1st session　Study on Mechanical Properties of steels by Thermo Mechanical Control Process in Exposure to Heat of Fire

京都大学工学研究科　学生員　○Lei Tong Kun
京都大学工学研究科　正会員　杉浦 邦征
京都大学工学研究科　正会員　北根 安雄
熊本大学くまもと水循環・減災研究教育センター　正会員　松村政秀

1. Introduction

Producing the steel in an efficient way and high quality is always a challenging topic. In order to achieve that, the companies nowadays are eager to adopt the TMCP method, which stands for Thermo-Mechanical-Controlled Process, to produce the steel. Comparing to the conventional Steel producing method, the TMCP involves one additional rolling process and one water cooling process. When the fire accident happens, the steel is heated up to a certain temperature and with different heat lasting time. Plastic deformation at this lower temperature promotes fine grain sizes. the additional water cooling process also brings the steel to the transformation temperature range. The transformation from austenite to ferrite results in fine ferrite grains and fine dispersed precipitates. Accelerated cooling sometimes may result in bainite formation as well as ferrite formation. In this research, the effect of high temperature and the different heat lasting time on the strength, ductility, toughness and the hardness due to the change of the steel grain size and the space among the grains is investigated.

2. Specimen

In this research, the TMCP steel SBHS500 would be used for the experiment. First of all, the tensile test would be operated so as to get the relevant data such as the Young's modulus , tensile strength, fracture strain, the Poisson's ratio. After that the Charpy impact energy test and the Vicker's Hardness test would be done in order to determine the toughness and the hardness. The type of the steel would be same as the one used in the tensile test. However, the size of the specimen would be different in each of these test. In the tensile test, the No.5 specimen under JIS standard is used. In the Charpy impact energy tests, there is a standard Charpy-V notch size for the specimen. It is 55 mm long, 10 mm width and 10mm thickness. In addition, it has a 2 mm deep notch with a tip radius of 0.25 mm machined on one face.

On the other hand, in the Vicker's hardness test, a size of 25 mm x 10 mm (thickness) cylinder material is prepared. Although there is no standard size of the specimen for the Vicker's hardness analysis, we should make sure that both the thickness and the diameter should be bigger than the indenter otherwise the indenter may possibly be able to reach the bottom of the specimen and the hardness is not able to be observed.

After the experiment, the cross section of the specimen would be magnified 400 times by using digital microscope. The particle pattern and the size of the grains can be observed to do the comparison between each case.

3. Method

In this research, tensile test, Charpy impact test and Vicker's hardness test will be operated. There are 6 pieces of SBHS500 steels at the beginning. Before doing experiment, heat treatment is done in order to simulate the fire accident environment. At first, 1 specimen will be tested at the room temperature. Secondly the 2 specimen will be heated up to 600°C and 900°C respectively and 1 specimen will be heated up to 500°C . After the specimen reached the desire temperature, they will maintain in the same temperature for either 15 min or 60 min for cases with 600°C and 900°C while the one with 500°C is only heated for 15 min. Finally, they will be cooled down to room temperature by either Natural Cooling Method. By implementing that, we should be able to get 6 different cases of the specimen. It can be shown as follow:

Table 1 (heat treatment condition)

	I	II	III	IV	V	VI
Temperature	25°C	500°C	600°C	600°C	900°C	900°C
Heating Lasting Time (min)		15	15	60	15	60

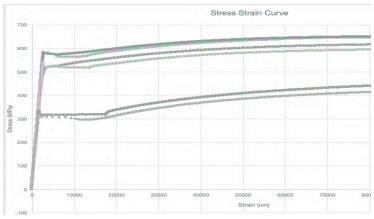
Keyword: TMCP, fire accident, Material properties. Safety Evaluation
Lei Tong Kun, Kunitomo Sugiura, Masahide Matsumura, Yasuo Kitane
Lei.kun.85z@st.kyoto-u.ac.jp

In the Tensile test, the universal testing machine is used and the strain gauge is sticked on the specimen. The test specimen is subjected to tension with the approximate speed of 0.2 mm/s until it fractures. The elongation is recorded against the applied force. By plotting it on the graph, the ultimate strength, yield strength, fracture strain can be recorded while the Young's modulus, Poisson ratio as well as the work hardening factor can be calculated.

