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Effect of cold rolling on strength of joint bolts

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Abstract: Considering that the cold rolled process is able to produce applicable metal sheets or sections in civil and construction industry, the present paper aims to study the effect of this metallurgy process on strength of joint bolts of the structural steel. The high strength and quality of produced steel by cold rolled will contribute members to have less deformation and hold clearances between hole and bolt under tensile forces. To get the aim several samples were prepared and subjected to mechanical and metallographic testing and the obtained results were simulated using Deform 3-D (v6.1 SP2) software to determine their properties. The analyzed results showed that cold rolling as a useful option can change the mechanical specification of materials for the members under tension or compression forces and due to low crippled and less deformation in area around holes will be applicable for section containing joint bolts.

Key words: *Cold rolling; Metallographic testing; Deform 3-D; Mechanical specification*

1. Introduction

Cold rolled steel or cold formed steel (CFS) are the name of common products made by rolling or pressing thin gauges of sheet steel into goods which are created by the working of sheet steel using stamping, rolling, or presses to deform the sheet into a usable product. The manufactured members of this method have been used in buildings, bridges, storage racks, car bodies, railway coaches, highway products, transmission towers, transmission poles and several various types of equipments (Yu, 2000; Yu and LaBoube, 2010). The design of industrial building is mainly governed by functional requirements and economical condition of construction (Satpute et al. 2012, Jami et al., 2012; Ungureanu and Dubina, 2004; Szabo et al., 2004). In this regard the CFS framing refers specifically to members in light-frame building construction that are made entirely of sheet steel, formed to various shapes at ambient temperatures. The building elements that are most often framed with cold-formed steel are floors, roofs, and walls, although other building elements and both structural and decorative assemblies may be steel framed. Although cold-formed steel is used for several products in building construction, framing products are different in that they are typically used for wall studs, floor joists, rafters, and truss members.

Both USA and Great Britain were the first country which employed the CFS for in building construction (Wei-Wen, 2000; Satpute et al. 2012) but acceptance of CFS as a construction material was limited because there was no adequate design standard and limited information on material use in building codes. According to Chuck Greene, P.E of Nolen Frisa Associates (American Iron and Steel Institute, 2007) the joists were adequate to carry the initial loads and spans, based on current analysis techniques. But in the recent years, the CFS sections are increasingly used in residential and commercial construction as both primary and secondary framing members. Web crippling at points of concentrated load or reaction is well known to be a significant problem, particularly in thin-walled beams (Uzzaman et al. 2012; Hancock et al., 1994; Schafer, 2000; Schafer, 2002; Yang and Hancock, 2004; Gotluru et al., 2000). The CFS as recognized method is able to improve the strength of steel and increase the strength of structural steel as well as mechanical specification without additive (Satpute et al. 2012; Hancock et al., 2001; Hancock, 2003).

Due to recognized properties such as lightness in weight, high strength and stiffness, ease of prefabrication and mass production, fast and easy erection and installation, substantial elimination of delays due to weather, more accurate detailing, non-shrinking and non-creeping at ambient temperatures, no formwork needed, termite-proof and rot proof, uniform quality, economy in transportation and handling, non-combustibility and recyclable material and the relatively low cost associated with their supply and installation, the CFS structural members are used in building construction throughout the world (Lewis et al. 2008; Gregory et al., 2001). Fig. 1 presents the accepted methods for preparation of cold rolled section. Some of those instruments work

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automatically (with high accuracy and controlling in thickness reduction) and some of them work manually which usually maybe used in work site.

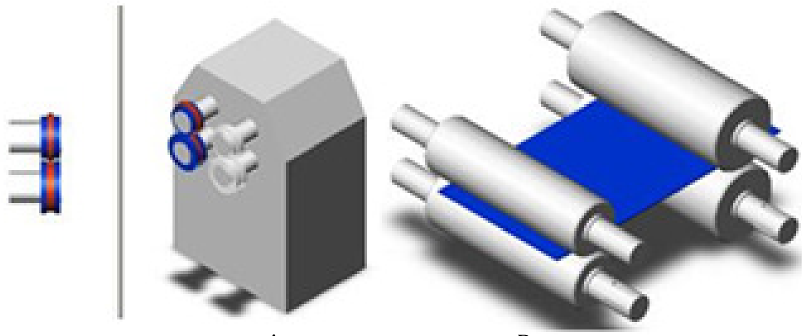


Fig. 1: Two applicable procedure in cold forming process (A: for sections, B: for sheets)

On the basis of the stress-strain graph as one of the main property of steel for behavior description, the CFS mainly falls into two categories with sharp yielding and gradual yielding type. According to reduction in thickness, the produced metal sheets by colld rolled process can be categorized in four groups.

