TECHNISCHE UNIVERSITÄT DARMSTADT

Influences of Parameters on Defects of Asymmetrical Roll Forming

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02.08 2016

Outline

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- Units & Abbreviations
- Numerical Model & Measurements of Defects
- Explanation of Defects
- Investigation on Twist
- Investigation on Curving
- Conclusion and Outlook

Introduction

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- Roll Forming: continuously transversal bending a long metal strip into constant, desirable cross-sectional profile
- Efficient and Effective in mass production for metals
- When deforming, only deformations in transversal direction are necessary
- Reluctant strains result in unexpected deformations
- Unexpected deformations over the elastic range cause permanent defects, such as curving, twist, spring-back
- Especially for asymmetrical profile, the sheet undergoes non-uniform bending forces
- Previous research has been done on
- —pertinent methods to reduce the defects for asymmetrical profile (Ona & Jimma 1983)
- —influences factors for symmetrical profiles (Safdarian et al, 2015)
- Lack of research on the reason of defects and the influence factors for asymmetrical profiles

Units and Abbreviations

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- MPA Units: mm in length, s in time, MPa in pressure
- Abbreviations
- S: short flange length (mm)
- W: web length of the desired cross section (mm)
- T: thickness of the sheet (mm)
- F: fillet radius of the top rolls (mm)
- HC: Horizontal Curving VC: Vertical Curving

Influence Factors

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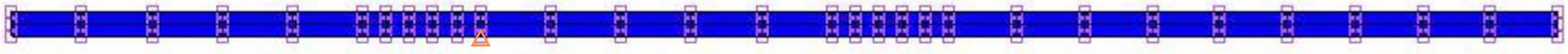
- Short Flange and Long Flange Ratio

short flange (mm)	15	25	35
Long Flange(mm)	77	67	57

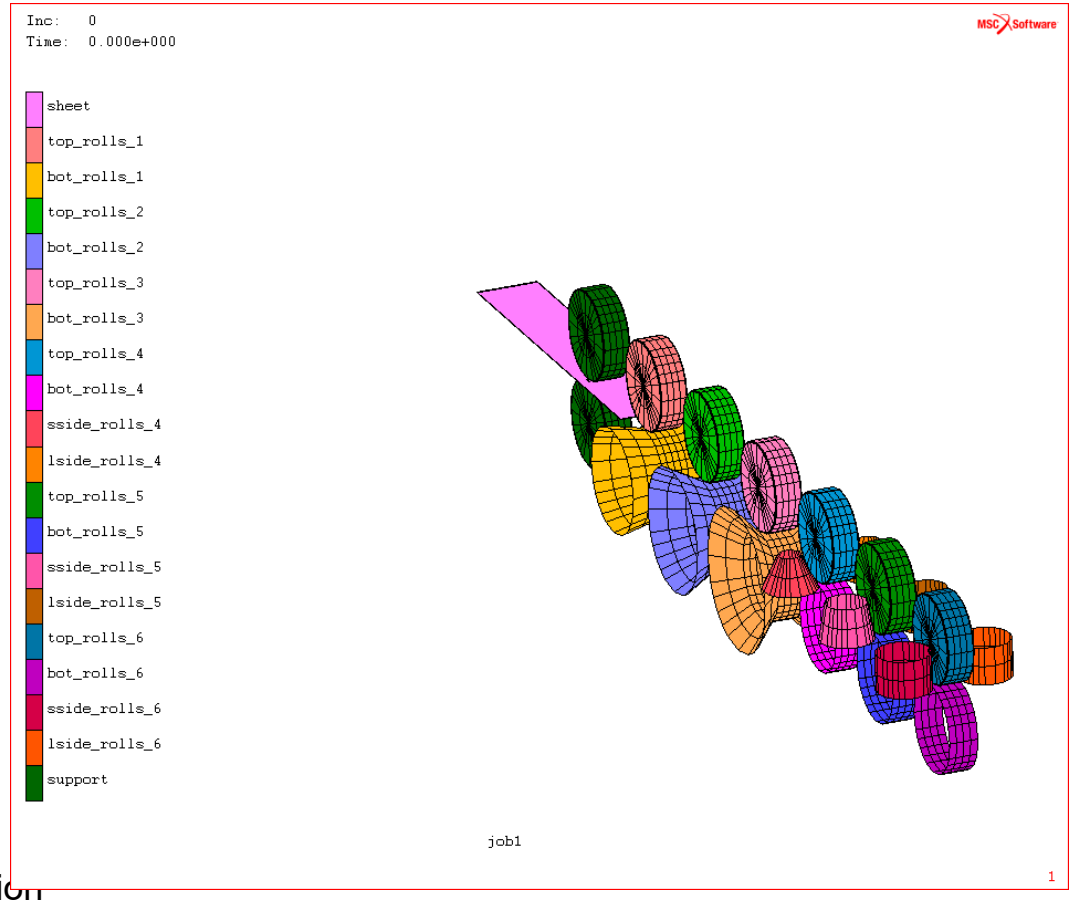
- Length of Web: 40mm or 80mm
- Thickness of the flat sheet: 1mm or 2mm
- Radius of the fillet of the top rolls: 3mm or 6mm

Numerical Model



Fig· *Front View of Sheet for S35T40T2 at t=0s*

- ① **flat sheet**:
- leftmost bottom node on web section fixed (0,0) in x-y plane, marked as
- thickness × width × length(1002mm)
- initial position -100mm in z-direction
- ② **6 roll stations**:
- distance between stands 400mm
- radius & center of roll
- first stand location in z-direction
- ③ **supporting rolls**:
- located at negative 400mm in z-direction
- no deforming forces, only supportive in y-direction



Fig· *Numerical Model*

Setting for simulations

- **Material Properties** ZstE500
- Young´s Modulus 210000 MPa =2.1×10^{5}MPa
- Poisson ratio 0.29
- Plastic Behavior

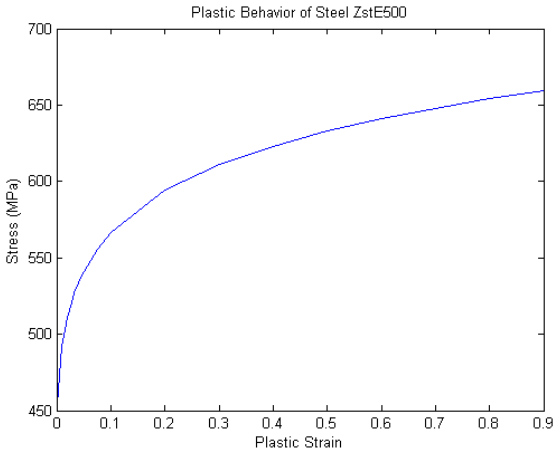


Fig. Plastic Behavior for ZstE500

- **Contact Body & Table**
- flat sheet deformable
- rolls rigid: translate 100mm/s in negative z
- all touching

- **Boundary Conditions**
- I. center of sheet front-end fixed x-direction in the first 5s
- II. center of sheet back-end fixed all directions in the simulation

- **Job Setting**
- stepping multicriteria
- save data every 0.5s

Measurements of Defects

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- Curving:
- defined by translation of the centroid of the cross-section along the channel horizontally or vertically
- measured by coordinate differences of central nodes locating on the web section of two cross sections at the same time
- horizontal curving positive, when sheet convex in z-x plane; vertical curving positive, when sheet convex in z-y plane
- Twist:
- defined by rotation about centroid of cross section along the length of sheet
- measured by the magnitude of twist angle per meter
- positive, when the long flange approaches the short flange

