Dynamic Crack Opening Displacement; Effect of Yield Stress, Relation with Overall Strain

By G. Pluvinage - B. Savage - and F. Montariol
Université des Sciences et Techniques de Lille - France

Although the concept of crack opening displacement (C.O.D) as a criterion for initiation of fracture was introduced several years ago, there is a relatively little use because of the complexity of the test using a clip gauge. The clip gauge displacement is converted in crack tip displacement using a geometrical relation,who assumed that the crack faces open in a simple hinge mechanism about a center of rotation defined by a rotational factor.The values of the rotational factor are different with authors,1/3 or 1/2 and aslo 1/8 when the C.O.D values are little. The two-notch technique is more simple and is the only pratical method to evaluate C.O.D in dynamic conditions. The two-notch specimens have the same dimensions as the charpy V impact test and two symetrical notches 2mm deep and 0.25mm wide.During the test,C.O.D values are the same from the two nothes and,with a notch spacing of 5mm,plastic hinges are relatively separated and C.O.D not affected (figure1).

DETERMINATION OF IN FLUENCE OF METALLURGICAL FACTORS ON C.O.D

grain size affectes C.O.D values and transition temperature defined at C.O.D=S=$2\pi\varepsilon yT$,this value is more elevalated with a coarse grain and scattering larger because of the probalistic theory of fracture.

8 carbon and low allied stells are utilised;type of AFNOR steels, transition temperature and yield strengh are indicated in table I.

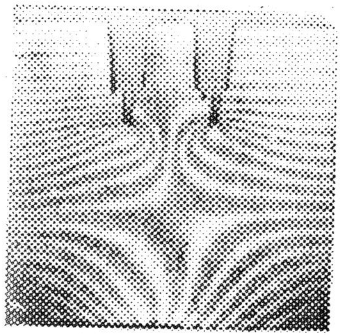

Figure I: evidence of plastic zone in double notched specimens with moire-patterns

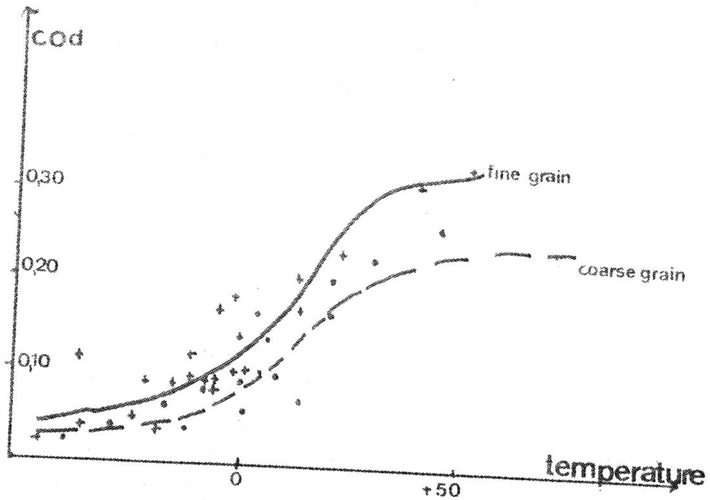

Figure II : Influence of grain size on C.O.D - Temperature curve

steel	C28d	XC32	XC38	XC48	XC55	55S7	XC80	42CD4
σ_y	29,2	31,4	33,3	39,1	43,1	55,0	48,4	78,5
transition temperature at $S=2\pi\varepsilon_y T$	-45	-40	0	40	120	not defined		150°C

Increasing yield stress results in an increase in transition temperature and decreasing C.O.D value at general yielding but for XC80 and 55S7 the choosen requirements are not satisfied because at all test temperature the equality of yield plastic zone and thickness of the test specimens is not satisfied; bainitic steels like42CD4 give a particular temperature curve;yield stress is about 80 Hbar but we can defined a C.O.D transition temperature (figure 3).

We remark that the scatter increases when yield stress decreases certainly because of interference of more large plastic hinges and too large notch acuity for this steel fatigue crack are more convenient for low dynamic yield stress steels in satisfaction to WELLS's relation :

$\rho = \frac{\pi\sigma_y}{E} T$ T Thickness   E = YOUNG's modulus

This thickness of test piece, altough it is difficults to propagate two identical fatigue corrosion cracks,permises two notch specimens prepar on with great acuity. We hope to devellop this technic to obtain a simplifing test type in order to promote its extension. Scattering of S values of double notched technic is estimated of 25% with XC38 steel at room temperature with 75 test pieces.

