SM570, in JIS structural steel specification, is the strongest grade (tensile strength \( \geq 570 \text{ MPa} \)) which requires high impact strength (Charpy impact absorbed energy \( \geq 47 \text{ J/-5}^\circ\text{C} \)). Therefore, a building applying with SM570 can not only reduce the weight and the consumption of steel, but also upgrades the anti-seismic ability of structure. In Taiwan, most of SM570 steel plates and H-beam are products are used in skyscrapers, such as Taipei 101 for example, used to be the highest skyscraper (509.2 meters high) of the world during Dec. 31st 2014 to Jan. 4th 2010. Dragon Steel Corporation has developed SM570 steel narrow plate (t \( \leq 40 \text{ mm} \)) and H-beam (t \( \leq 30 \text{ mm} \), up to width 900mm) products, by addition proper alloys and applying optimum temperature controlled rolling technique. With this two kind products, steel structure can be safer and more competitive due to their higher strength and lower weight.

KEYWORDS: SM570, High Strength structural steel, H-beam, Steel narrow plate
1. Introduction

In order to enhance the safety of structure, and to reduce the cost and the energy consumption of making structural materials, it becomes more and more popular to use high strength structure steel SM570 in skyscraper. In past skyscraper projects, SM570 steel plates were divided, cut, and then welded together to make bracing column and cross beam.

Therefore, Dragon Steel Corporation has devoted ourselves to develop SM570 steel narrow plate (t ≤ 40 mm) and H-beam (t ≤ 30 mm, up to width 900mm) products, in order to reduce the cutting and welding process of steel plate. With these two kind products, steel structure can be safer and more competitive due to their higher strength and lower weight.

2. Properties of welded structure SM570

SM570 is the strongest grade in JIS structural steel specification. The chemical compositions and mechanical properties of JIS structural steel specification can be found in Table 1 and Table 2.

The restriction of [C] and [Mn] content is resulting from weldability. Higher the content, the heat affected area after welding is easy to be produced hard and crisp martensite. As well as restriction of [P] and [S] is for the toughness requirement.

Limitation of TS and YS value means that the steel could resist deformation and fracture in order to reduce/decrease the consumption of steel and increase the building capacity. With higher EL value, it also has proper workability and formability. Most important is the requirement of low temperature impact absorption energy (≥ 47 J / -5°C). It makes sure that parts using SM570 have enough impact resistance at low temperature.

With these all strict requirement, a building applying with SM570 can not only reduce the weight and the consumption of steel, but also upgrades the anti-seismic ability of structure.

Table 1. JIS G3106 SM570 chemical compositions (%)

<table>
<thead>
<tr>
<th>C %</th>
<th>Si %</th>
<th>Mn %</th>
<th>P %</th>
<th>S %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.18 max</td>
<td>0.55 max</td>
<td>1.70 max</td>
<td>0.035 max</td>
<td>0.035 max</td>
</tr>
</tbody>
</table>

Table 2. JIS G3106 SM570 mechanical properties

<table>
<thead>
<tr>
<th>Thickness mm</th>
<th>YS MPa</th>
<th>TS MPa</th>
<th>EL %</th>
<th>Charpy Absorption Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 ≤ T&lt;16</td>
<td>460 min</td>
<td></td>
<td></td>
<td>(-5°C)47J</td>
</tr>
<tr>
<td>16 ≤ T&lt;20</td>
<td>450 min</td>
<td>570~720</td>
<td>26 min</td>
<td></td>
</tr>
<tr>
<td>20 ≤ T&lt;40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 ≤ T&lt;50</td>
<td>430 min</td>
<td></td>
<td>20 min</td>
<td></td>
</tr>
</tbody>
</table>

3. Design of chemical content and production process

SM570 requires high strength, good ductility, and low temperature toughness with low CEQ. Those requirements are break down to two major concern, “Strength and toughness requirement” and “Better welding ability”, at design stage.

(1) Strength and toughness requirement

The amount of Carbon and Magnesium in steel are important strengthen factor. But the restrict of [C] · [Mn] constrains the strength level.

Therefore, in order to reach TS ≥ 570 MPa, the addition of other elements is required. Addition of Niobium and Vanadium increases the precipitate amount of Nb(C,N) and V(C,N),
decreases the grain size and improves the strength and toughness of steel.