Explanation of Defects

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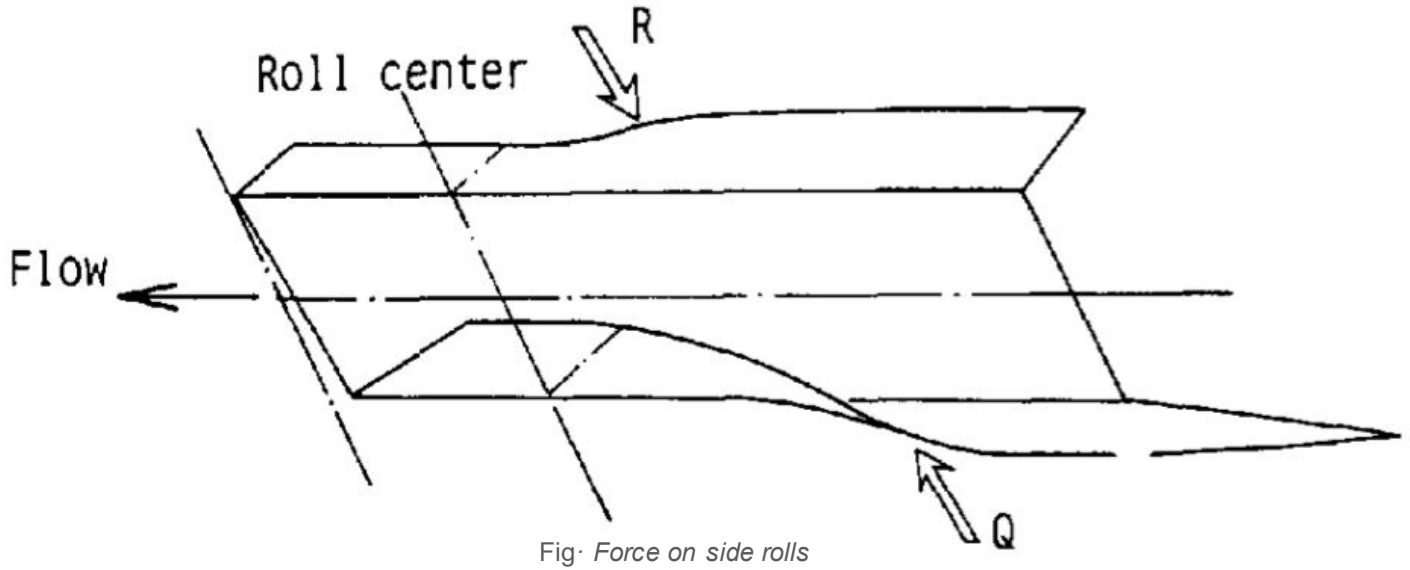
- Forces on the side rolls



Fig· *Force on side rolls*

- Horizontal Curving & Twist:
- —force on long flange occurs before force on short flange
- —torsional & horizontal bending moment
- Vertical Curving: edges of flanges stretched more than web

Reference: H. Ona & T. Jimma, 1983, "*Experiments into the cold roll-forming of straight asymmetrical channels*"

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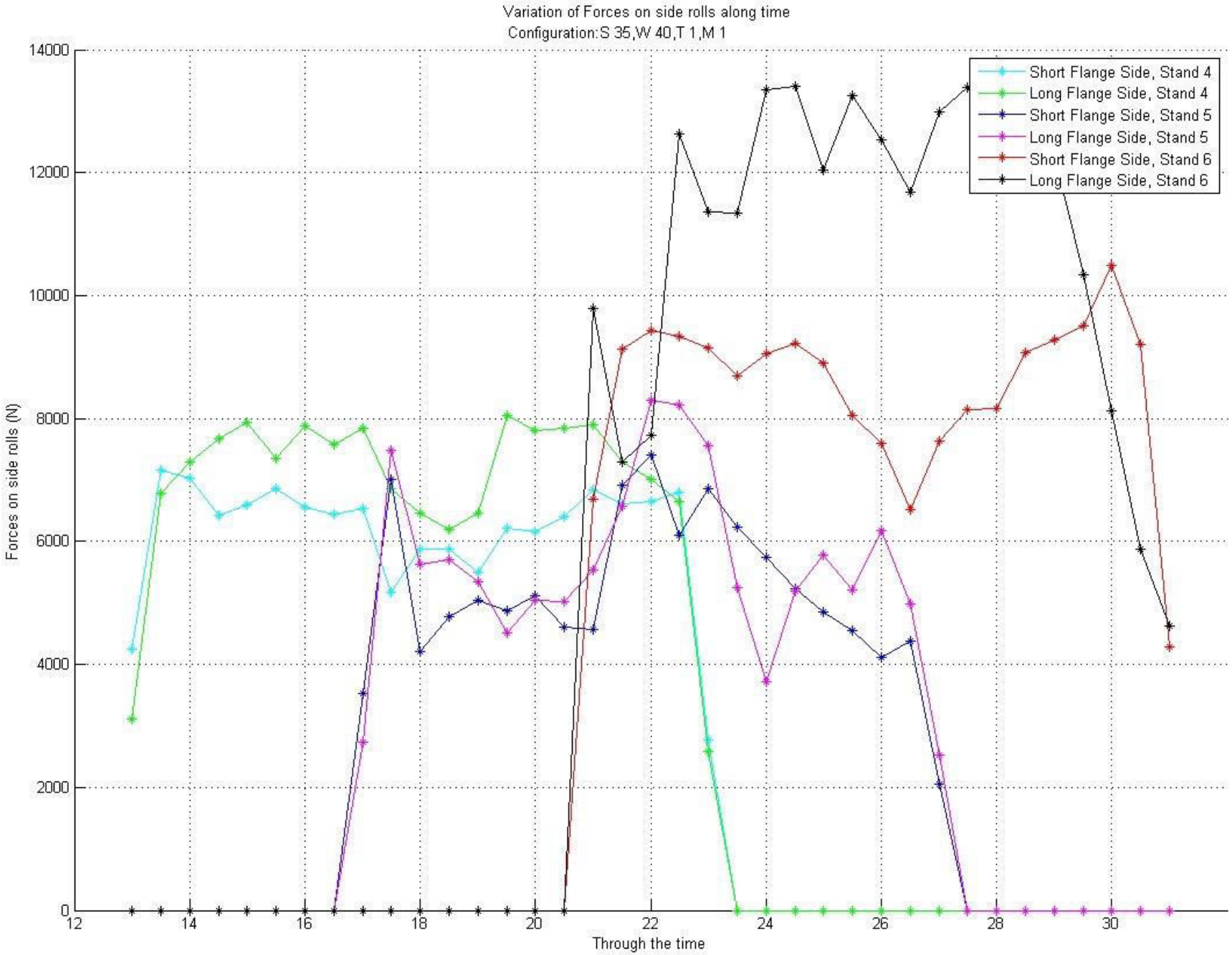