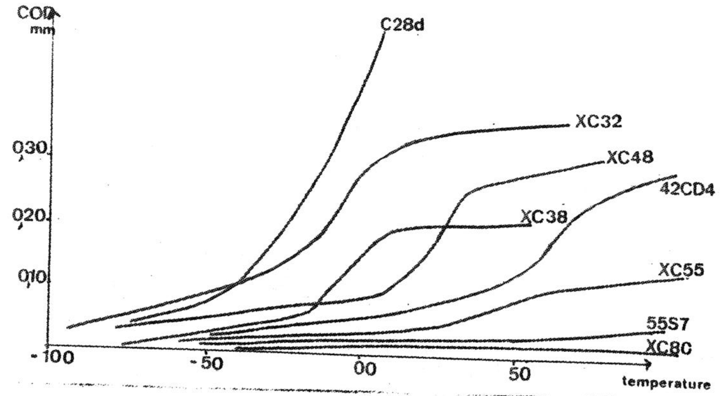

Figure 3 : Influence of yield stress on C.O.D temperature curve; Increasing yield stress decreases transition temperature and C.O.D values at general yielding,XC38 is a dirty steel,inclusions affects C.O.D values.

<u>DYNAMIC CRACK OPENING DISPLACEMENT MEASUREMENT TECHNIQUE</u>

Crack opening displacement can be measured with double notched specimens or with instrumented CHARPY impact test. Time to brittle fracture is required and C.O.D cross-head deflection relationships were evaluated. For low strength steel this relation is pratically independant of yield stress. (Fig 5) For medium strenght steel (for exemple XC80) this relation is different for all steels. Fracture energy of single notch and a double notch specimen are not very different (figure6).

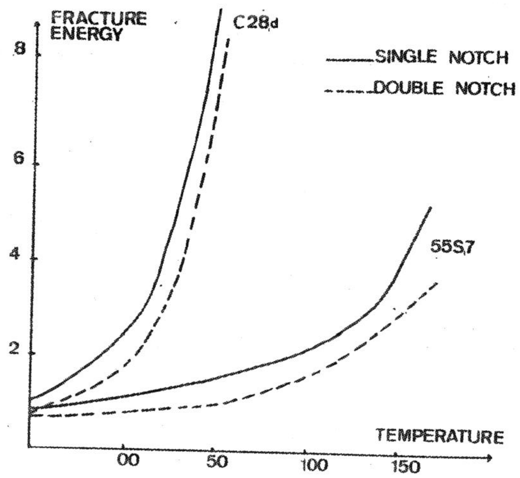

Figure 4 : Fracture energy -Temperature curve for single and double notched specimens

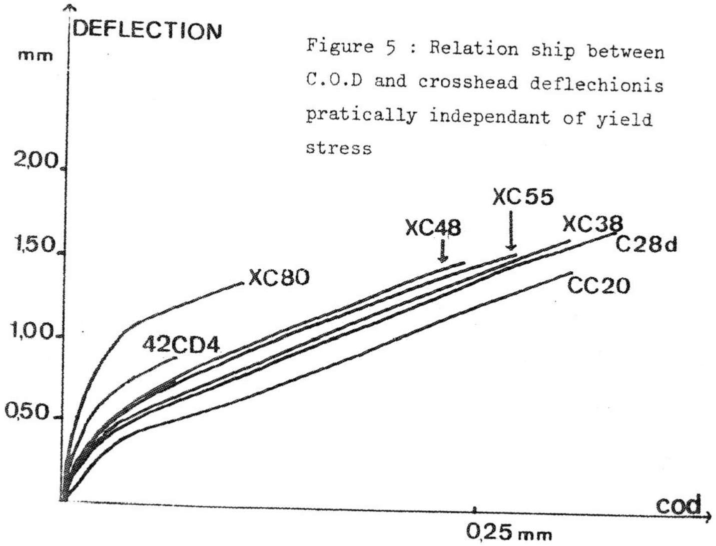

Figure 5 : Relation ship between C.O.D and crosshead deflechionis pratically independant of yield stress

