# Research on Distortional Bucking Stability of Cold-Formed Thin-Walled Lipped H-section Steel by Bending

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## Abstract

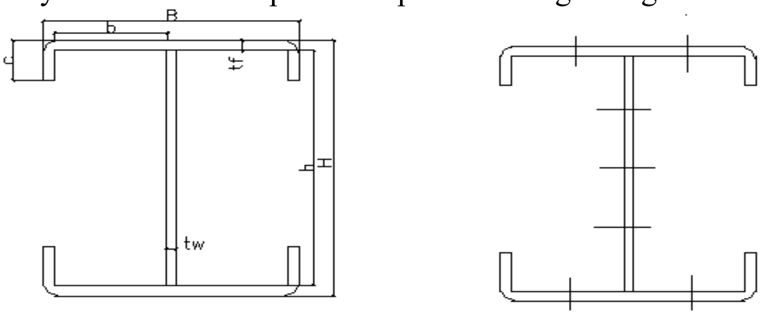
**The direct strength method was used to research on distortional buckling stability of Cold-formed thin-walled lipped H-section steel by bending,and use the finite software CUFSM to calculate the stress that is geometrical parameters of different section distortional buckling stability of Cold-formed thin-walled lipped H-section steel by bending.According to the results of numerical calculation, the law curve of different parameters is obtained, and some optimization suggestions are put forward for the engineering design.**

## Keywords

**Cold-formed thin-walled lipped H-section steel; direct strength method; CUFSM;distortional buckling.**

## 1. Introduction

Cold-formed thin-walled lipped H-section is a special crimping thin-walled steel, and the inertia moment of the two axis is close to that of the plate. Therefore, compared to the general C type and Z type section, its bending rigidity is relatively large, and the cross section is easy to expand(As shown in Figure 1).It has a significant advantage and can be used as the main load-bearing components. Due to the rolled edges can increase the winding weak axis of the moment of inertia, When the strength of cold-formed thin-walled lipped H-section steel as the main under the bending load, the rolled edges of the stiffening or partially stiffened can improve the post buckling strength of flange[1].




a b

a—Direct cold pressing ; b—Two C shaped steel composite forming

Figure 1. The composition of the H shaped steel cross section of the curling edge.

The effective width method is used to calculate the cold formed thin walled members in China. However, the direct strength method is used in North America and Australia. The direct strength method compare the effective width method is more superiority, which does not require a section for calculation of the effective width, only need to clear component of section properties. So it is very easy to design the cold formed thin walled steel by direct strength method and can greatly simplify the design steps and difficulty.

The cold formed thin walled steel easily happen three basic buckling modes. The first buckling mode is local buckling, the intersection between adjacent panels maintained the original straight-line and the outline of the cross section does not change after buckling. Due to the film effect, the components have a certain strength after local buckling and not sensitive to geometric imperfections. The Second buckling mode is the distortional buckling. After buckling, the adjacent compression plate can happen relative rotation, and the shape of the cross section and the shape of the contour can be changed greatly. The component is sensitive to the geometrical imperfection, and the strength is lower. The third buckling mode is the overall buckling. The rigid body displacement is only occurred in the process of buckling, and the plate itself without buckling .The adjacent plate parts have no relative rotation, and the post buckling strength is lower. This paper will adopt the direct strength method as the criterion and the software CUFSM to design the 4 groups of data (Each group of 5 components) to study the distortional buckling performance of cold-formed thin-walled lipped H-section members.

CUFSM software mainly is based on the theory of generalized beam (abbreviated as GBT). CUFSM software is a semi analytical finite strip method, which can discretize the thin walled sections into a series of longitudinal bars or components and base on the elastic strip to analyze the obtained geometric stiffness matrix.

