ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume XI (XXI), 2012, NR1

SAMPLES USED TO TEST COOLING LIQUIDS

Mudura Pavel
University of Oradea, pmudura@uoradea.ro

Keywords: cooling liquids; cooling capacity, test samples;

Abstract : This paper is an overview of the types of samples used in the testing and evaluation methods of cooling liquids: requirements for the samples, their characteristics, and the advantages and disadvantages of these samples are outlined.

1. INTRODUCTION

As we know, cooling is a basic operation of thermal treatment, which is represented by the evolution of the temperature field in the volume of the part, during it's cooling process. Of the cooling mediums used regarding thermal treatment, cooling liquids have the largest share.

The samples, used in test methods of cooling liquids, play an important role in determining the representative sizes of these liquids, and are specific to each method. These methods can be grouped as follows [1] :

- *thermophysical methods*, targeting the coolant's ability to extract heat from a metal sample while it is cooling.
- *metellurgical methods,* which aim to determine the liquid's capecity to harden a certain steel by quenching.
- *physico-chemical methods,* using physico-chemical properties of the coolants, in order to determine their ability to maintain their quenching capacity during work.

Thermophysical methods use to charactarize coolants, the notion of *cooling capacity*, while the metallurgical methods use the notion of *quenching capacity.* These two terms, accordint to „Metals Handbook" [2], are defined as follows: the *cooling capacity* is the thermal response of the coolant, or the mode of heat removal from a sample, usually standardized; the *quenching capacity* is the metalurgical response of a steel sample, or the liquid's capacity to create quenching structures in a given section of the steel.

3. SAMPLES USED TO TEST COOLING LIQUIDS

3.1 OBJECTIVES

The samples used to test cooling liquids will meet the cooling methods' objectives [3].

3.2 SAMPLE REQUIREMENTS

To determine the characteristics of the cooling liquids used when hardening steel, the cooling operation needs to be reproduced, using a heated body (sample) which will be cooled with the liquid in question..

The samples used in the testing and evaluating methods of cooling liquids, will have to meet the following requirements:

- to allow the separation of different stages of cooling (calefaction, nucleic boiling, convection);
- to have a perfectly controllable state of surface, and a geometry that is easily machinable with the large surface/volume ratio;

- to have a sufficient thermal capacity and high thermal conductivity;
- to have a sufficient thermal time constant for the response constant of the thermocouple to be negligible;

3.3 FACTORS THAT INFLUENCE THE COOLING OF SAMPLES

Table 1.1. – Factors that influence the cooling of samples

a) factors prior to cooling	sample	- chemical composition; homogeneity; omogenitatea - particularities of development;	
		- structural condition;	- thermal history of the structure; - granulation;
		- state of internal tensions;	
		- thermophysical factors and state parameters;	- thermal conductivity; - specific heat; - expansion constant; - density;
		- shape of the sample; - size of the sample; - surface/volume ratio [m^{-1}];	
		- technological particularities;	- plastic deformation, casting etc.
		- state of surfaces;	- roughness; - chemical nature;
		- heating conditions;	- temperature; - duration;
	cooling liquid	- nature of the liquid;	- physical properties and state parameters; - chemical properties; - hydrodinamic factors; - thermophysical factors;
b) factors during cooling	Sample-liquid interaction	- method of cooling (immersion, spraying, etc.); - reactivity to the sample; - sample-liquid temperature difference; - behavior of the fluid in motion relative to the sample; - moistening characteristics; - sample-coolant relative speed (agitation); - effective heat transfer coefficient; - ratio: heat stored in sample / volume of liquid; - izofilm phenomenon: depositing a thin layer on the sample's surface ; - structural transformation; - intensity of certain physical fields (gravitational, electrostatic, ultrasonic etc.);	

3.4 CLASSIFICATION

Samples can be classified under the following criteria:

a) *according to the purpose of the test*:
- samples for testing the cooling capacity (fig. 1,3,8);
- samples for testing thardening capacity (fig. 4,5);
- mixed samples for testing both cooling and hardening capacities (fig. 2) ;
- samples for testing the hardening capacity of a industrial plants;
- samples for testing internal stresses that cause cracking or deformation of the

workpiece (fig. 7,9);

- samples for aging tests: trials in permanent or intermittent operation mode;