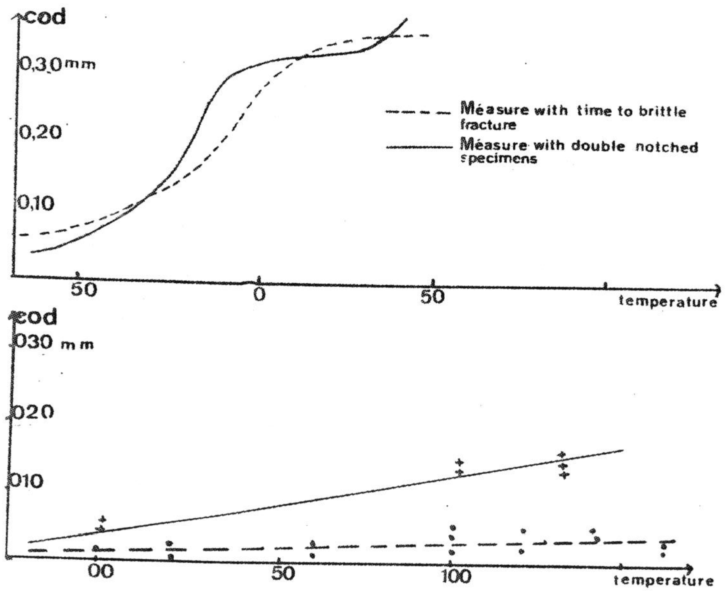

Figure 6 : Comparaison of dynamic C.O.D with double and single notched specimens.

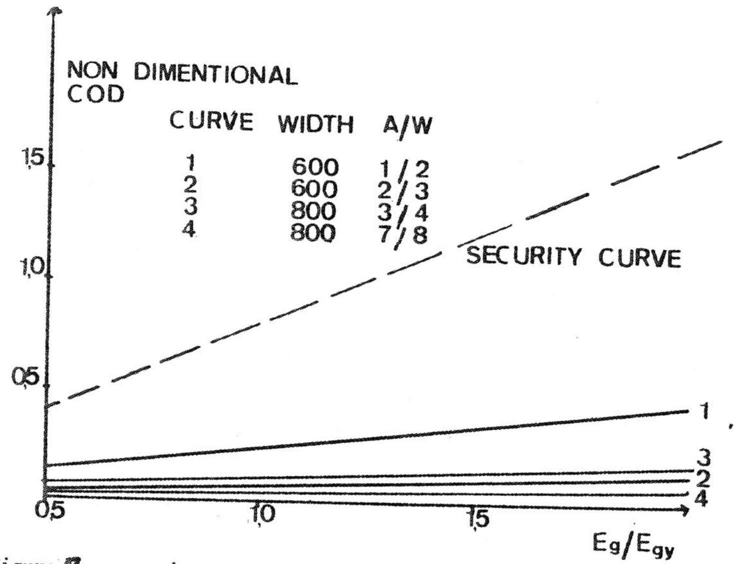

Figure 7 : experimental relation between no dimentional C.O.D and ratio overall strain to overall yield strain

All tests plates have 300X300 mm dimensions. Ratio of slot length to gauge length is plotled on all curves.

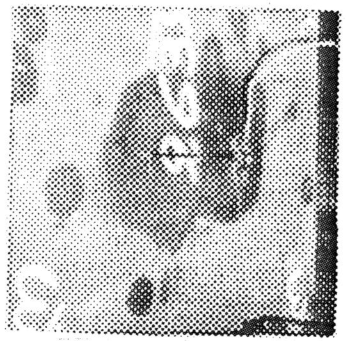

Figure 7 Bis : experimental attachement, C.O.D. is mesured with clip gauge, overallstrain with dial gauge.

Good corelation is obtained between this two techniques for C.O.D value betow transition temperature. For higher values of fracture energy, decreasing of speed of hammer give surestimated value. For the higher strength steel XC80,55S7 value with instrumented CHARPY impact test are upper double notch value because this technique gives off load measurement of C.O.D, plastic component is only taken in consideration.

EXPERIMENTAL RELATION BETWEEN C.O.D AND OVERALL STRAIN

Theorical analysis from BURDEKIN and STONE gives a linear relation ship between C.O.D and the ratio of overall strain Eg to overall yielding strain Egy (after Eg/Egy=1)

Experimental confirmation from wide plate tensile tests on mild steel A42 was performed.The specimens were made with central transversal slot Jeweller's sawcuts were made in the edges of these slots. 6 types of wide plates tests were loaded in tension with a 60 tonnes capacity machine. Dimensions of test plates were 300X300mm, 400X400mm, 500X500mm,600X600mm and 800X800mm; thickness of plates was 8mm.

Crack opening displacement was measured at 20mm from the edge of this artificial defect with a clip gauge. Overall strain was measured on a 100mm gauge length with a dial gauge. Ratio Eg/Egy was experi mentaly estimated, Egy is the value at the point where stress overall strain curve becomes non linear. Influence of the ratio of slot length to gauge length was examined with 300.300mm wide test plates. All curves were linear and included in a scatter band, slope of curve is few affected from this ratio probably because of finite width effects.