4. Test Result

The tensile test shows the when the temperature is room temperature, the yield stress is 523MPa, which is almost the design value (500MPa). The detailed data can refer to Fig 1 and Table 2.

Fig 1 Stress Strain Graph



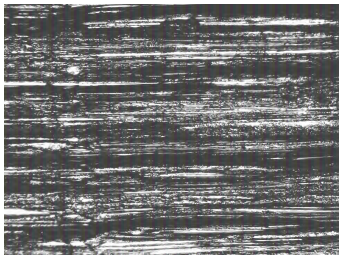
Fracture strain is mostly affected by temperature. Below the recrystallization temperature, the strain decreases when temperature increases. When the temperature is higher than the recrystallization temperature, the strains increase significantly compare to room temperature but more brittle behavior. Yield Stress and maximum stress increase when the steel receive a short and light heat treatment. The stress values drop significantly when the temperature is above the recrystallization. Generally, the longer the heating time, the weaker the steel. Strain hardening factor and Max/Yield ratio significantly increase when above the recrystallization temperature. The Poisson ratio and Young's Modulus didn't change much.

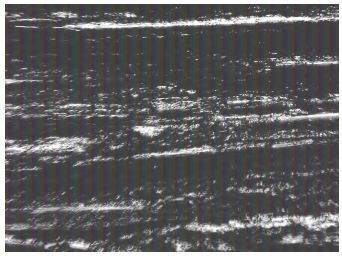
Table 2 Tensile test result

	Int-1	500°C15m	600°C15m	600°C60m	900°C15m	900°C60m
Fracture Strain mm	16.990	16.150	17.150	15.480	23.170	20.850
Yield Stress MPa	523.694	583.618	582.592	520.831	316.400	296.305
Maximum Stress MPa	619.921	647.014	651.165	596.134	470.150	435.916
Poission Ratio	0.376	0.2772	0.2727	0.3497	0.3575	0.2944
Young's Modulus GPa	188.4	211.5	208.7	196.7	185.6	187.5
Strain Hardening Factor (normal stress)	0.0662	0.0531	0.0573	0.0761	0.1943	0.1769
Strain Hardening Factor (True Stress)	0.0997	0.1036	0.0984	0.1128	0.2343	0.228
Maximum stress/ Yield Stress.	1.184	1.109	1.118	1.145	1.486	1.471

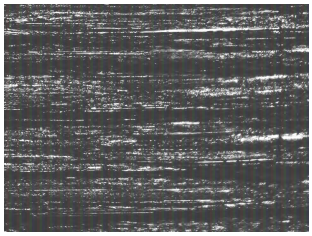
Graph 2 (Micro observation)

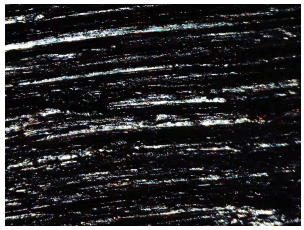
25℃ **500℃ 15 min**



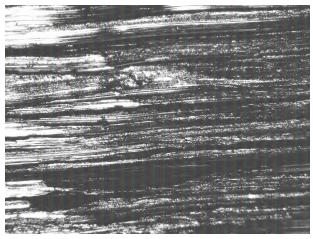


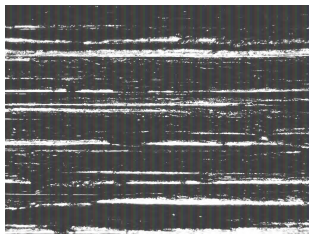
600℃ 15 min **900℃ 60 min**





600℃ 60 min **900℃ 15 min**





The red region is hardly found when temperature is at 900°C. It probably reacts with carbon. Hence the amount of pearlite decrease (black region). That can explain why the strength decrease at 900 °C. The longer the heating time, the denser the arrangement pattern.

6. Reference

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

Keyword: TMCP, fire accident, Material properties. Safety Evaluation
Lei Tong Kun, Kunitomo Sugiura, Masahide Matsumura, Yasuo Kitane
Lei.kun.85z@st.kyoto-u.ac.jp