In this regard the present paper aims to investigate the effect of CFS process on strength of joint bolts in a structural point of view by using the Deform 3-D (v6.1 SP2) software. To achieve the objective, several specimenes form CFS products were selected and subjected to varius exprimental tests such as chemical, metalogelaphy and tensil test.

2. Research model and theoretical background

As presented in Fig. 2, the crystal structure of structural steel is BCC (Body Center Cubic) crystal lattice. Therefore increasing in distance between two atoms due to applied force on section will be occurred which results in moving the new atom to a new position. This phenomenon is called slipping (Abbaschian, 2008).

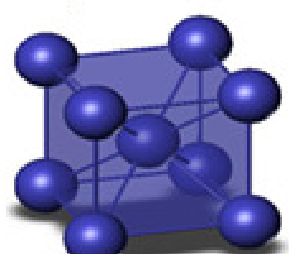


Fig. 2: The simplified diagram of BCC crystal lattice

Direction of slipping in the metals with BCC crystal structure often happened in highest density of atom. In some material like structural steel with BCC crystal structure, slipping usually happened in plane (111) which is shown in Fig 3B. But microscopic observations showed slipping had happened on plane (110) and (112) (Fig. 3A, C). In cold rolled state occurrence of plane (110) is probable and so this is a possible slip plane candidate in mentioned conditions (Dieter. 1976).

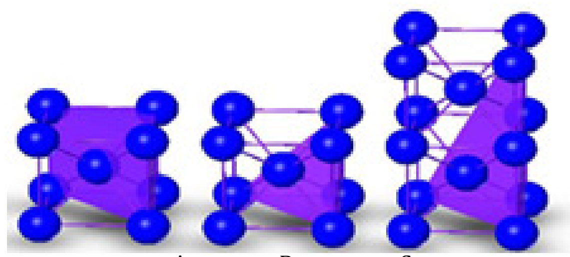


Fig. 3: Slipping plan in BCC crystal structure: A. plane (110), B. plane (111), C. plane (112)

Fig. 4, shows the effect of shearing stress by small deformation in crystal lattice which indicate that the blue atoms were located in normal and pink atoms in dislocated positions. The dislocation phenomena appear in the boundary between transformed and none transformed parts of crystals positions. The dislocation phenomena happen in all directions with a direct relation between shear stress and the number of dislocation in different directions. The blue atoms located in normal position and pink atoms is dislocated atoms (in y direction) and yellow one is othe direction of atoms that dislocated in other direction (x direction). These phenomena also contact together in same place (Fig. 4 A, B). The red atoms in this location happened junction of dislocation and called dislocation lock.

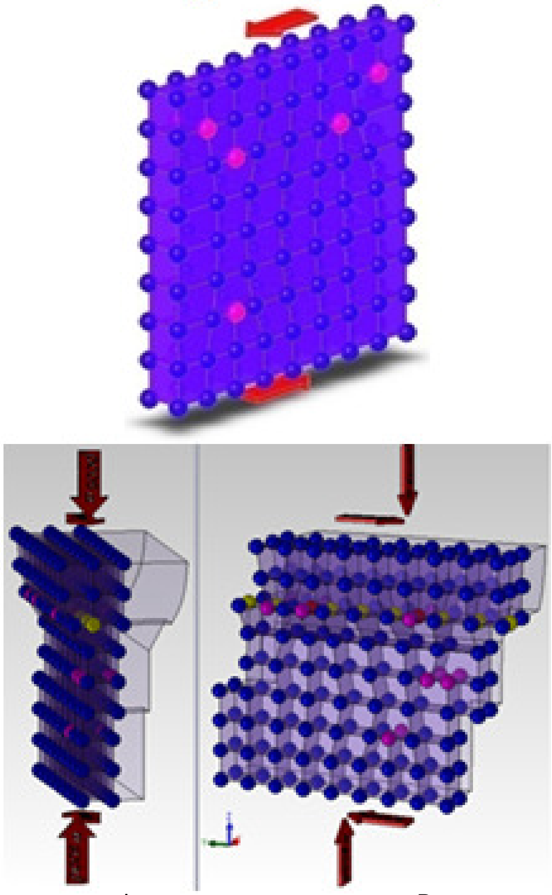
In fact, a lot of dislocations junctioned in red point acted like one dam against slipping also can imagine dislocations developed around lock, by increased of shear stress and slipping planes number of these lock increased and thus these lock also prevented from more plastic deformation, this phenomena principle of hardening material are called case of cold rolled (Dieter. 1976).