Fig· *Force on side rolls for S35W40T1 profile*

Explanation of Defects

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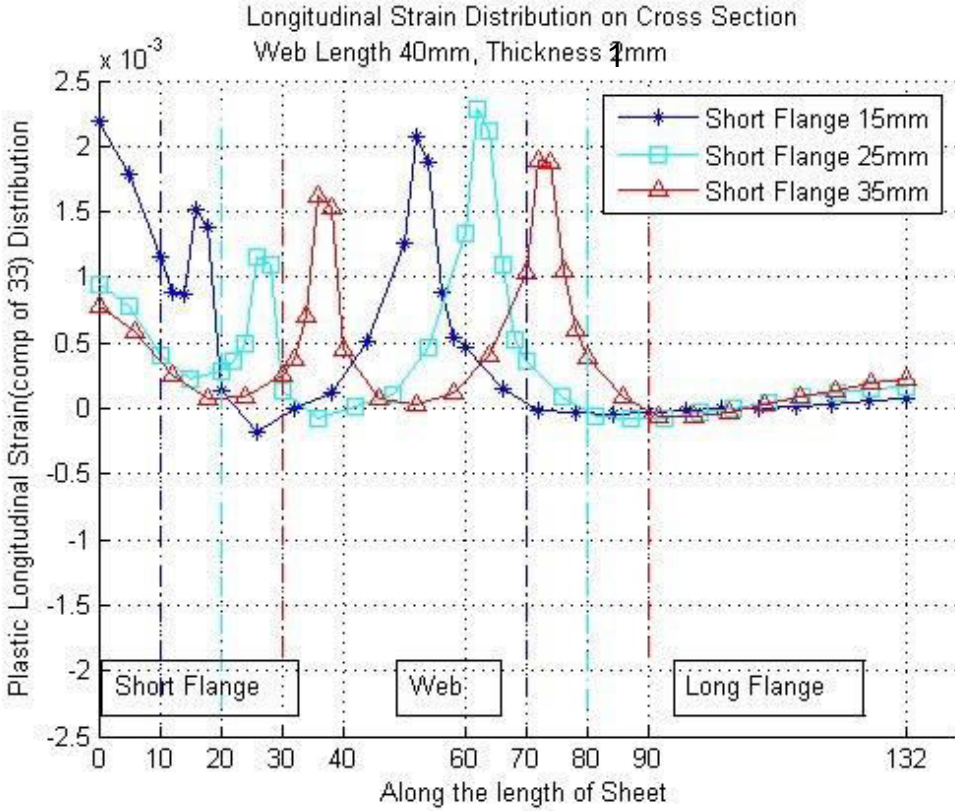
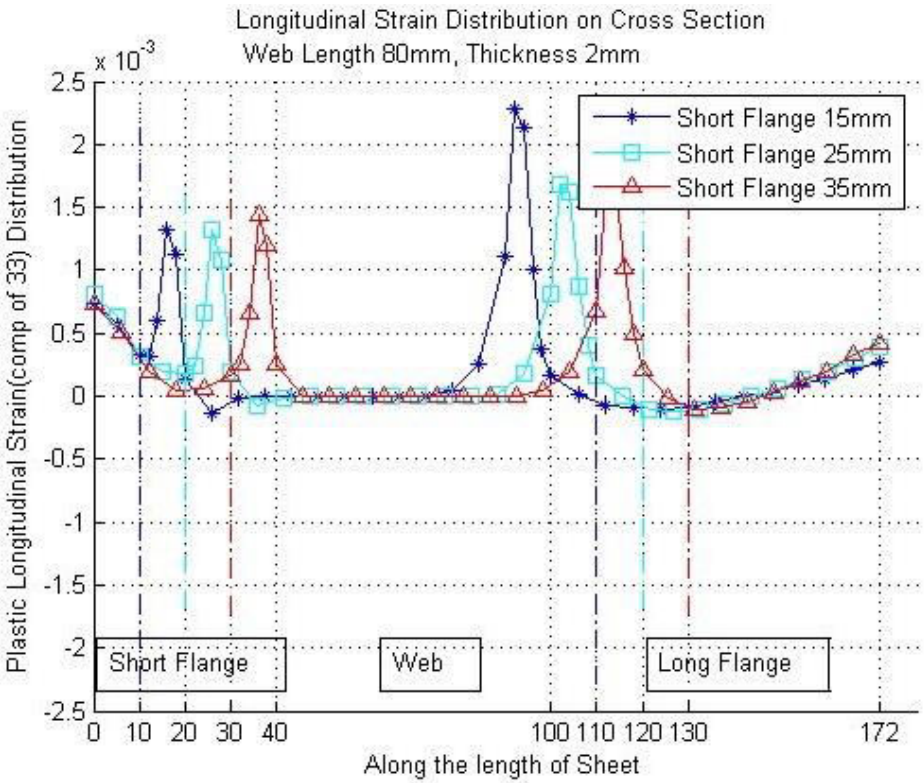
- Non-uniform Distribution of Longitudinal Strain on Cross Section



Fig· *Longitudinal Strain Distribution on Cross Section W40T1*



Fig· *Longitudinal Strain Distribution on Cross Section W80T2*

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Progressive Twist Zone

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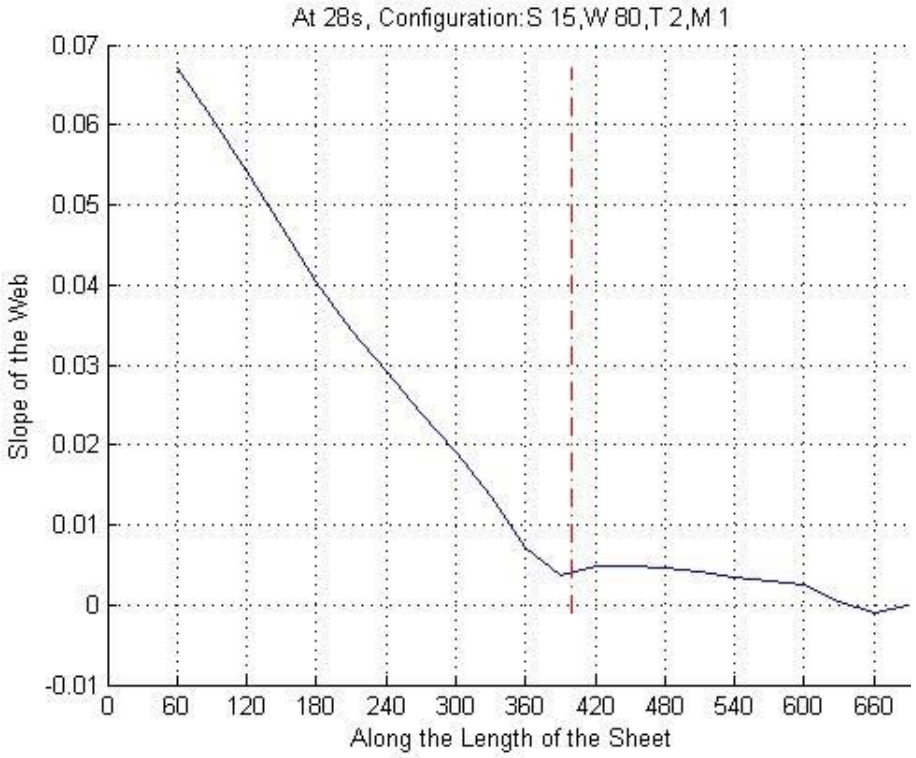
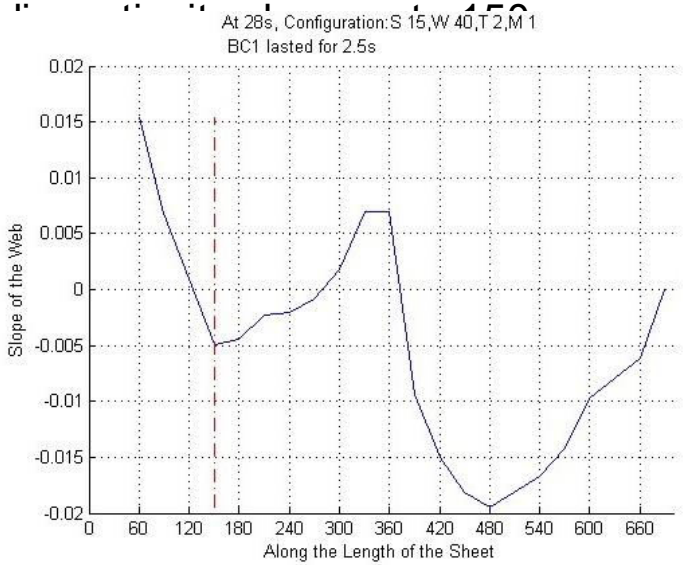
- Slope of the Web