With different size of width of test plates, ratio of slot length to gauge length beeing constant and equal to 1/3, we precise finite with effects,plastic zone cannot reach edge of plates at Eg/Egy<2,5. Linear relationship is also ascertained with large plates and large slot but buckling effect can occur when Eg.Egy>2,5.

Artificial defect in welded joints in the same test plates gives linear no dimentional C.O.D overall strain curve in scatter band (Fig8). The upper limit of this scatter band give a "security curve" which can be use for prediction of critical defect size.

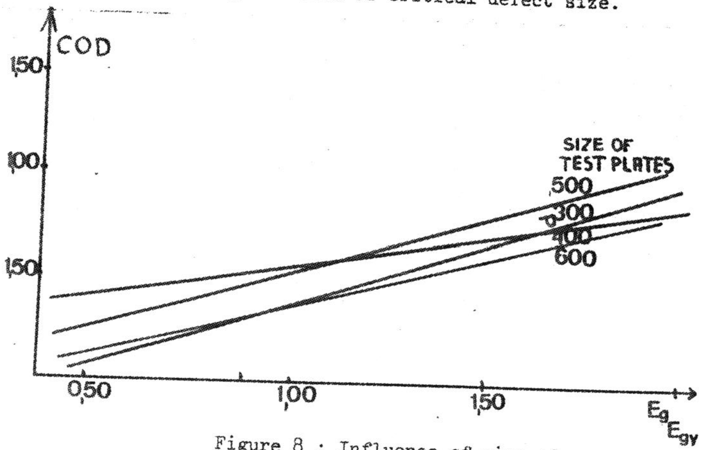

Figure 8 : Influence of size of tests plates on non-dimentional C.O.D and overall strain.

CONCLUSION

Crack opening displacement can be measured with double notched specimens and transition temperature be defined from a yielding stress below 45Hbar. Dynamic crack opening displacement can also be measured with instrumental impact test but better correlation is obtained with double notch specimens.

There is a linear relationship between non dimentional crack opening displacement and overall strain. This is important for practical application because permissible defect size is directly proportional toS/Ey   Ey : yield strength

BIBLIOGRAPHY

1/ WELLS R.A. British Welding Journal 1963, 10 p 563 - 520
2/ BURDEKIN and STONE : Journal of strain analysis 1966 12 - 145-153
3/ PLUVINAGE - MONTARIOL : To publish "Revue de Métallurgie".

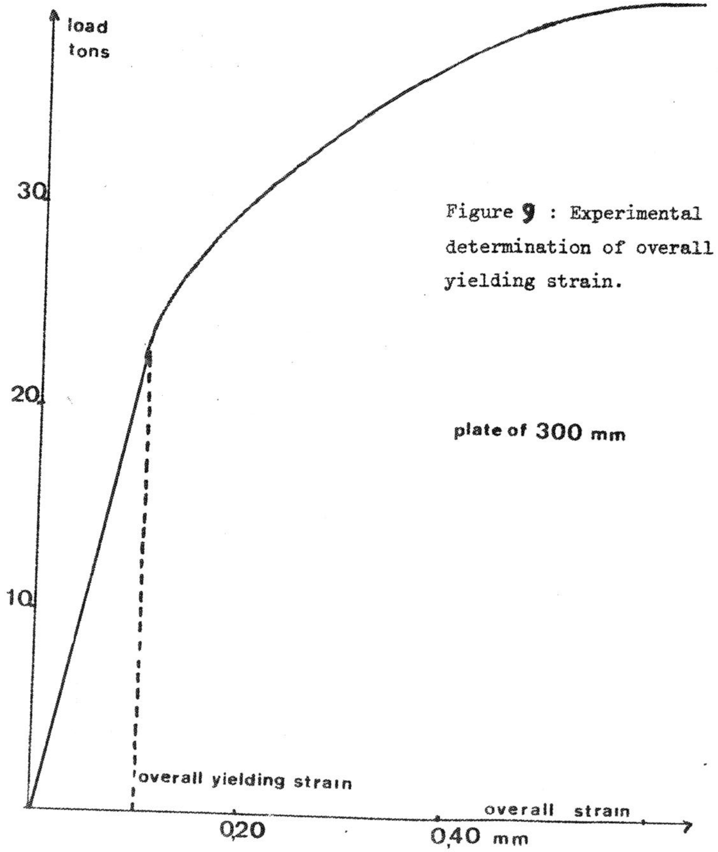

Figure 9 : Experimental determination of overall yielding strain.