The phosphorus and sulfur in steel is an inevitable element, which are harmful to toughness. Under same grain size, the higher the residual phosphorus and sulfur leads to lower toughness. Consequently the mechanical performance would be better due to designing of low phosphorus and sulfur content.

The ductility and toughness of the steel are on the contrary of its strength. Generally, the strengthening mechanism increases the strength of the steel and usually adversely affects its ductility or toughness.

Grain refinement is one of the best way to approach high strength and good toughness at the same time. Because grain refinement does not change the nature of ferrite, it blocks the movement of dislocation and also disrupts the crack propagation.

By adding alloy elements (Niobium, Vanadium), controlled the rolling temperature and reduction to obtain the microstructure of fine grain, it results in not only high strength and high toughness but also good weldability of steel.

In rolling process, fine grain could be obtained from controlled rolling technique. The using of non-recrystallization area reduction could refine the austenite grain and reinforce the steel strength. It could be put into practice as per following steps:

(a) In reheating furnace: in order to make Niobium, Vanadium alloy to achieve solid solution effect and to avoid grain coarsening, heating temperature target is over 1200 °C.

(b) Controlled rolling: with increasing the thickness, the amount of reduction will be decreased. In order to refine the grain and enhancing the strength and toughness, reduction will be carried out when rolling slab thickness is double target thickness and cooling down to specific temperature. Due to different thickness and size, the setup temperature is various.

(2) Better welding ability

With the higher content of \([C]\) and \([Mn]\), hard and crisp martensite structure is easier to be produced at the welded area. Meanwhile, martensite is easy to be filled with hydrogen atoms, to be coupled with the residual stress, then to be leaded to embrittlement. Therefore, the designed CEQ will be below 0.44% for better welding toughness.

By addition of \([Nb]\) and \([V]\), steel could be designed with lower \([C]\) and \([Mn]\) content. It could raise AR3 temperature and shift the CCT curve to left avoiding the formation of banite and martensite.

4. Chemical composition and mechanical performance

Results of chemical composition and mechanical properties in Table 3~4 and Figure 1~2 shows that mechanical properties are superior to the specification requirements.


<table>
<thead>
<tr>
<th>(Frangle) Thickness</th>
<th>C %</th>
<th>Si %</th>
<th>Mn %</th>
<th>P %</th>
<th>S %</th>
<th>V %</th>
<th>Nb %</th>
</tr>
</thead>
<tbody>
<tr>
<td>10~40 mm</td>
<td>0.15</td>
<td>0.34</td>
<td>1.46</td>
<td>0.013</td>
<td>0.003</td>
<td>0.073</td>
<td>0.023</td>
</tr>
<tr>
<td>JIS 3106 SM570</td>
<td>0.18 max</td>
<td>0.55 max</td>
<td>1.70 max</td>
<td>0.035 max</td>
<td>0.035 max</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The microstructure shows in Figure 3, and the ferrite grain size is between in ASTM #8.5~9.5. The use of controlled rolling results in fine ferrite
and perlite. This kind of refinement structure contributes to the high mechanical performance.


<table>
<thead>
<tr>
<th>(Frange) Thickness</th>
<th>YS MPa</th>
<th>TS MPa</th>
<th>YT</th>
<th>EL %</th>
<th>Charpy Test (-5℃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10–40mm</td>
<td>479</td>
<td>621</td>
<td>77</td>
<td>33</td>
<td>145</td>
</tr>
</tbody>
</table>

Figure 1. Chemical composition performance.

The microstructure shows in Figure 3, and the ferrite grain size between in ASTM #8.5–9.5. The use of controlled rolling results in fine ferrite and perlite and this kind of refinement structure contributes the high mechanical performance.

Figure 2. Mechanical properties performance.
different kind of H-beam and narrow plate SM570 produced in Dragon Steel Corporation. We could not only satisfy customer’s welding processing and structural seismic performance requirements but also shorten the duration and cost by simplifying of welding construction procedures.

6. Reference


5. Conclusion

In Dragon Steel Corporation, by lowering the [P] and [S] content, adding proper alloy element and applying specific temperature controlled rolling, SM570 H-beam and narrow plate steel products are successfully developed. Moreover, its mechanical properties are stable and far better than requirement of specification.

SM570 is the strictest grade in JIS G3106 rolled steels for welded structure. There are

Figure 3. Micro-structure of SM570 H890x299, H900x300, H912x302.