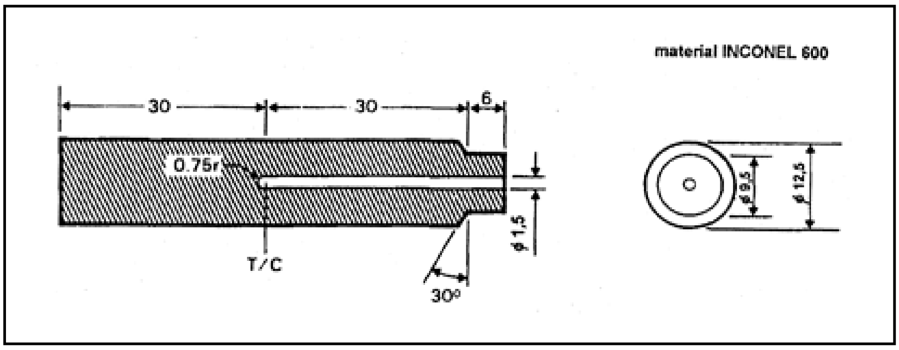

Fig.1 Cooling by immersion sample – WOLFSON test [4]

b) *according to the material's nature*:

The requirements for the samples are met by metallic materials that have a sufficient thermal capacity, and high thermal conductivity. Such materials are:

- *Silver,* which has the following advantages:
  - has a high thermal conductivity which grants the sample a low thermal inertia, so that the cooling stages are defined precisely;
  - provides some guarantee regarding purity, and it is available worldwide;
  - no state changes to influence cooling;
- *Austentic stainless steel;*
- *A steel to be hardened*, when the hardening capacity of a liquid is tested in relation to that steel;

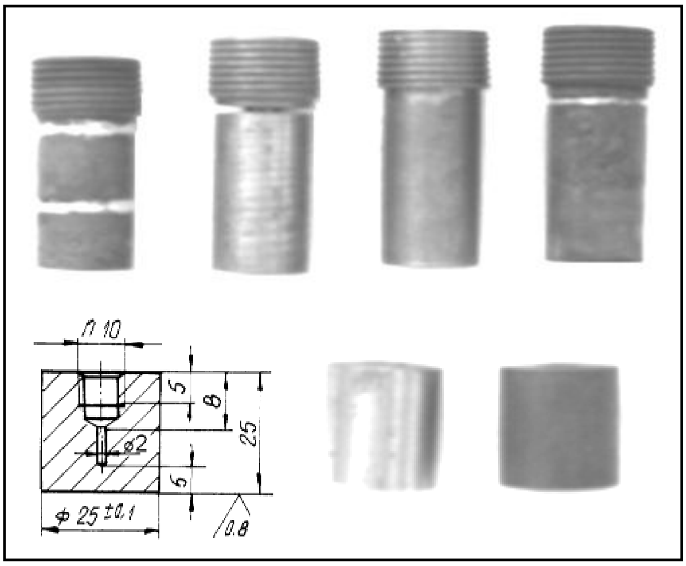

Fig. 2 Axial cooled samples [3]

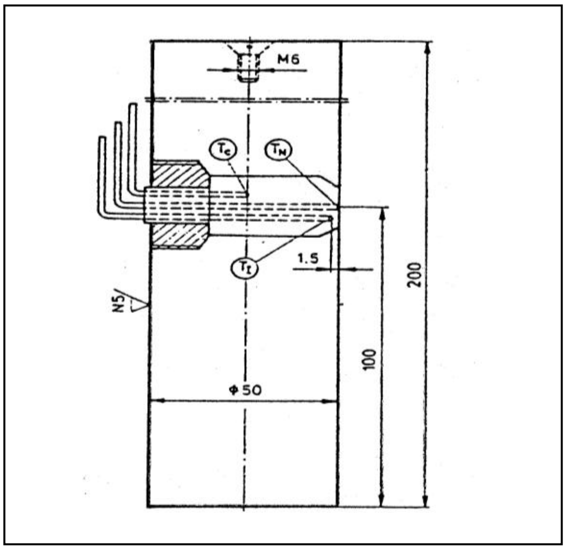

Fig. 3 LISCIC sample – NANMAC [5]