Fig· *Slope of web S15W80T2*

- Progressively Twist Zone: approximately Linearly change of twist region

- Discontinuity of the slope (at 400mm)
- Boundary Condition 1 (center of sheet front-end fixed x-direction in the first 5s)
- After first 5s, a sudden change in x-direction
- Set BC1 lasted 2.5s, the location of



Fig· *Slope of web S15W40T2*

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Progressive Zones and Magnitude of Twist

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- Progressive Twist Zone

Choice of Measuring Zone (from/to a specific position on the sheet along length(mm))

S15 W80 T2	S25 W80 T2	S35 W80 T2	S15 W40 T2	S25 W40 T2	S35 W40 T2
90/330	90/330	90/330	60/210	60/210	90/330
S15 W80 T1	S25 W80 T1	S35 W80 T1	S15 W40 T1	S25 W40 T1	S35 W40 T1
90/330	60/210	90/330	60/180	Weird behave	90/210

Table· Progressive Twist Zones

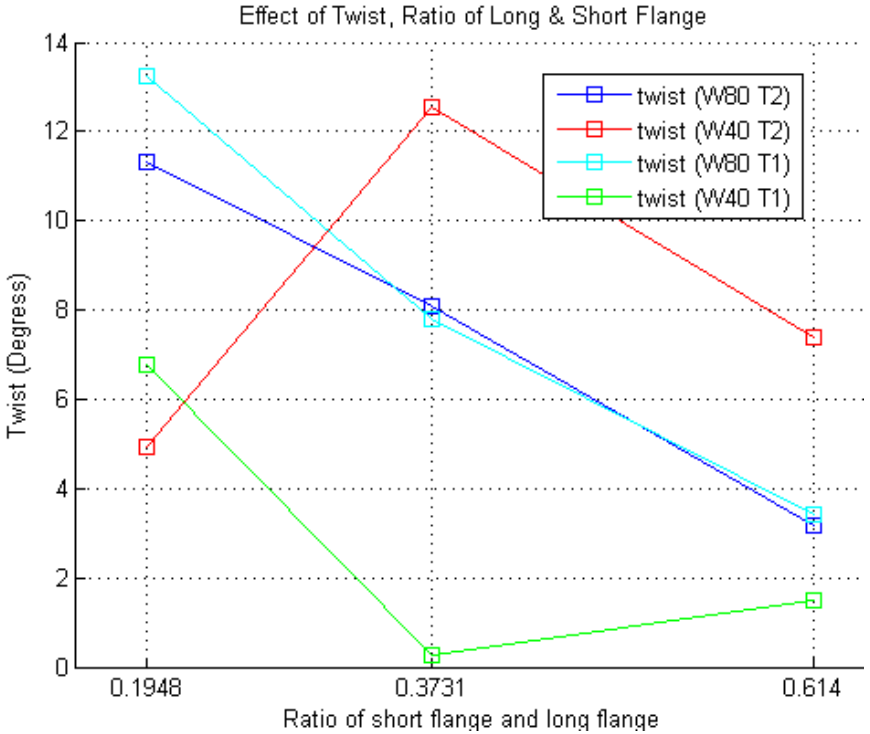
- Magnitude of Twist (degree per 1000mm)

profile	twist	profile	twist	profile	twist	profile	twist
S15W80T2	11.3006	S15W40T2	4.9517	S15W80T1	13.2461	S15W40T1	6.7630
S25W80T2	8.0791	S25W40T2	12.5284	S25W80T1	7.8057	S25W40T1	0.2671
S35W80T2	3.1807	S35W40T2	7.3903	S35W80T1	3.4236	S35W40T1	1.4859

Table· Magnitude of Twist

- Tolerance of Twist: 1 degree per 1000mm
- Unexpected Results:
- Web length=40mm
- Short flange=15mm

Tendency



Fig· *Tendency of Twist with respect to ratio of flanges*

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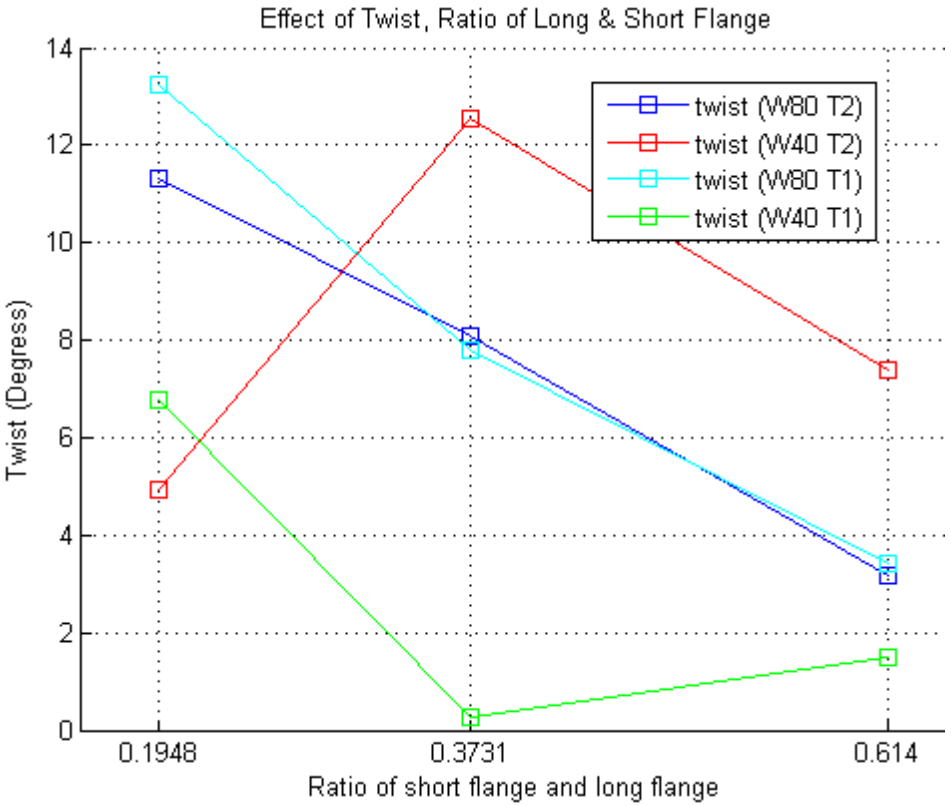
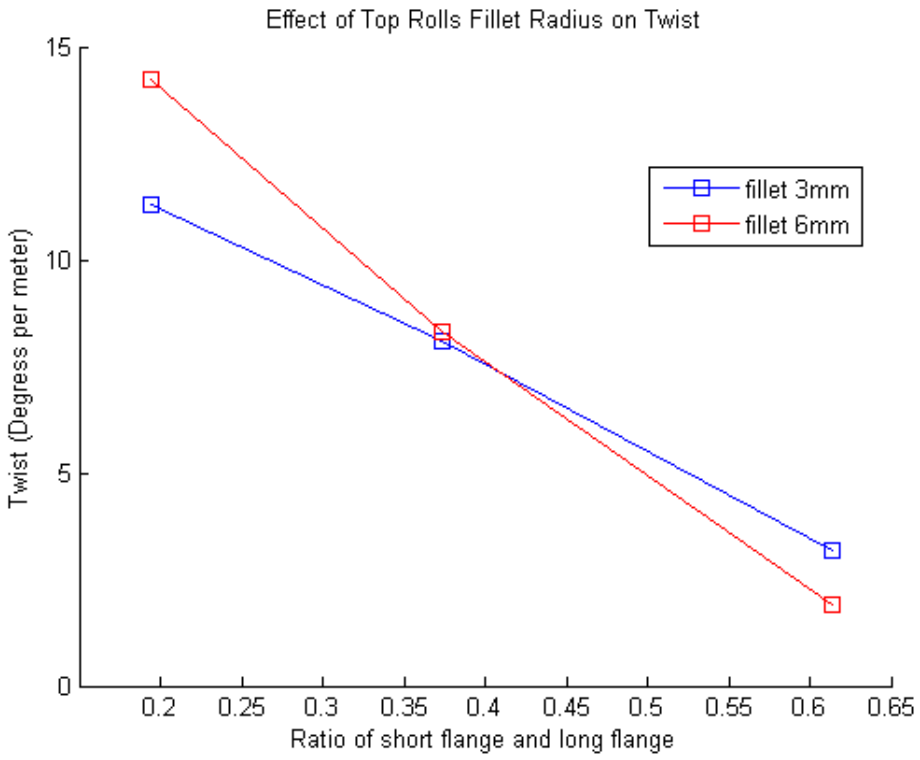
Effect of Input Parameters on Twist



