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Numerical Modeling of a Charpy Test Study of the Impact Resistance of Low Alloy Steels and Unalloyed Steels

Ltaief Lammari*, Sana Ben Khlifa ,SalimAbdelli, ChihebSlama , HassenKharroubi
Laboratory of mechanical and agro-industrial engineering, National School of Engineers of Medjez El Beb, University of Jendouba, Route du Kef Km 5 9070 Medjez El Bab, TUNISIA

ABSTRACT
The level of validation of the operation of parts subjected to sudden shocks in a mechanical system characterizes the quality and resistance of the materials used as well as their limits, which are mainly determined by defects in shape and caused by various factors intervening in the process of manufacturing, geometry, type of constraints and transformation required. Based on the finite element tool, this article aims to study by numerical simulation the two types of steels (35CrMo4, C40) in industrial and agricultural activities most commonly used and consumed in manufacturing and to study their reaction. to sudden mechanical stresses through numerical models of the CHARPY test known from KCU and KCV in order to avoid sudden damage and to open the possibility of improvement by heat or other treatment if necessary, it is therefore necessary to determine the effect of these forces applied in order to choose the most suitable one which avoids cracking under the effect of contacts. The JONSON CKOOK model can guide us to the desired results and answer the questions posed.

Keywords:*materials, finite element, numerical simulation, CHARPY test, sudden damage, crack coefficient, Johnson–Cook model*

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I. Introduction

These tests were made quantitative by BARBA in 1893. The use of the pendulum hammer, proposed by RUSSELL in 1897, was popularized by the work of CHARPY, whose name has remained attached to the impact test. The CHARPY test is widely used today, both for the study of brittle fracture resistance and for factory control, in the agricultural field, it makes it possible to follow the evolution of the properties of the material of the tank during its aging under shocks due to the severity of the working environment[1,2].Model the behavior of materials and the phenomena of damage caused by the deformation of plastic materials under sudden stresses to reduce the cost and time of experiments. Among the most important mechanical tests that will identify the part subjected to shock stresses, the famous CHARPY resilience test is a shock bending test, carried out on a pendulum hammer [3]. It provides information on the fracture behavior of the tested material. The energy of bending by shocks makes it possible to characterize the ductility of steel and its sensitivity to brittle fracture as a function of temperature and speed; it is used to define the qualities of normalized steel[4,5,6]. The result of this test is expressed in terms of energy, which is called the resilience of the material. This test involves breaking a notched test piece with a pendulum hammer and measuring the energy consumed. If the pendulum hammer is instrumented, it is then possible to establish the force-displacement curve of the part tested, it consists in determining the impact resistance of metals, or the known resilience KCU or KCV[7, 8].

II. Material and method

The specimen is broken by impact under the effect of a pendular mass (Figure 1), in its initial position, the angle of the pendulum with the vertical is α (energy: Wi), after rupture of the specimen at the maximum angle of ascent is β (energy: Wr). The difference (α-β) characterizes the energy expended (energy: Wa) for the rupture of the specimen so Break energy:
$Mgl(H-h)=M.gl(\cos\alpha-\cos\beta)$. Indeed, if there were no specimen to break, the pendulum would rise to a position symmetrical to the starting position with an angle α [9,10,11].

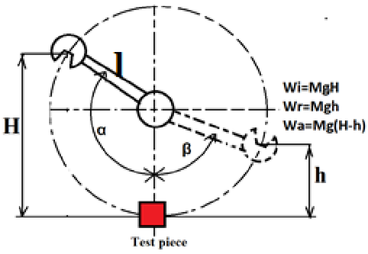


Figure 1. Characterization of the energy expended for the rupture of the specimen

the macroscopic phase of this material is more particularly studied. On one face of this element, the surface S and the resistant zone Sr are raised. The zone of crack SD is defined [12]:

$$SD = S - Sr \quad (1)$$

The damage variable D may depend on microscopic considerations. We define this variable as the ratio of the surface area of the defects to the total area (Equation 2):

$$D = \frac{SD}{S} = 1 - \frac{Sr}{S} \quad (2)$$

This definition, valid on an element face, becomes true for the whole material if it is considered isotropic and homogeneous: cracks and cavities are reflected in all directions. The damage variable is thus an adimensional value between 0 and 1.To better represent the phenomenon of sudden cracking, it is necessary to identify and determine the progression of damage in the materials. In this work, we owe this reference to experimental research [13] and we have reproduced the same test conditions numerically, with the aim of determining the fracture parameters ∑Di according to Johnson's fracture law - Cook compound of three multiplicative terms [2,6,14,15] equation 3:

- a hardening term that depends on three characteristic parameters of the material A, B and n.
- a term of dependence on the plastic strain rate $\dot{\varepsilon}$.
- a term of dependence on the which depends on the melting temperature of the material Tm, on the ambient temperature Tr and on a parameter m.

$$\sigma f = (A + B\varepsilon^n)\left(1 + C.\ln\left(\frac{\dot{\varepsilon}}{\dot{\varepsilon_0}}\right)\right)[1 - (\frac{T-T_r}{T_m-T_r})^m] \quad (3)$$

Where σ is the equivalent stress andƐthe equivalent plastic strain.In conclusion, Johnson and Cook proposed that strain failure depends on the stress triaxiality ratio, strain rate, and temperature. Thus, the failure model can be written as follows (Equation 4)[14,16]:

$$\varepsilon_f = (D_1 + D_2 . e^{D_3\frac{\sigma m}{\sigma eq}})(1 + D_4 \ln\left(\frac{\dot{\varepsilon}}{\dot{\varepsilon_0}}\right))(1 + D_5\left(\frac{T-T_r}{T_m-T_r}\right)) \quad (4)$$

The model is said to be dynamic because the plastic deformation at break is dependent on the equivalent plastic strain rate $\dot{\varepsilon}_p$, material parameters D1, D2, D3, D4 and D5, depends on the hydrostatic pressure [10], the stress equivalent σeq, of the plastic deformation $\dot{\varepsilon}$ [11] , of the melting temperature of the material Tm , of the ambient temperature Tr and of the contact temperature .

The dynamic damage effort must be justified to validate the support on the JOHNSON - COOK model, so for our approach to be clear it is important to find a clear relation between the speed and the impact force, since the energies kinetics and potentials to break the specimen are written respectively:

$$Ec = \frac{1}{2}m.v^2 = \frac{1}{2}m.l^2.\dot{\alpha}^2 \text{et Ep=} \quad Ep = m.g.l.\cos\alpha \quad (5)$$

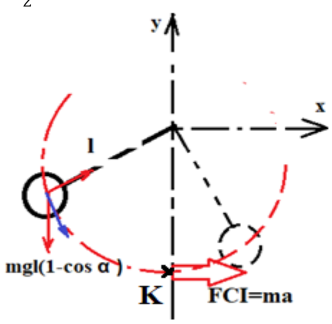


Figure2.Explanatory diagram of the angular system

The law of conservation of energy tells us that the speed has become maximum so that an angle takes a value of zero at the moment of rupture of the specimen at point K.

$$V = (2gl\cos\alpha)^{1/2} \quad (6)$$

III. Result and discussion:

A distinction is made between U-notched and V-notched ISO specimens whose dimensions and machining tolerances are accepted for the Charpy test, Figure 2. An increase in the stress level of the specimen causes a displacement of the resilience curve towards higher temperatures and also to an increase in the energy level of the ductile plate [2]. Our work consists in studying the specimens are subjected to different speeds of solicitation in other words loads with different values[3,4]:

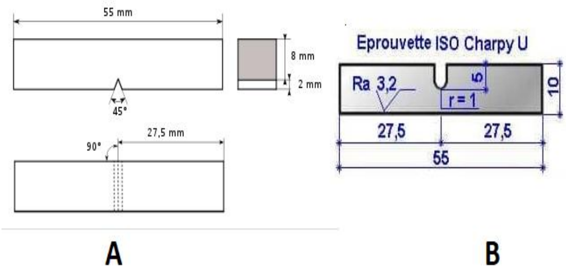


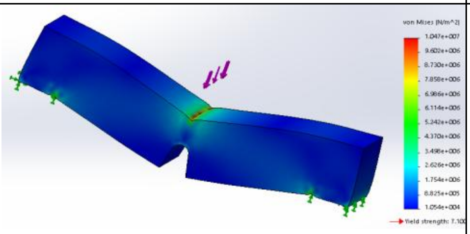
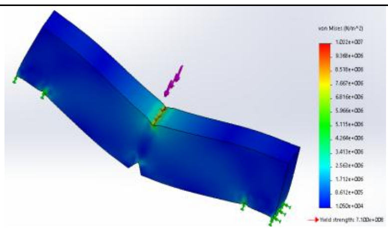
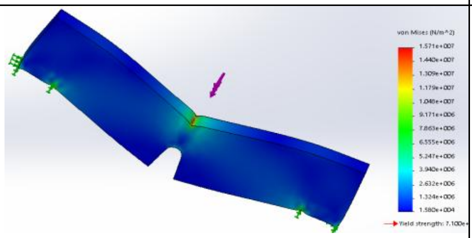
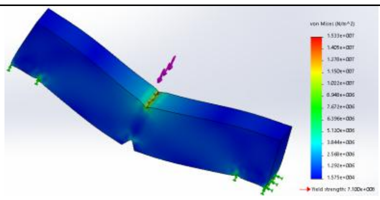
Figure 2: standardized dimensions of a specimen for CHARPY testing[17]

In our numerical model, the boundary conditions have been defined by exactly two sides of the specimen studied, a supposedly ambient temperature and each time The speed variation is verified theoretically by the loading modifications which will be converted into fracture energy.
The numerical tests are presented in the following table for the two materials chosen because in our field it is very important to identify the mechanical properties and the resistance limits to avoid sudden breakage of the parts as much as possible.

Table3. the mechanical properties of the two materials [19,20]

	34CrMo4	C40
Rm ($N.mm^{-2}$)	800/1200	530 / 580
Re ($N.mm^{-2}$)	550/800	260 / 320
A %	11/15	16 / 17

Table 1. Numerical simulation results for low alloy steel A (35CrMo4)

ME	A		σ(en $N.m^{-2}$) $1N.mm^{-2}$=1MPa	
FORCE	KCU	KCV	KCU	KCV
50			**1.047e+7**	**1.022e+7**
75			**1.571e+7**	**1.553e+7**