3. Experimental tests

In this paper, the chemical, metallography, hardness and tensile test have been carried out. On the basis of chemical analysis and according to Table (1) the tested samples fall in structural steel grade.

In order to have a better resolution a microscopic metallographic test with two samples made of ordinary structure steel (sample A) and CFS (sample

B) were conducted and presented in Fig. 5 which seems that all of the grains are stretched in the direction of rolling forces (pictures are provided by electronic microscope and amplitude 500).

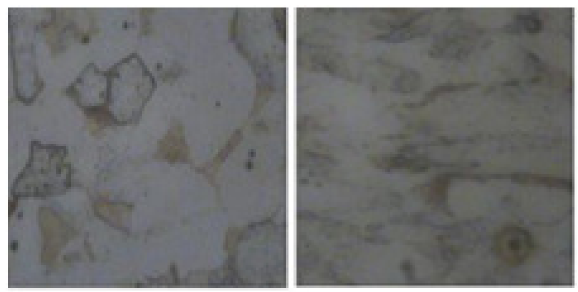


A B

Fig. 4: Schematic plan of dislocation and junction in crystal structure

In general, hardness usually implies as resistance to deformation and metals property, it's a measure of metal resistance to permanent or plastic deformation. This test specified that sample B has more hardened than sample A. When rolling process happened, hardness of sample B close to 220-230 HB while sample A is harder than other (around 170-180 HB). Therefore, it can be concluded that in sample B which were under the effect of rolling the hardness increased between 25%-30%.

Considering that the behavior of material under cold forming can be predicted by tensile properties, thus the tensile test was conducted for two specimens with the previous mentioned conditions and presented in Figs. 6 (normal manufactured steel) and 7 (CFS manufactured). The results showed that the yield point of the normal sample is 322.89N/mm^2 and ultimate tensile stress is 438.55N/mm^2 and the yield point of 467.5 N/mm^2 and ultimate stress is 521 N/mm^2 for CFS respectively which obviously display a significant increasing in both yield and ultimate stress. The comparisons of these results are presented in Fig 8 which clearly show that yield point is noticeably increased about 144.5 N/mm^2 and also ultimate point increased about 81 N/mm^2, although stress is increased by cold rolling but strain declined up 37%.



A B

Fig 5: Metallography picture from Sample A, B: sample A produced by normal structural steel, sample B produced by cold formed structural steel

Table 1: Chemical composition of tested samples

	C%	Si%	Mn%	Ni%	Al%	Cu%
Sample 1	0.129-0.142	0.160-0.163	0.633-0.635	0.0289-0.0296	0.0011-0.0017	0.016-0.017
Sample 2	0.112-0.114	0.156-0.162	0.626-0.632	0.0292-0.0288	0.0014-0.0015	0.016-0.016

4. Tensile test on joint bolt and software simulation

According to Fig 9, two holes with 10.5mm in diameter were made on mentioned samples and were connected to two jaws by bolts. After test, thickness of section reduced about 12.5% and the results show that the thickness of cold rolled sample is less than normal one. Figs. 10 show two related samples which sample A belongs to normal steel and sample B categorized in CFS respectively. Considering the Fig. 10A (normal section), it can be seen that the holes are ovalized and moreover an approximate 3.5mm elongation in hole diameter in the direction of tensile force has been occurred but this elongation for diameter in cold formed sample (Fig 10B) is approximately 1 mm.