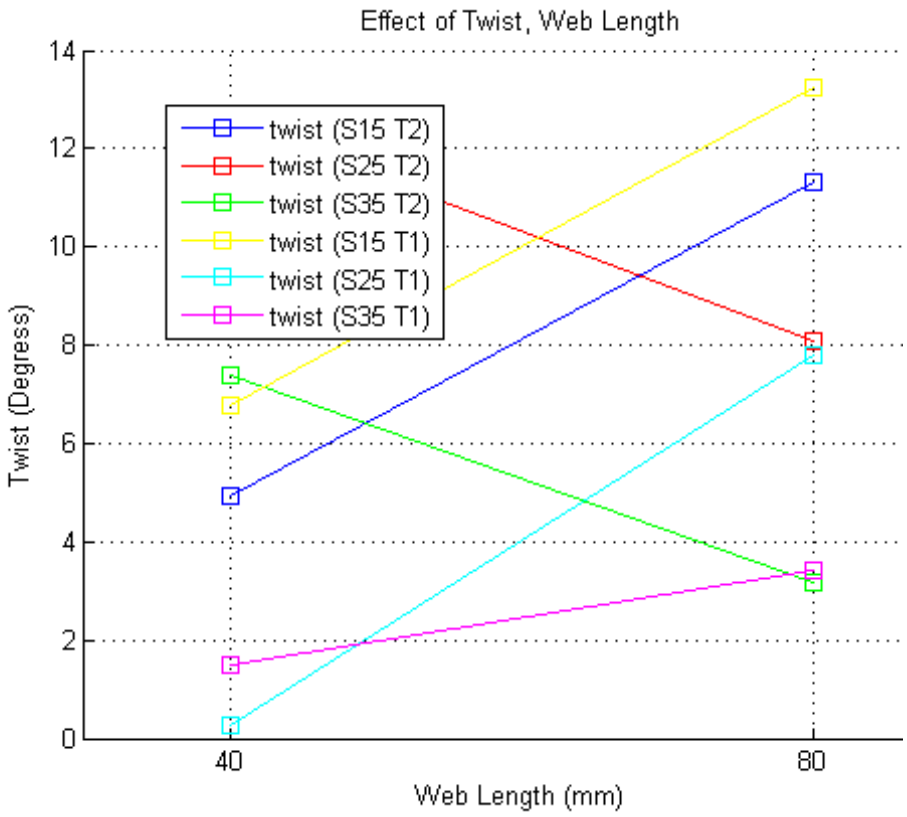
Fig· *Tendency of Twist with respect to ratio of flanges*



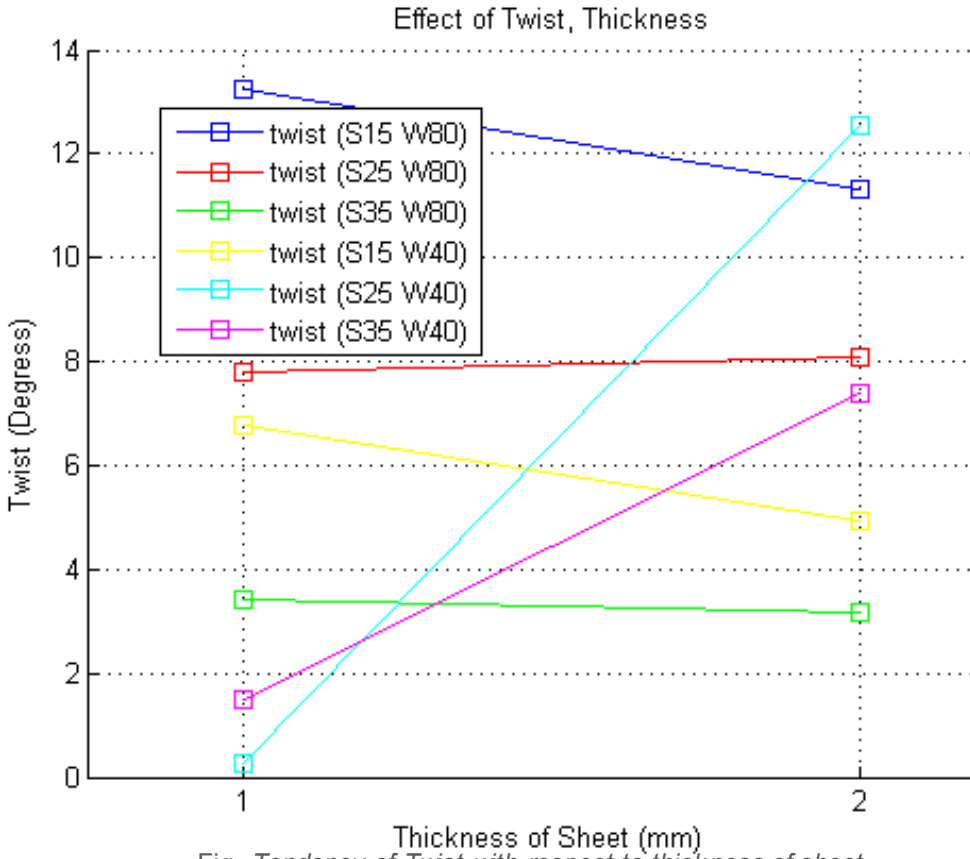
Fig· *Tendency of Twist with respect to radius of top rolls fillet*

-twist values are decreasing with increase of ratio of flanges,
except W40T2 grows up first and then drops, and W40T1 decrease first and increase then
-fillet radius has very less influence on the magnitude of twist

Effect of Input Parameters on Twist



Fig· *Tendency of Twist with respect to web length*



Fig· *Tendency of Twist with respect to thickness of sheet*

-twist values are increasing with increase of web length, except S25T2 and S35T2
-twist values are decreasing with increase of thickness, except S25W80, S25W40 and S35W40