- *Inconel*: (72-76)%Ni, 16%Cr, 8%Fe, 25Si. This alloy is refractory and corrosion resistent;

c) *according to geometric shape and size*:

- spherical samples;
- cylindrical samples;

- wedge sample;
- wire samples;

d) *according to the cooling mode*:

- immersion cooled samples (fig.1,3,5,6,7,8,9), whch have some disadvantages: they do not allow precise control of the sample-liquid relative speed; they don't allow testing in conditions of shortening the calefaction phase;

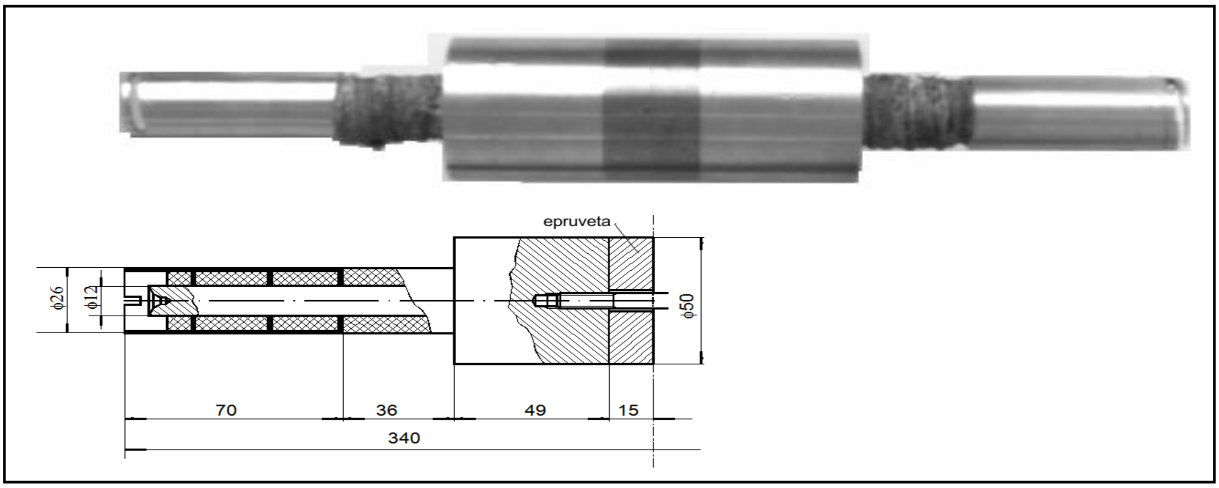

Fig. 4 Device with 2 radially cooled samples

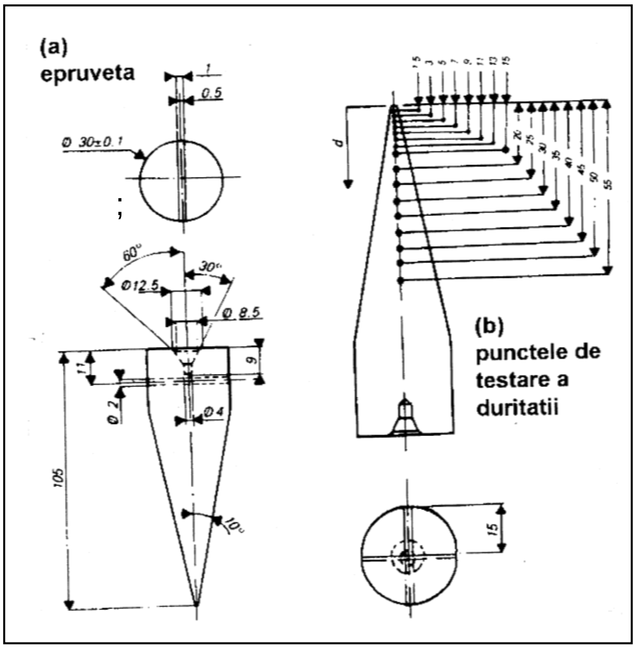

Fig. 5 Wedge sample propused by ATTT [7]