## 2. Theoretical basis

### 2.1 Calculation formula of direct strength method of Hancock

In 1994, the Australian professor Hancock and his team got the calculation formula of the ultimate load of the cross section in the post buckling.For flexural members[2]:

Among the parameters $\lambda_d = \sqrt{M_y / M_{crd}}$ ;

When $\lambda_d \le 0.561$,

$M_d = M_y = W_x f_y$ ;

When $\lambda_d > 0.561$,

$$M_d = \left[1 - 0.25\left(\frac{M_{crd}}{M_y}\right)^{0.6}\right]\left(\frac{M_{crd}}{M_y}\right)^{0.6} M_y .$$

In the formula, $M_d$ is the ultimate bending moment in the post buckling;$M_{crd}$ is the critical moment of the elastic plastic; $M_y$ is the bending moment; $\lambda_d$ is the influence coefficient of the distortional buckling.

### 2.2 Calculation formula of direct strength method of Schafer

In 1998, Professor Schafer got the calculation formula of the ultimate moment value of the plate after buckling. For flexural members[3-4]:

Among the parameters $\lambda_l = \sqrt{M_y / M_{crl}}$ ;

When $\lambda_d \le 0.776$,

$M_l = M_y = W_x f_y$ ;

When $\lambda_d > 0.776$,

$$M_l = \left[1 - 0.15\left(\frac{M_{crl}}{M_y}\right)^{0.4}\right]\left(\frac{M_{crl}}{M_y}\right)^{0.4} M_y$$

In the formula, $M_l$ is the ultimate bending moment in the post buckling;$M_{crl}$ is the critical moment of the elastic plastic; $M_y$ is the bending moment; $\lambda_d$ is the influence coefficient of the distortional buckling.

## 3. CUFSM modeling and analysis

In this paper, the cross-sectional dimensions of the basic test piece is 300mm × 200mm × 40mm×4.5mm×6.0mm, the reference value is: the curling width ratio of flange (c/b) is 0.41; the height thickness ratio of Web ($h/t_w$) is 64; the width height ratio of Cross section (B/H) is 0.67; the width thickness ratio of flange ($b/t_f$) is 15.3.

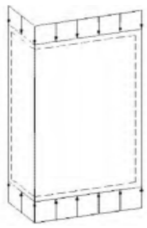
### 3.1 Modeling

This paper uses Q345 steel in China. $f_y$=345Mpa,E=$2.06\times10^5$Mpa,G=$7.9\times10^4$ Mpa, Poisson's ratio v=0.3.This paper does not consider the effects of the Slenderness ratio. The boundary conditions of the specimen are simply supported, and the plate parts are simplified as:

(1)When the web is subjected to axial pressure, the flange will be constrained to the web, and the web is assumed to be simply supported;

(2)The end part of the flange is a part of the stiffened plate, which is assumed to be a simple supported plate.

a



b

a - Web; b - Reel

Figure 2. Stress calculation chart of plate

The calculation model of the plate is shown in Figure 2. The dotted line indicates that the plate is simply supported.

### 3.2 Data analysis

This paper sets up the four sets of data(HA、HB、HC、HD) were studied and discussed various the curling width ratio of flange( c/b), the width height ratio of Cross section(B/H), the height thickness ratio of Web($h/t_w$),the width thickness ratio of flange($b/t_f$) to analyze influence for the distortional buckling stress of the cold-formed thin-walled lipped H-section steel in the press bending effect. The four groups of data are input in finite strip CUFSM software, then it can obtain the distortional buckling stress of the cold-formed thin-walled lipped H-section steel in the press bending effect. The following table(1-4):

Table 1. Basic data and calculation results of HA series

| N0. | H/mm | B/mm | c/mm | $t_w$/mm | $t_f$/mm | c/b | f_crd |
|---|---|---|---|---|---|---|---|
| HA1 | 300 | 200 | 20 | 4.5 | 6 | 0.2 | 240.79 |
| HA2 | 300 | 200 | 20 | 4.5 | 6 | 0.3 | 289.87 |
| HA3 | 300 | 200 | 20 | 4.5 | 6 | 0.4 | 329.18 |
| HA4 | 300 | 200 | 20 | 4.5 | 6 | 0.5 | 356.5 |
| HA5 | 300 | 200 | 20 | 4.5 | 6 | 0.6 | 369.96 |