Explanation of Unexpected Results

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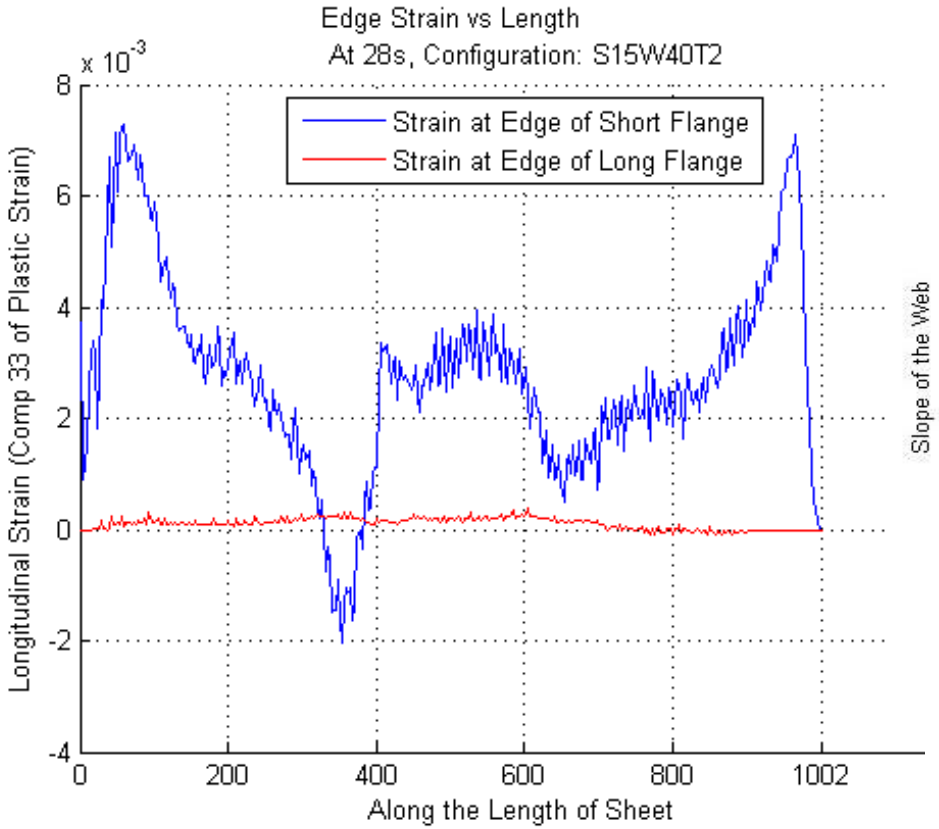
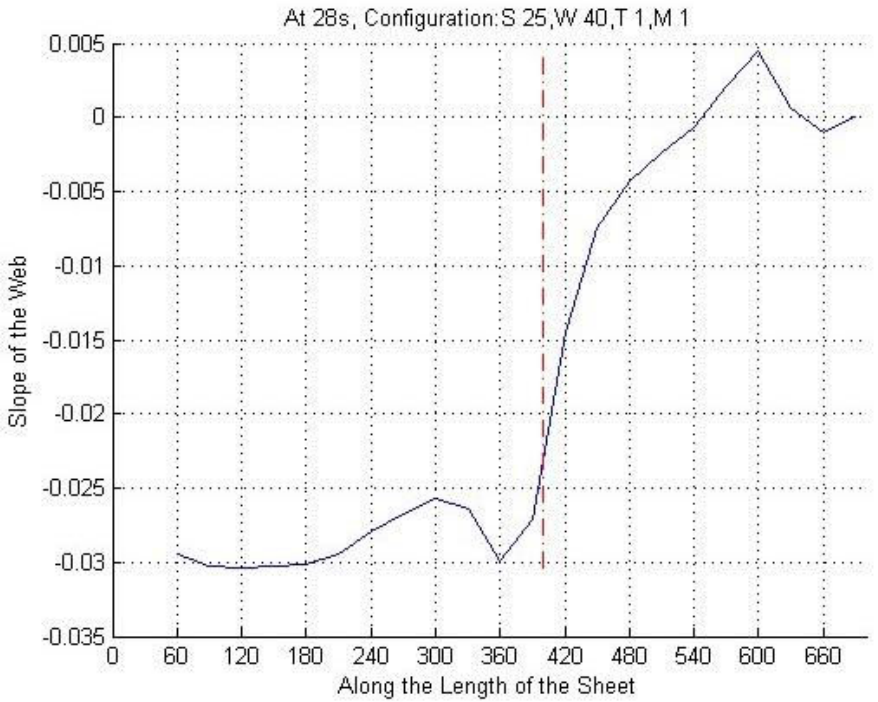
- non-constant longitudinal



Fig· *Flange Edge Longitudinal Strain S15W40T2*

- counterclockwise twist



Fig· *Slope of the Web S25W40T1*

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Explanation of Unexpected Results

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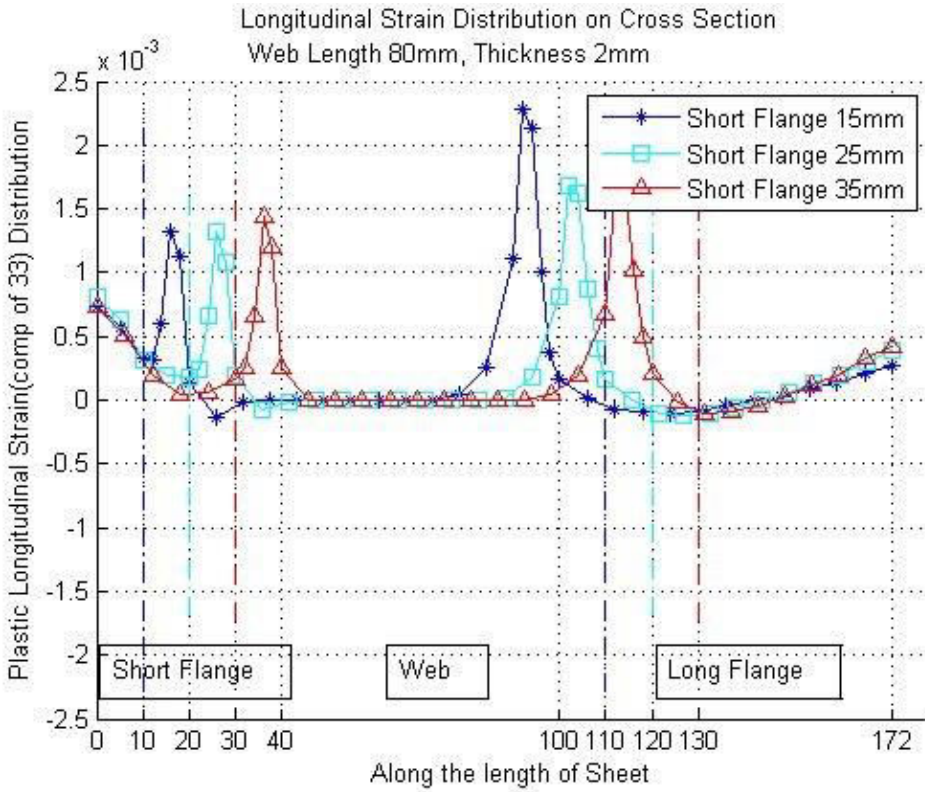
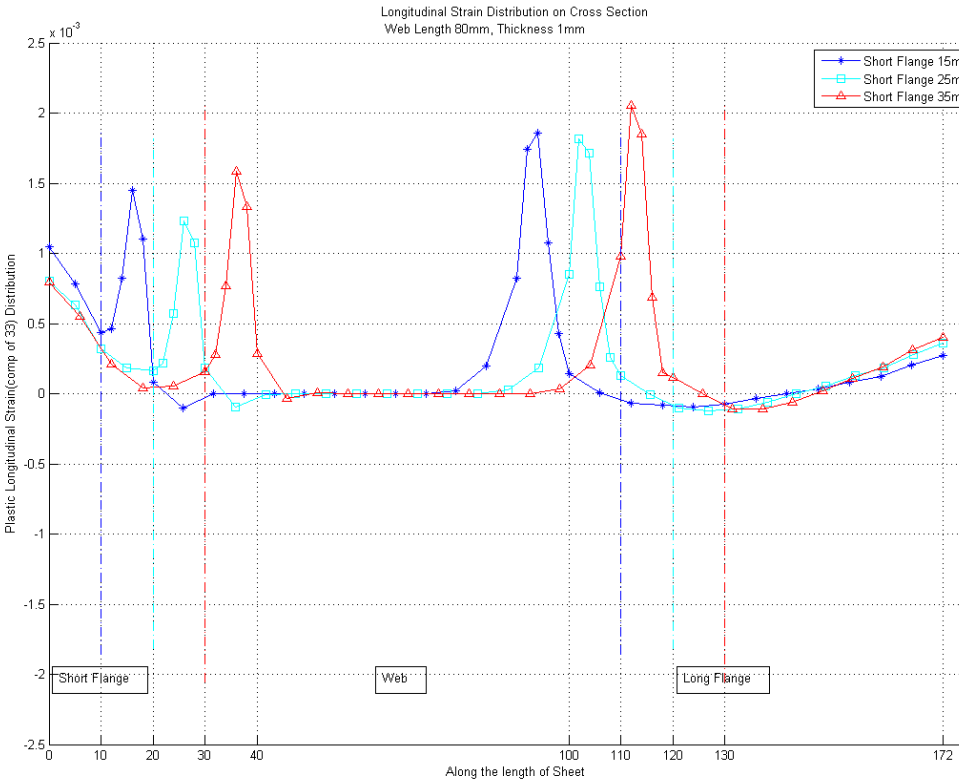
- constant longitudinal strain on web for web length 80mm



