QUENCHING CRACK DETECTION BY ACOUSTIC EMISSION

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OUTLINE

Acoustic emission during quenching is used to detect crack formation. To ensure coupling between specimen and transducer, we used either coupling by a wave-guide or by the quenching medium. For 55 S7 steel, cracks occur when quenching cylindrical specimens into water, especially hot water. Cracking occurs at the end of cooling probably during the martensite formation in the centre of the specimen.

INTRODUCTION

The quenching crack mechanism of formation is not yet completely understood in the case of steel. One result which seems of interest to us is the precise moment during quenching when the cracking occurs. By measuring the internal temperature of specimens during quenching and knowing the delay of cracking one is able to determine the temperature level of the cracks. Acoustic emission used during quenching appeared to us the most suitable method for determining the moment when cracks occur.

EXPERIMENTS

The experiments reported here are one part of the thesis of Mr. Flahaut who studied the effects of quenching liquids on hardness and the occurence of quenching cracks in 55 S7 steel. During that experiment we measured the internal temperature of cylindrical steel specimens as a function of sample radius (3 to 12 mm) and quenching medium.

Results reported here concern two steel qualities : 55 S7 and 55 SC7. Their chemical analysis appear in the table below :

	C	Mn	Si	Cr	Ni	Cu	S	P
55 S7	0.56	0.75	1.67	0.09	0.07	0.105	0.020	0.019
	C	Mn	Si	Cr	Ni	Cu	S	P
55 SC7	0.57	0.70	1.72	0.35	0.25	0.24	0.013	0.016

They were heat-treated at 900°C in a vertical furnace under argon atmosphere. Among the quenching liquids used, the only one leading to crack formation is water and in particular hot water.

Our study by acoustic emission is made easier by the fact that cracking time is very short during quenching. Consequently the acoustic power is high. Difficulties come from coupling the transducer to the specimen which is initially at a high temperature.

For coupling we used three kinds of devices as represented in figure 1 :

1. The specimen is quenched on a wave-guide which is left to soak in the liquid.
2. The specimen is screwed to a vertical rod which goes through the furnace; the transducer is coupled at the upper end of the rod.
3. The sample is quenched near a wave-guide which is soaking in water.

The acoustic emission apparatus is an Audimat S from Leanord. The gain is 80 to 90 db. with a threshold value of 2 volts. The resonance frequency of the transducer is 500 kHz. The signal is high-pass filtered at 200 kHz. We recorded the summation of acoustic emission counts as a function of time during quenching on an analog recorder.

Complementary experiments consisted of dilatometry during tempering, optical and SEM micrography, hardness measurements.

RESULTS OF THE EXPERIMENTS

Occurrence of cracks

Two types of cracks appeared: cylindrical ones which are strictly located at the ends of the samples (about one millimetre deep) and extended radial cracks as shown in figure 2.

Radial cracks were observed only after quenching in water at a temperature above 20°C. In 55 S7 steel they occur only in water above 80°C for specimen diameters below 8 mm. In 55 SC7 steel, crack occurrence is more and more frequent as the temperature of the water is increased; cracks appear for specimen diameters below 18 mm.

Acoustic emission and cracking delay

Among the experimental devices used, the third one was the most suitable mainly because it does not disturb the quenching itself: no hole was drilled into the specimen - no contact with the wave-guide. Figure 3 shows the relationship between the summation of acoustic emission counts and time. On the same diagram we have marked the temperature-time curve of the centre of the specimen and of its lower end. At the beginning of the cooling period, the counting rate is high (4.10^5 counts for six seconds); it lowers considerably when the vapour film becomes stable on the sample. At the beginning of boiling, there is an increase of counts; then, the counting rate is extremely low. One or several bursts are then recorded when the sample cracks (here, after 20 seconds). This has been confirmed by observing about 200 cracked and non-cracked samples.

The cracking delay and the intensity of the cracking noise depends on the sample sizes and the quenching conditions. The recorded values of the cracking noise vary from 10^3 to 10^5 counts; the average value is about 20 10^3 counts for a gain of 88 db. Figure 4 shows the cracking delay as a function of water temperature for 55 S7 steel samples of 10 mm diameter. It shows that the average cracking delay increases when water temperature becomes lower.

