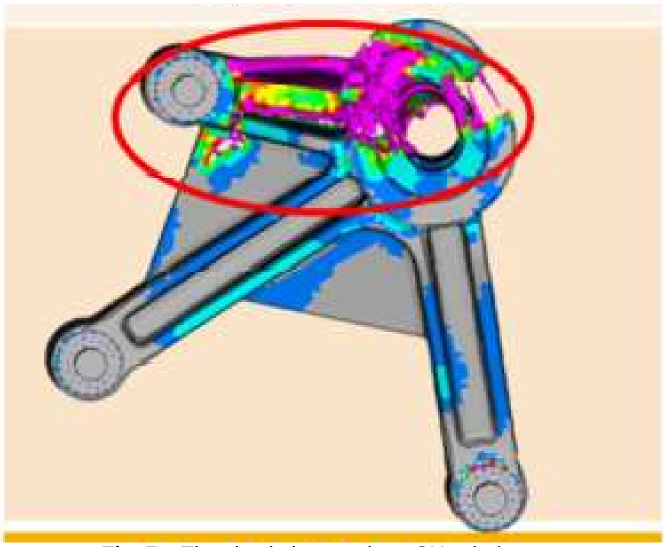

Fig. 7 – The simulation result on OX axis /
Rezultatul simularii efectuate pe axa OX

Breaking load relating to the tests is 36.6 kN (Figure 8). In simulations, there is a tendency of materials 1 and 16 to produce very late rupture, 62% and 68% difference found from testing. 26 material associated to Grunson law allows us to identify a tensile close to the experimental results (Figure 9).

Efortul de rupere in urma incercarilor este de 36,6 kN (figura 8). In simulari, se observa tendinta materialelor 1 si 16 de a produce ruptura foarte tarziu, 62% respectiv 68 % ecart constatat fata de incercari. Materialul 26 asociat legii Grunson ne permite sa identificam un efort de rupere apropiat de rezultatele experimentale (figura 9).

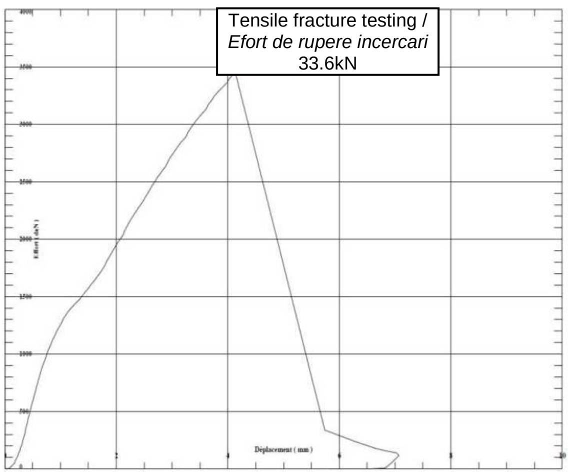

Fig. 8 – The experimental result on OX axis /
Rezultatul experimental obtinut pe axa OX

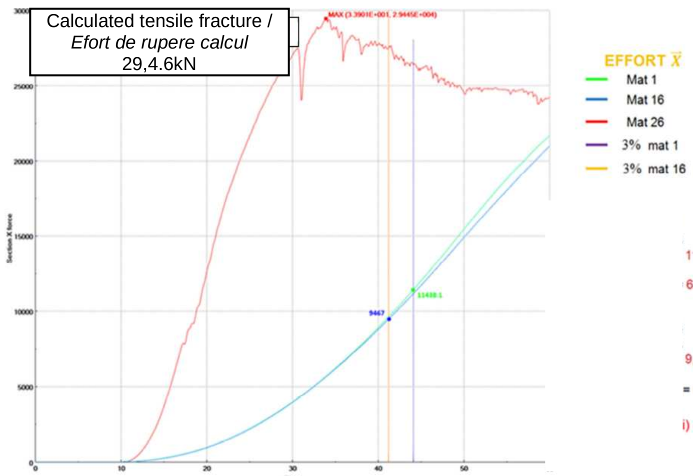

Fig. 9 – The simulation result on OX axis /
Rezultatul simularii efectuate pe axa OX

Results for the OZ axis

In this case we opted for a two- rigid modelling (one for the bracket element and one for the mounting), connected by a spring which blocks the translation of the mounting axis. This modelling is more realistic than a bonding between the two components (Figure 10).

Rezultate dupa axa OZ

In acest caz am optat pentru o modelare cu doi rigizi (unul pentru elementul de fixare, altul pentru suport), toate legate de un arc, care blocheaza translatia pe axa suportului. Aceasta modelizare este mult mai realista decat o lipire intre cele doua piese (Figura 10).

Fig. 10 – The model of the engine mounting on the OZ axis /
Modelul suportului motor dupa axa OZ

As in the previous case, after the virtual simulation, it is noticed that the rupture corresponds to the rupture area obtained in the bench tests than for the law GRUNSON type (Figure 12). Other types of laws are not predictive in determining the rupture zone.