Fig· *Cross Section Longitudinal Strain W80T2*



Fig· *Cross Section Longitudinal Strain W80T1*

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Explanation of Unexpected Results

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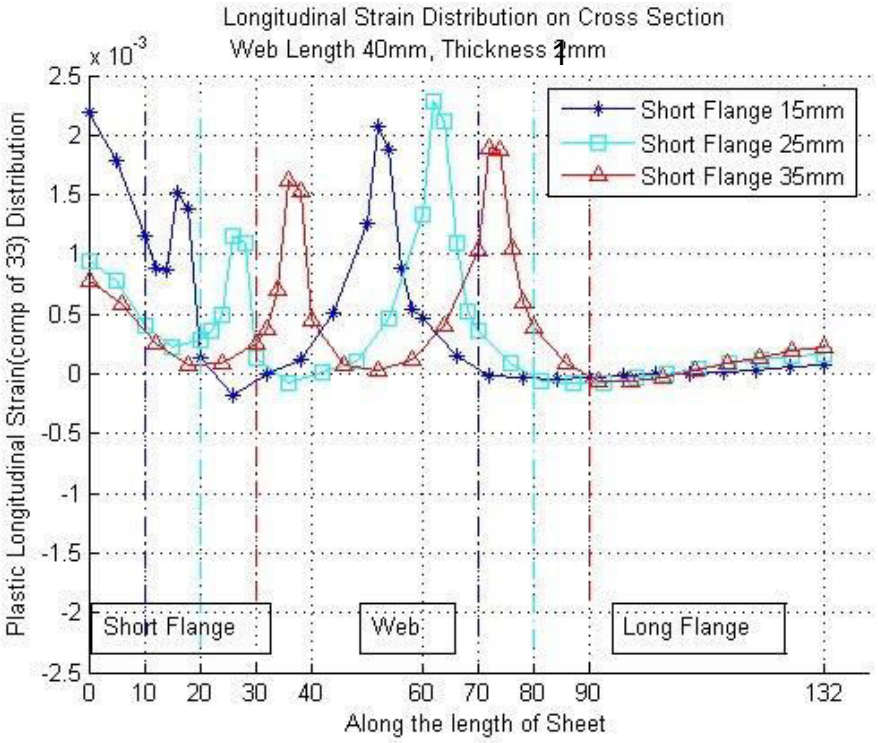
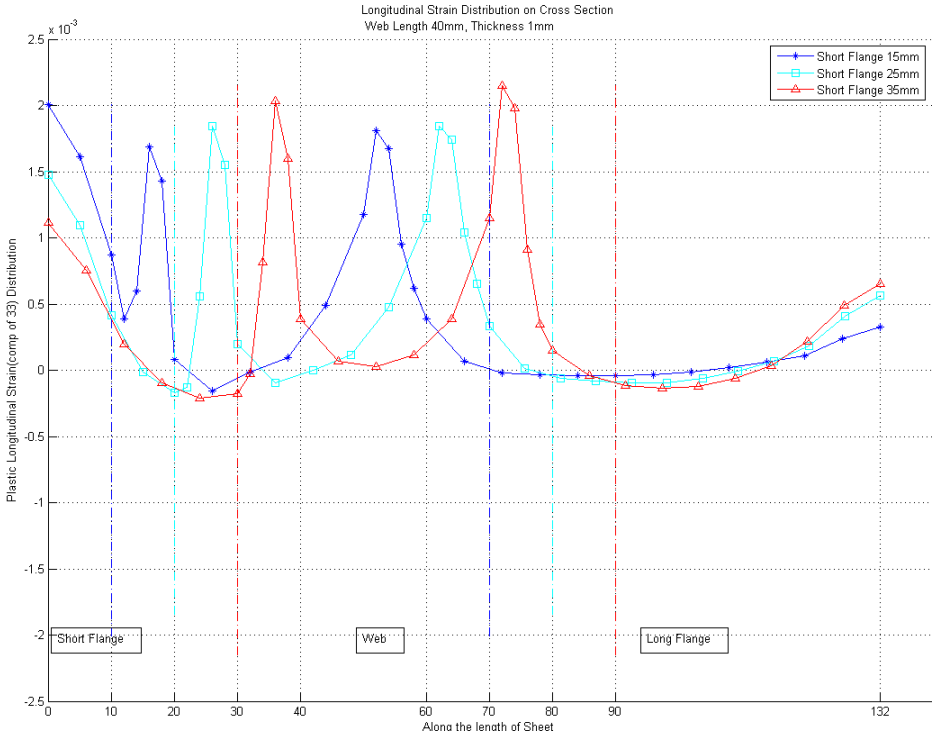
- unstable behaviour for web length 40mm



Fig· *Cross Section Longitudinal Strain W40T2*



Fig· *Cross Section Longitudinal Strain W40T1*

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Explanation of Unexpected Results

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- Deformation Length $L = \sqrt{\frac{8a^3\Delta\Theta}{3t}}$

- bending angle increments $\Delta\theta$ are 13°, 16°, 18°, 18°, 15°, 10°

	(mm)	minimum deformation length	maximum deformation length	(mm)	minimum deformation length	maximum deformation length
short flange	15	28.0178514522438	37.589892258425	15	39.6232255123179	53.160135440008
long flange	77	325.862231739234	437.19006088123	77	460.838787590789	618.280113432954
thickness	2			1		
short flange	25	60.284817817252	80.8805703903395	25	85.2556069623489	114.38239957849
long flange	67	264.490540333536	354.851296554862	67	374.046109259075	501.835516213563
thickness	2			1		
short flange	35	99.8619417366166	133.978854052919	35	141.226112368835	189.474712472843
long flange	57	207.544019427205	278.44952145766	57	293.511567063378	393.787089681721
thickness	2			1		

Table· Deformation Length

- distance between stands = 400mm

Reference: Bhattacharyya et al. 1984, "*Prediction of strain development while roll forming fundamental sections, Advanced technology of plasticity*"