Table 2. Basic data and calculation results of HB series

| N0. | H/mm | B/mm | c/mm | $t_w$/mm | $t_f$/mm | c/b | f_crd |
|---|---|---|---|---|---|---|---|
| HB1 | 200 | 200 | 40 | 2.9 | 6 | 1 | 282.68 |
| HB2 | 250 | 200 | 40 | 3.7 | 6 | 0.8 | 312.24 |
| HB3 | 300 | 200 | 40 | 4.5 | 6 | 0.67 | 329.18 |
| HB4 | 350 | 200 | 40 | 5.3 | 6 | 0.57 | 329.01 |
| HB5 | 400 | 200 | 40 | 6.1 | 6 | 6.1 | 311.70 |

Note: In order to ensure that the thickness of the web is not changed, the thickness of the section is adjusted.

Table 3. Basic data and calculation results of HC series

| N0. | H/mm | B/mm | c/mm | $t_w$/mm | $t_f$/mm | c/b | f_crd |
|---|---|---|---|---|---|---|---|
| HC1 | 300 | 200 | 40 | 2.5 | 6 | 115.2 | 200.34 |
| HC2 | 300 | 200 | 40 | 3.5 | 6 | 82.3 | 262.78 |
| HC3 | 300 | 200 | 40 | 4.5 | 6 | 64 | 329.18 |
| HC4 | 300 | 200 | 40 | 5.2 | 6 | 55.4 | 371.81 |
| HC5 | 300 | 200 | 40 | 6 | 6 | 48 | 434.50 |

Table 4. Basic data and calculation results of HD series

| N0. | H/mm | B/mm | c/mm | $t_w$/mm | $t_f$/mm | c/b | f_crd |
|---|---|---|---|---|---|---|---|
| HD1 | 300 | 200 | 40 | 4.5 | 4.5 | 20.7 | 304.2 |
| HD2 | 300 | 200 | 40 | 4.5 | 5.0 | 18.6 | 311.02 |
| HD3 | 300 | 200 | 40 | 4.5 | 5.5 | 16.8 | 317.70 |
| HD4 | 300 | 200 | 40 | 4.5 | 6.0 | 15.3 | 329.18 |
| HD5 | 300 | 200 | 40 | 4.5 | 6.5 | 14.0 | 340.78 |

HA, HB, HC, HD series of specimens of the influence curve can be obtained (Figure 3-6). Some valuable conclusions can be drawn according to these curves, which can be used for design.