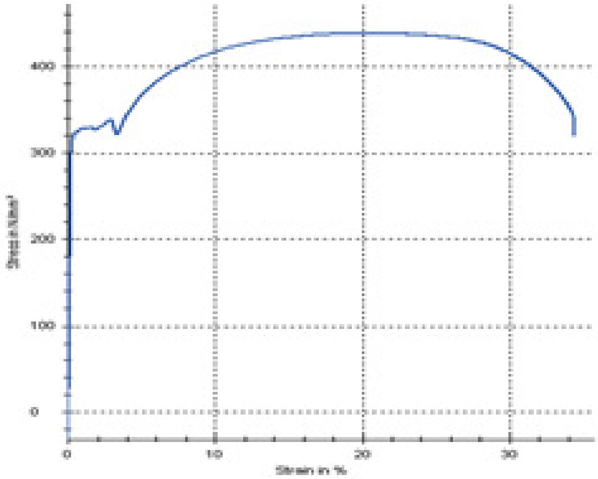


Fig6: Strain-stress curve of normal section of structural steel

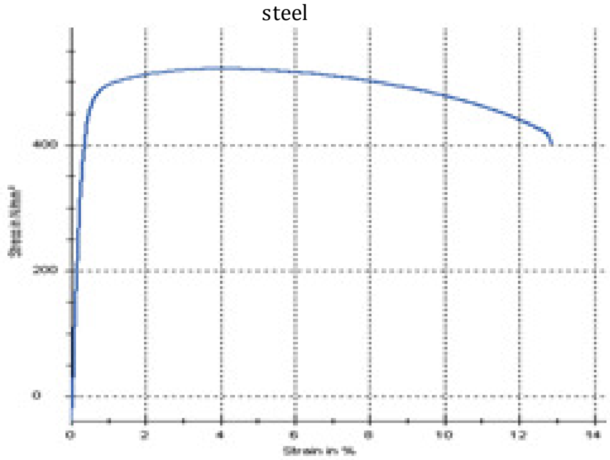


Fig. 7: Strain-stress curve of cold rolling section of structural steel

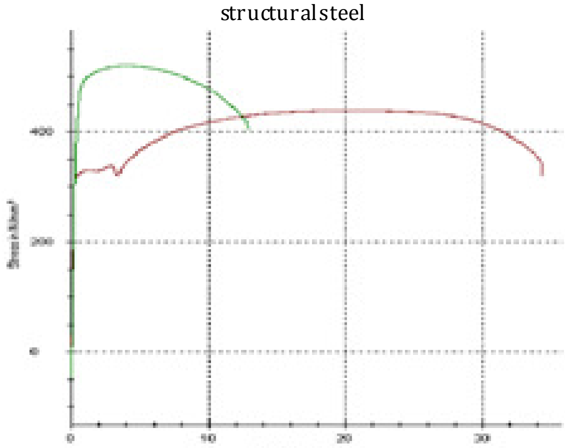


Fig 8: Comparison between tensile test of rolling section and normal section

It is also can be notified that in normal sample all of edges has been deformed and edges which is near to holes also became thinner (more than 1mm reduced in width of section). Around holes section necking happened but in other sample (Fig.10B) all of edges is straight.

The comparison of yield point of cold rolled sample curve (a) regarding to normal one (b) are presented in Fig. 11. The graph (a) shows yield point of 291 N/mm^2, and ultimate point of 484 N/mm^2 while graph (b) shows yield stress of 201 N/mm^{2}and ultimate stress of 357 N/mm^2 respectively. The cold formed sample has higher yield and ultimate point, yield factor rise up to 291 N/mm^2 and in normal one, it's 201 N/mm^2, which it can be say this item rise about 45%, and another factor also rise from 357 N/mm^2 in normal sample to 484 N/mm2. One increased 30% in ultimate factor. Strain factor also in normal sample is15% more than cold formed one.

According the obtained results as the input of Deform 3D software, Fig. 12A shows rate of stress effective factors of cold rolling process simulated with this computer code. Fig. 12B also illustrated surface expansion ratio which indicate that sheet metal has most deformation. Due to increase of hardness in cold rolled process, this way could produce high strength section.