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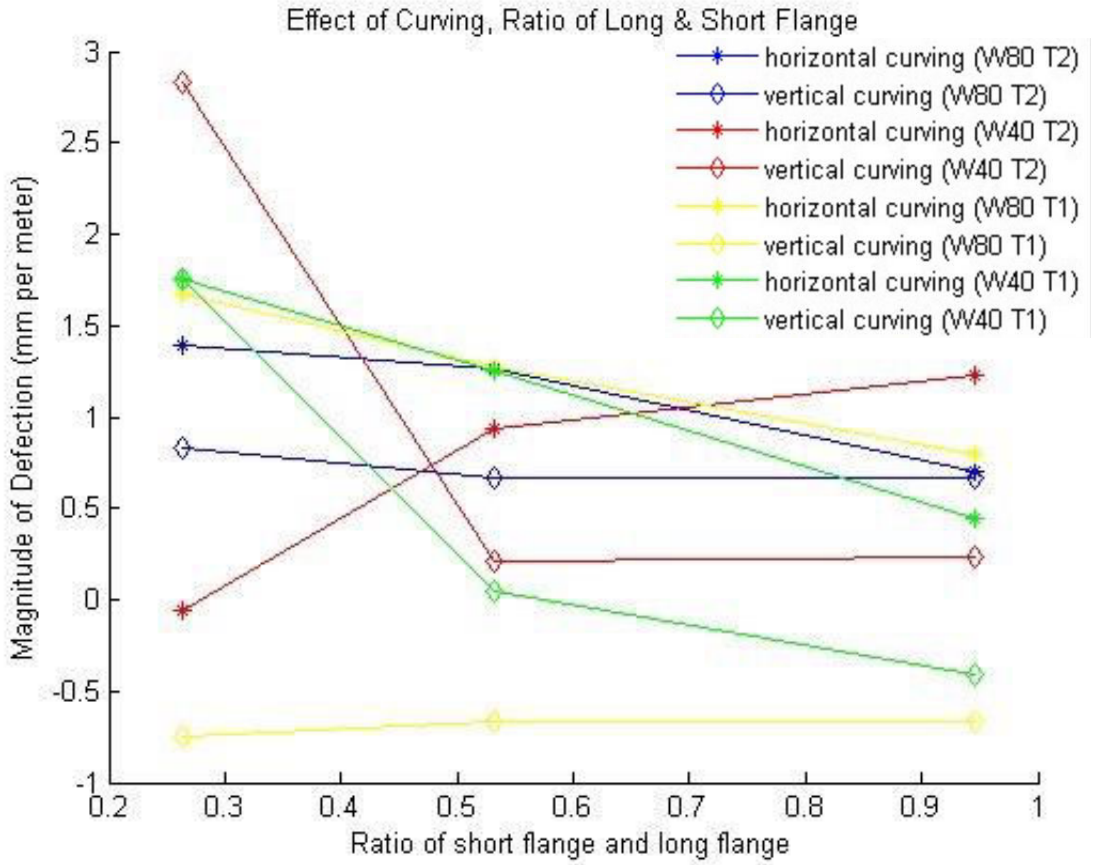
Effect of Input Parameters on Curving



Fig· *Tendency of Curving with respect to flange ratios*

- The magnitude of curving is always around 1mm per 1000mm
- not problematic

Conclusion & Outlook

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Conclusion

1. In summary, magnitude of twist decrease when the profile cross-sectional area grows to more symmetry.

—ratio of short flange length to the long flange length increases,

—web length decreases,

—thickness increases.

2. The twist is partially progressive because of the boundary condition I.

3. For S15T2, S15T1 and S25T1 profile, the deformation length is sometimes larger than distance between two neighbour stands, which is problematic.

Outlook

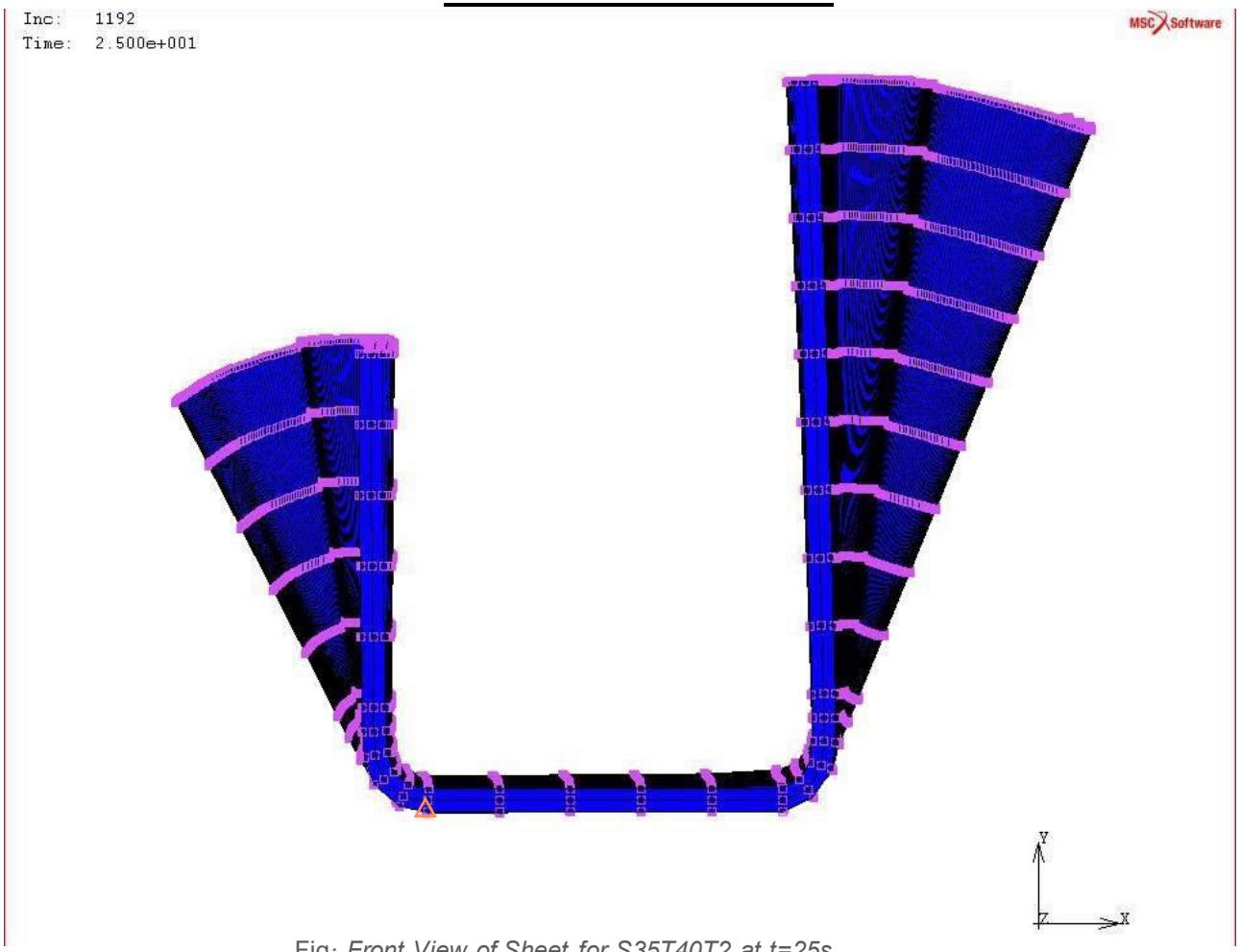
1. In order to neutralize the effect of boundary condition I, we can implement supportive rolls in both x and y directions

2. Investigation on different type of materials

3. Investigation on simulations with asymmetric fillet radius of top rolls

Thank you for your attention!

- Front View of the Sheet after deformation at time t=25s



Fig· *Front View of Sheet for S35T40T2 at t=25s*

Initial Position of Sheet

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