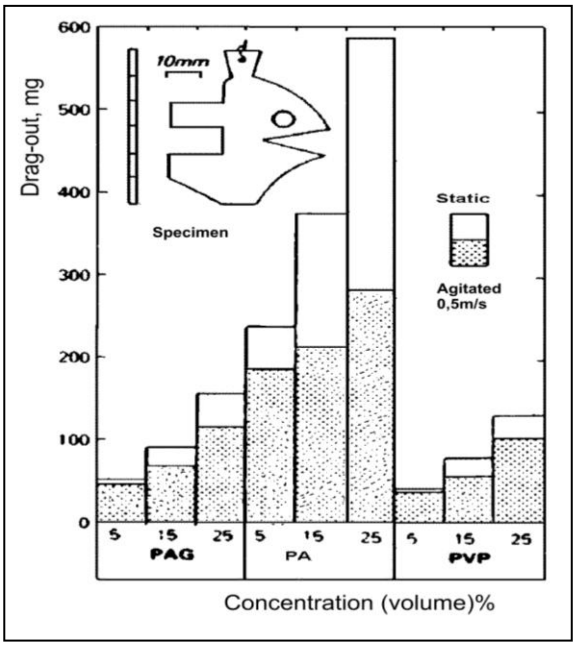

Fig. 6 Sample used for training test for polimers of varying concentration [8]

- samples cooled axially by a frontally applied liquid jet (fig.2), which allows an accurate control of the liquid-sample relative speed.;
- samples cooled radially by immersing the device through axial rotation (fig. 4);

e) *according to the nature of the cooling medium*:

- samples for oil;

- samples for aqueous polymer solutions;
- samples for salt baths;

f) after the manner of realization of the thermocouple:
- samples with independent thermocouples;
- samples with the body acting as a thermocouple thermoelectrode

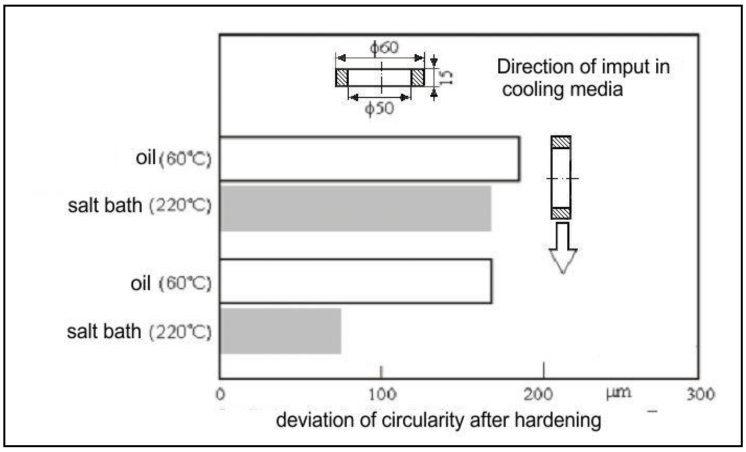

Fig.7 The ovality of the rings in function of immersion and the medium, µm [9]

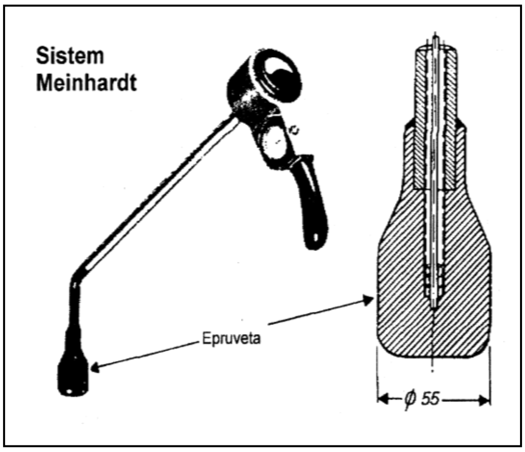

Fig. 8 MEINHARDT sample [10]