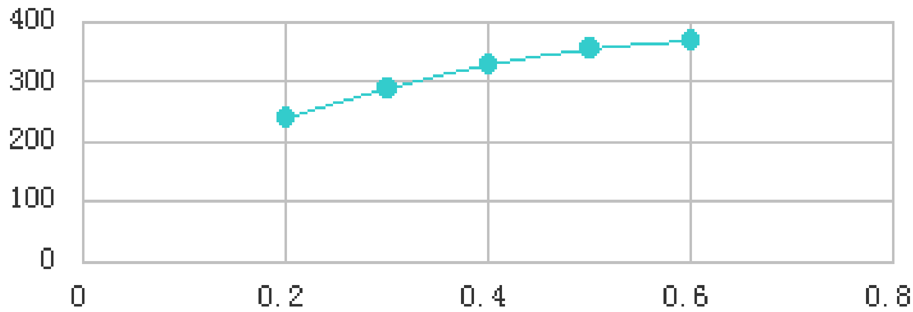



Figure 3. Curve of the influence of the curling width ratio of flange

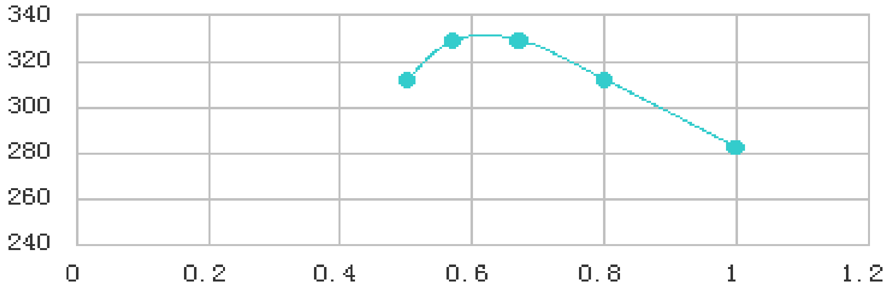



Figure 4. Curve of the influence of the width height ratio of Cross section

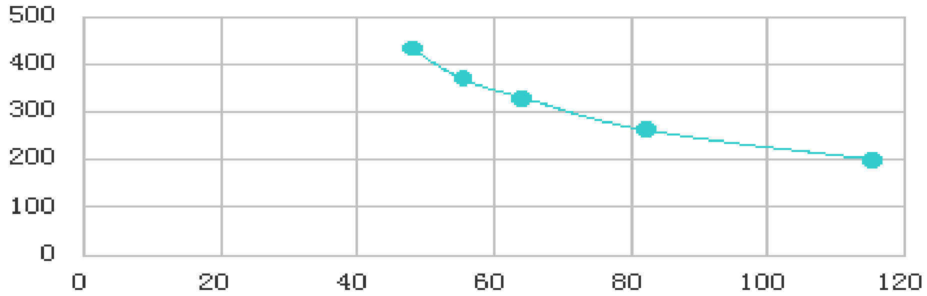



Figure 5. Curve of the influence of the height thickness ratio of Web

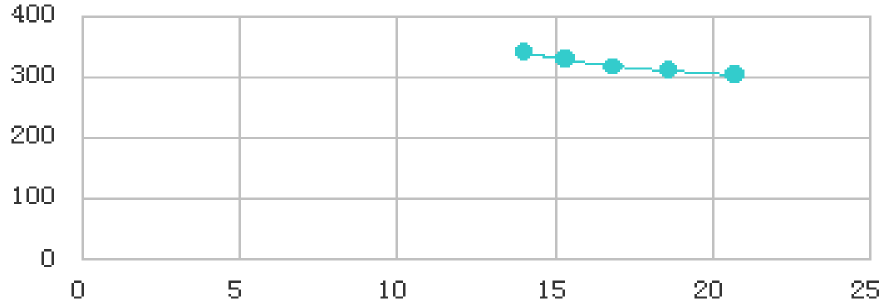



Figure 6. Curve of the influence of the width thickness ratio of flange

## 4. Conclusion

(1)Because of the existence of the curling, the component has a certain strength after buckling, and it can be seen from Figure 3 that the constraint effect of the flange width is more obvious as the improvement of the curling width ratio of flange. the curling width ratio of flange is more obvious in the range of 0.2~0.4.Therefore, from the economic point of view, 0.2~0.4 is more suitable.

(2)From Figure 6, it can be seen that, when the cross section width height ratio to 0.6 ~ 0.4, the distortional buckling stress is increasing. When the width height ratio of Cross section to 1 ~ 0.6, the distortional buckling stress is decreasing. This is due to the improvement of the width of the cross section, which leads to the rigidity of the flange too large to decrease the distortional buckling stress. When the width height ratio of Cross section is 0.6, the bearing capacity of the specimen is maintained at a relatively high value. Therefore, it is recommended to take 0.6.

(3)From Figure 7, we can know that with the increase of the height thickness ratio of Web, the distortional buckling stress is decreasing. It is due to the increasing of the web height, but the restriction of the flange is not increasing. Therefore, in the design, it is recommended not to arbitrarily increase the height thickness ratio of Web, so as not to cause the buckling of web.

(4)From figure 8, we can know that, with the increase of the width thickness ratio of flange, the distortional buckling stress is decreasing , but the amplitude is very small. Therefore, it is suggested that the width thickness ratio of flange is less than 20.

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