On Figure 4, we have also drawn out the cooling time up to 100°C and 200°C at the centre of the samples. One can see that cracking occurs at the end of the cooling of the centre. Further experiments: dilatometry during tempering, hardness measurements and optical micrography allow us to attribute cracking occurrence to a partial martensite transformation of the specimen centre (at least 50). In addition, we can also note that crack propagation goes along the grain boundaries as shown to us by SEM micrographies.

CONCLUSION

Acoustic emission seems to fit to the detection of the quenching cracks and to the evaluation of their temperature formation. (As long as cracking does not occur at the beginning of the boiling process). This work allows us to state that quenching cracks occur during the martensite transformation of the centre of the specimen.

Nevertheless these conclusions must not be extended, without further experiments, to other steel qualities and sizes of specimens.

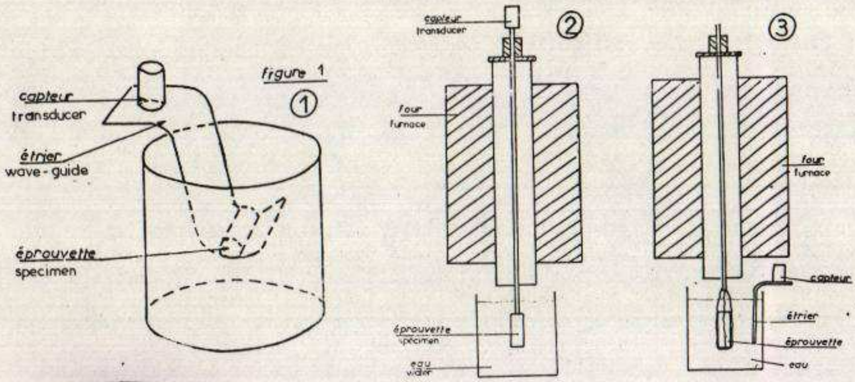
figure 1
①
capteur
transducer
étrier
wave - guide
éprouvette
specimen
②
capteur
transducer
four
furnace
éprouvette
specimen
eau
water
③
four
furnace
capteur
étrier
éprouvette
eau

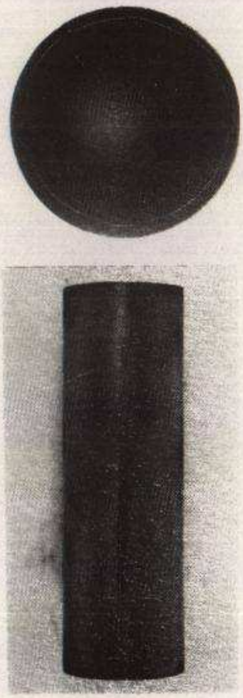

Figure 2

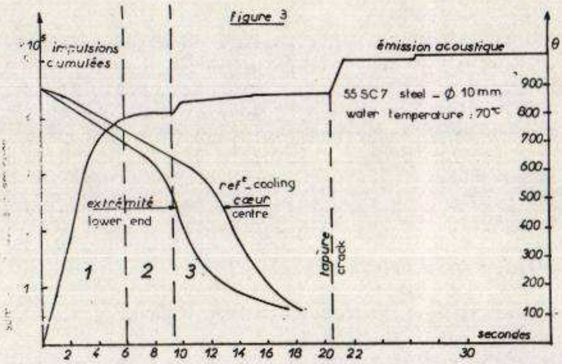
figure 3
impulsions cumulées
émission acoustique
θ
55 SC 7 steel - ϕ 10 mm
water temperature : 70°C
ref^t. cooling
cœur
centre
extrémité
lower end
tapure
crack
1
2
3
secondes
900
800
700
600
500
400
300
200
100
2 4 6 8 10 12 14 16 18 20 22 30

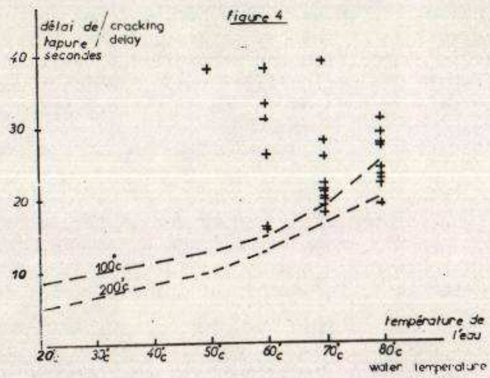
figure 4
délai de tapure / secondes
cracking delay
40
30
20
10
100°c
200°c
température de l'eau
water temperature
20°c 30°c 40°c 50°c 60°c 70°c 80°c