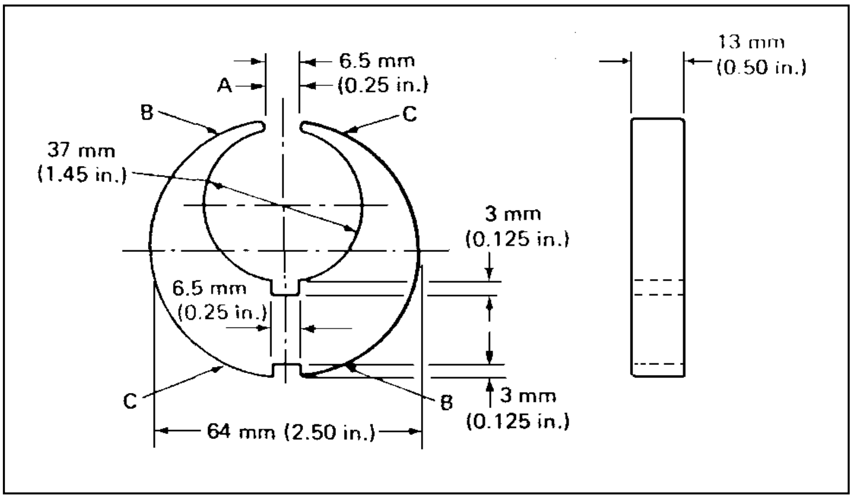

Fig.9 Sample for testing internal stress [2].

4. CONCLUSION

Most researchers indicate that the phenomena of cooling a sample by a certain cooling liquid is best represented by the cooling curves. These need to be interpreted in terms of metallurgic results, obtained from cooling a certain steel that has undergone thermal treatment. In this regard, the type of the sample will be chosen by establishing criteria for: choosing the material, the shape and size of the sample, and the position of the thermocouple in the sample.

Silver, inconel, and austentic steel samples, though they have some advantages, it is difficult to interpret the cooling curves obtained by cooling them with a coolant.

Cylindrical samples of steel to be thermally treated, that are cooled frontally, have the advantage of allowing a better correlation of the cooling curves with the metallurgic results obtained after cooling, because eventually, their hardness variation on generators can also be measured.

Bibliography:

1. RUIN, M., Sur la drasticité des fluides de trempe , in Traitement Thermique Nr. 240 -1990, p.67 –71.
2. * Metals Handbook, vol. 4 (Heat Treating), American Society for Metals 1991, 68-120**
3. MUDURA, P., Teza de doctorat „Contribuţii privind caracterizarea lichidelor de răcire", Instituţia: Universitatea Tehnică din Cluj-Napoca, domeniul: Inginerie mecanică, data/ susţinerii: 30.03.2000;
4. * Industrial Quenching Oils-Determination of Cooling Characteristics-Laboratory Method, Draft international standard ISO/DIS 9950, International Organisation for Standardisation (submitted 1988).**
5. LIŠČIĆ, B., A new method to measure and record the quenching intensity in workshop practice, in, Heat Treatment and Surface Engineering (Proceedings of the 6th International Congress on Heat Treatment of Materials). ASM International, 1988, p. 157-166.
6. MUDURA, P., UNGUR, P., Instalaţie experimentală pentru determinarea „curbelor u" de distribuţie a durităţii pe secţiunea călită, in: Buletin Ştiinţific, vol. II - Ştiinţa materiale-lor. Tratamente termice şi Termochimice, ISBN 973-8124-17-4, CONFERTNŢA INTERNAŢIONALĂ de Ştiinţa şi Ingineria Materialelor BRAMAT 2001,1-2 Martie 2001, Braşov- România, Editura Universităţii „Transilvania" din Braşov, 2001, p. 271-274
7. * Fluides de trempe. Determination de la séverité de trempe d'une installation industrielle. NFT 60/79, Association Technique de Traitment Thermique, Paris, France, 1988.**
8. HILDER, N., A., The Behaviour of Polymer Quenchants, in : Heat Treatment of Metals, 1987.2.
9. VOLKMUTH, J., Eigenspannungen und Verzug, HTM 51 (1996) 3.
10.* Houghton Abschreckprüfgerät (Houghton Quench Test Apparatus) Brochure from Houghton – Hildesheim, Germany.**
11.C.H. Gur, Investigation of the influence of specimen goemetry on quench behavior of steels by X-ray determination of surface residual stresses, Int. J. Mech. Sci. 44 (2002) 1335–1347.
12.G.E. Totten, C.E. Bates, N.A. Clinton, Handbook of Quenching and Quenching Technology, ASM International, Materials Park, OH, USA,1993, pp. 1–160.
13.G. Wang, B. Xiao, L. Zhang, K. Rong, Q. Wang, Heat transfer coefficient study for air quenching by experiment and CFD modeling, in: 137th Annual Meeting & Exhibition. Materials Characterization, Computation and Modeling, vol. 2, 2008, pp. 271e276.