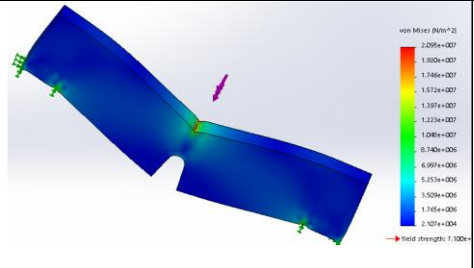
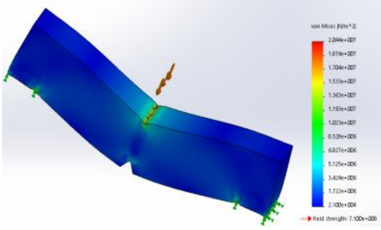
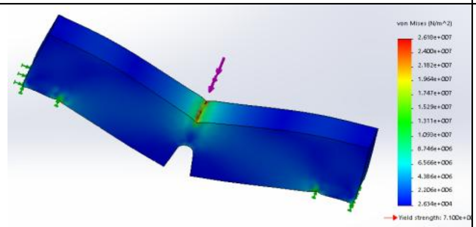
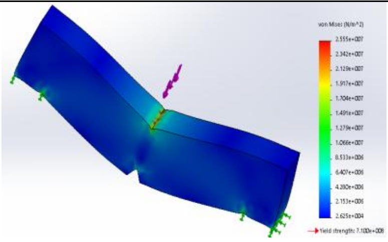
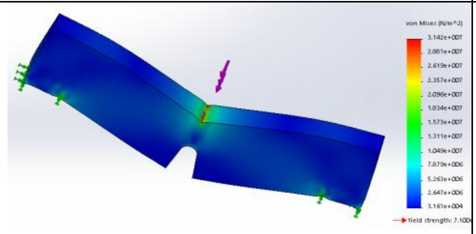
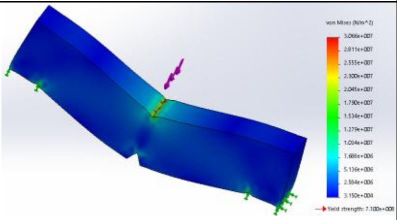
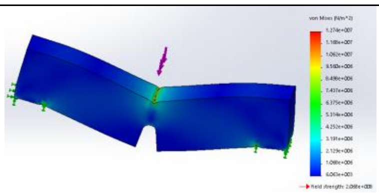
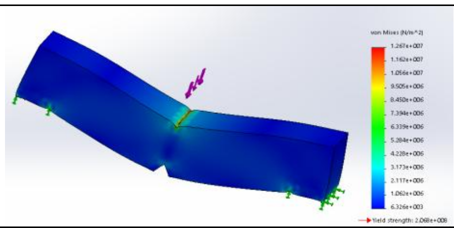
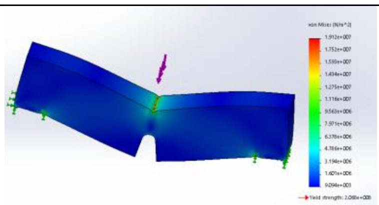
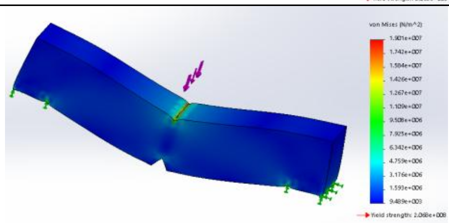
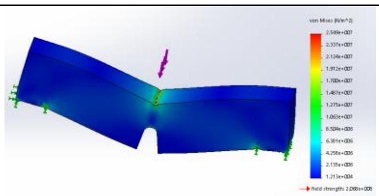
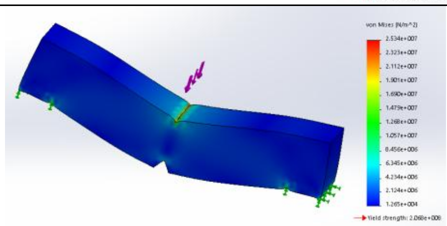
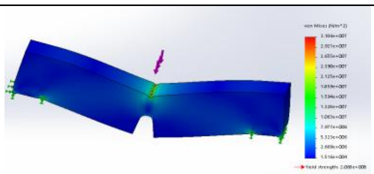
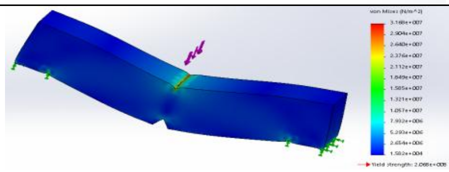
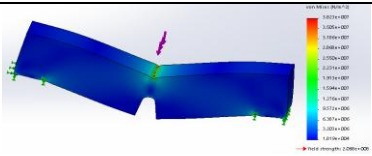
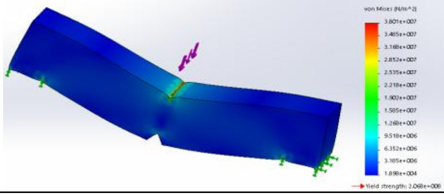
100			**2.095e+7**	**2.042e+7**
125			**2.618e+7**	**2.555e+7**
150			**3.142e+7**	**3.066e+7**

Table 2. Numerical simulation results for unalloyed steel (C40)

ME	B		Б(en $N.m^{-2}$) 1$N.mm^{-2}$=1MPa	
FORCE	KCU	KCV	KCU	KCV
50			**1.274e+7**	**1.267e+7**
75			**1.912e+7**	**1.901e+7**
100			**2.549e+7**	**2.534e+7**
125			**3.186e+7**	**3.168e+7**

150			**3.823e+7**	**3.801e+7**

The results show that for a more rigid material it takes less effort to break it is the opposite also because there are cases it is requested to intervene by one of the methods to increase the performances of the materials. the values also show that the KCU type sample is safer in the impact work piece design.

IV. Conclusion

The Charpy test is a complex test involving many physical phenomena The complete modeling of the test requires representing all the phenomena, in particular the crystallography of materials, the type of treatment carried out, the inertia, the diffusion of the temperature, L numerical tool can be used for sensitivity studies: speed effect, specimen size effect, impact radius effect The numerical tool can be used to analyze Charpy test results (example agricultural materials) to extract relevant data: behavior, brittle fracture, fracture of the
In conclusion that the increase in rigidity requires less shock force to break the specimen, so the shape of the U-shaped notch guarantees a safety factor in the event of manufacture than the V-shape.

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