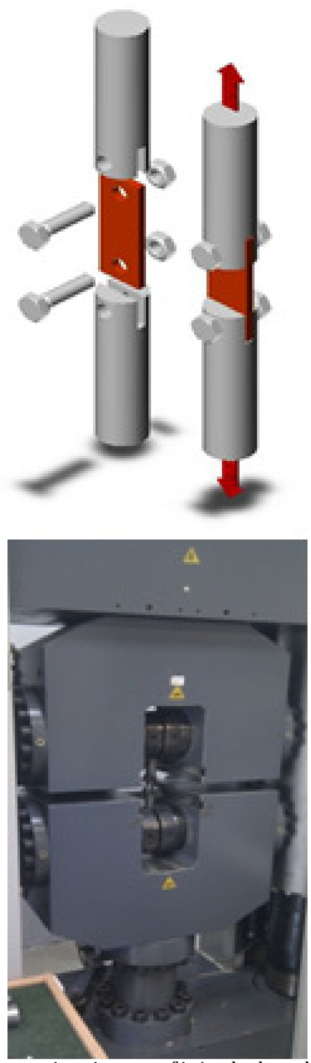


Fig. 9: Schematic picture of joint bolt and jaws and instrument of tensile test

(A)

(B)

Fig. 10: A: Normal sample B: Cold formed sample

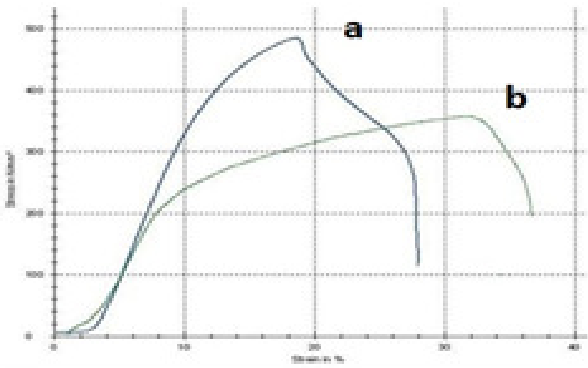
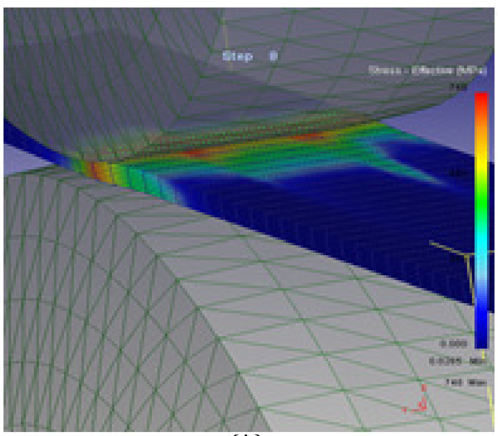
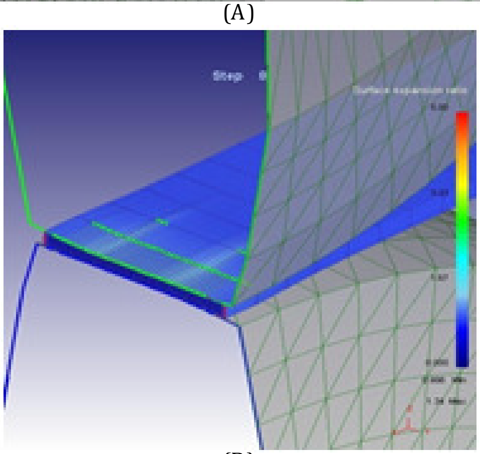


Fig. 11: Stress-strain curves (a: Cold rolling condition, b: Normal condition)



(A)



(B)

Fig. 12: Obtained results from Deform3D software (A: rate of stress effective factors of cold rolling process, B: surface expansion ratio of cold rolling process

5. Conclusion

It is proved that dislocation increased with cold rolling on joint bolts (which made by steel structure), and the strength increased by more rolled forces but this increasing limited when lock extended to all layers of section. However the analysis of the obtained results permits to express that the degree of deformation has a significant influence on the structure and mechanical properties of the investigated steels. Moreover a good correlation between changes of the structure and the effects of investigations of the mechanical properties was found.

The strength of the section rise up approximately between 15% to 30% by rolling process and with this way can some part of member like joint bolt down under effect of cold rolling.

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