第 I 部門　Analysis of charpy impact energy and Brinell hardness of TMCP steels by in Exposure to Heat of Fire

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1. Introduction

TMCP method, which stands for Thermo-Mechanical-Controlled Process, produces steel with high quality. Once the fire accident happens, the steel is heated up to a certain temperature and is cooled down and it is important to know influences of this process on material properties of TMCP steel. In this research, the effect of high temperature and the different cooling process on the Charpy Impact energy and the Brinell Hardness due to the change of the steel grain size and the space among the grains is investigated.

2. Analysis models

In this research, since the data from the reference tensile test such as the Young's Modulus and the Poisson Ratio are input in the Charpy Impact Energy Model and the Brinell Hardness Model. The type of the steel would be same as the reference tensile test, which is SM490YA. However, the size of the specimen would be different in each of this model. In the Charpy Impact Model Analysis, there is a standard Charpy-V notch size for the specimen. It is 55mm long, 10mm width and 10mm thickness. In addition, it has a 2mm deep notch with a tip radius of 0.25mm chinned on one face. This is the standard model for the specimen in the Charpy Impact Test.

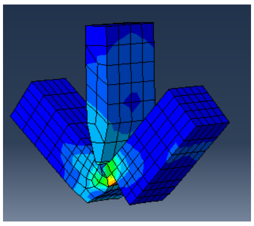
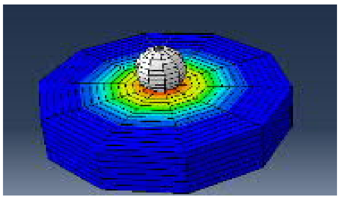

Figure 1 Charpy impact and Brinell Hardness analysis

On the other hand, in the Brinell Hardness test, a size of 25mm x 10mm (thickness) cylinder material is prepared. Although there is no standard size of the specimen for the Brinell hardness analysis, it should be ensured that both the thickness and the diameter should be bigger than the indenter Here, the indenter is a ball with the radius of 10mm, as shown in Fig 1.

3. Method

In both of the tests, since the data from the reference tensile test is utilized, the experiment condition should be same as the reference test. The experiment condition and the result are shown as follow:

Temperature (°C): 25, 600, 900
Cooling Method: Natural (N), Water (W)
Heating Time (min): 15

Table 1 Experimental result[1)]

Case	25	600n	600w	900n	900w
Temperature (°C) (Cooling method)	25	600 (n)	600 (w)	900 (n)	900 (w)
Young's Modulus	200GPa				
Yield stress (MPa)	428	420	430	365	701
Max. Tensile stress (MPa)	577	570	578	560	1089
Normal strain (%)	19	21	16	17	4.5
Fracture strain (%)	31	32	33	35	6

In the Charpy Impact Model, the Ductile Damage model would be used. Two pin supports would be set at the bottom of the steel, which are located at 8.89cm from left-end and right-end. For the indenter, the width would be 10cm, which is regulated by the standard. The step is set to be Dynamic motion so as to simulate the impact by the indenter. In addition, the surface between the indenter

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and the specimen should be set to be hard contact.

In the Brinell Hardness Model, the value of 0.5 is set in the friction coefficient in this model. A surface to surface standard contact is set between the outer shell of the indenter and the upper surface of the specimen. It can be set that the indenter is a rigid body so that the deformation of the indenter can be neglected so as to simplify the simulation. After the modelling, the center in the bottom of the specimen is set to be (0,0), in this case the method to know the radius of the compression is to check the x coordinate of the intersection surface between the specimen and the indenter.

4. Model Result

In the Charpy Impact Energy model section, the strain energy diagram can be obtained. The charpy impact energy would equal to the difference of the final value and initial value in the strain energy diagram. As shown in the figure, before the contact of the indenter the strain energy should be 0 in the specimen. However, the change of the strain energy in the final stage is the Charpy Impact Energy. By observing the data, Charpy Impact Energy can be obtained in each condition by marking the final failure of the strain energy.

Table 2 Charpy impact energy

Case	25	600n	600w	900n	900w
Energy (J)	125	112	80	60	30

The Brinell hardness model, the after observing the radius of the indentation by checking the x coordinate of the intersection point. The radius in each cases is shown in the following table. After obtaining the radius, the Brinell hardness can be calculated by using the formula:

$$\frac{2L}{\pi D(D-\sqrt{D^2-d^2})} \quad (1)$$

Table 3 Radius and hardness of the indentation

Case	25	600n	600w	900n	900w
indentation (mm)	2.94	2.941	2.941	2.942	1.47
Brinell hardness (HB)	96.58	96.52	96.52	96.52	417.7

5. Summary and Discussion

Both High temperature and water cooling method result in smaller impact energy and higher hardness comparing to the low temperature and natural cooling method. The water cooling method decreases the impact energy for 30J than the natural cooling method under the same temperature. The impact energy decrease a little (by 13J) at 600°C. The impact energy decreases significantly (by 65J) when the temperature is 900°C under the natural cooling method. It shows that the transformation point of the SM490YA should be between 600°C and 900°C. The change of the temperature plays a more important role comparing to different kind of cooling method. Meanwhile, although high temperature softens the hardness of the material, the soften level is very low (less than 0.01HB) under the natural cooling method. The water cooling method would significantly increase the hardness ***only*** if the temperature is beyond the transformation Temperature (4 times higher). While if the temperature is below the transformation temperature, no significant difference between each cooling method. The size of the grain affects on the impact energy and space between grain affects on the hardness

Reference: [1] 鋼橋の火災を想定した加熱および冷却過程が構造用鋼の溶接継手特性に及ぼす影響，廣田幹人，北根安雄，伊藤義人，鋼構造年次論文報告集，第 21 号, pp.879-824