Ca si in cazul precedent, in urma simularii virtuale se observa ca zona de ruptura corespunde cu zona de ruptura obtinuta in cadrul incercarilor pe stand decat pentru legea de tip GRUNSON (figura 12). Celelalte tipuri de legi nu sunt predictive in determinarea zonei de rupere.

Fig. 11 – The experimental result on OZ axis /
Rezultatul experimental obtinut pe axa OZ

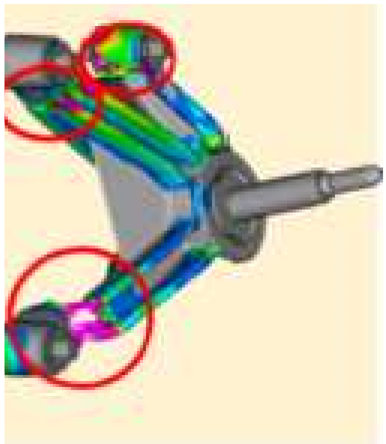

Fig. 12 – The simulation result on OZ axis /
Rezultatul simularii efectuate pe axa OZ

Breaking load relating to the tests is 19.7 kN (Figure 13). From simulations performed, the same trend is observed as for the X axis effort. Elastic-plastic material results are non correlated with our experimental results which allow us to conclude that for models that include contacts, 26 material associated Grunson law allows us to to simulate the experimental tests.

Efortul de rupere in urma incercarilor este de 19,7 kN (figura 13). In urma simularilor realizate, se observa aceiasi tendinta ca si in cazul efortului pe axa X. Rezultatele materialelor elasto-plastice sunt ne corelate cu rezultatele experimentale ceea ce ne permite sa concluzionam ca pentru modelele care includ contacte, materialul 26 asociat legii Grunson ne permite sa sa simulam testele experimentale.

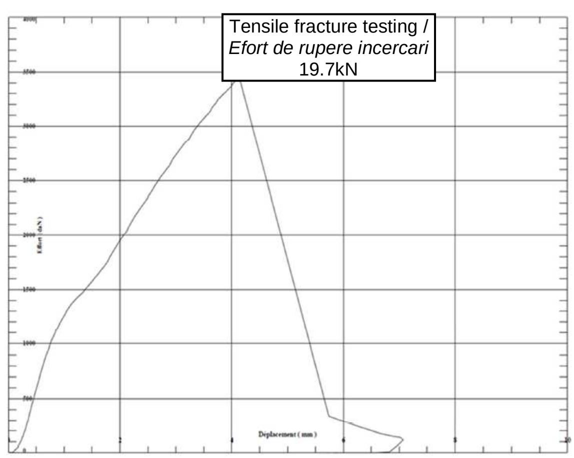

Fig. 13 – The experimental result on OZ axis /
Rezultatul experimental obtinut pe axa OZ

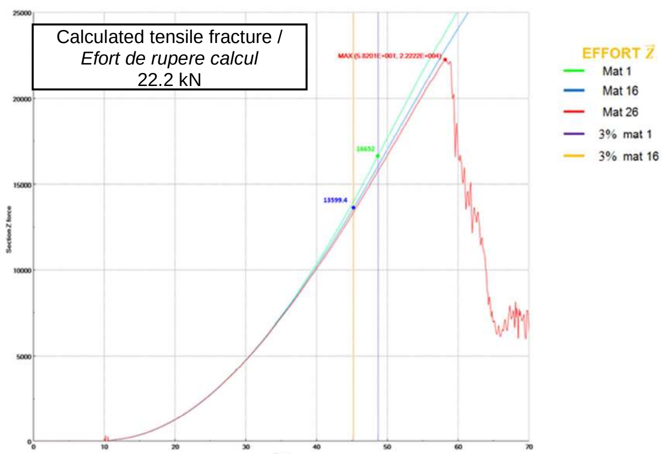

Fig. 14 – The simulation result on OZ axis /
Rezultatul simularii efectuate pe axa OZ

CONCLUSIONS

Following this analysis, there is a premature removal of elements for material types 16, 35 and 71 due to the high compression coefficient. Gurson's law only takes into account the phenomena of frosting between parts.

We can say that the elastic-plastic materials are not representative of models that take into account contacts and compressive stresses. The results obtained demonstrate that the areas split by virtual simulation do not correspond to areas of strain obtained in experimental trials.

The material 26 has a good behaviour, irrespective of the stress type - law of Gurson.

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CONCLUZII

In urma acestor analize, se observa o eliminare prematura a elementelor pentru materialele de tip 16, 35 si 71 ca urmare a uni coeficient de compresiune ridicat. Doar legea lui Gurson ia in calcul fenomenele de matuire dintre piese.

Putem afirma ca materialele elasto-plastice nu sunt reprezentative pentru modelele care iau in considerare contacte si solicitari de tip compresiune. Rezultatele obtinute demonstreaza ca zonele de ruptura obtinute prin simulare virtuala nu corespund cu zonele de ruptura obtinute in incercarile experimentale.

Un comportament bun al materialului 26 oricare ar fi tipul de solicitare - legea lui Gurson.

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