Laser Forming
Applications, Advantages and Disadvantages

PG 1st Year-Second Semester

School of Laser Science and Engineering

Buckling Mechanism

- Generally, BM is used to bend thin sheets and tubes with a small temperature gradient through the material thickness, which is negligible.

- Moreover, the laser beam diameter is much greater than the material's thickness, and in some cases, by a factor of ten.

- This is to allow more energy to penetrate the material.

- Hence, the scanning speed should be slower than the TGM's case in order to achieve a uniform distribution of temperature in the direction of thickness.

- Depending on a number of factors including the process parameters, the pre-bending orientation of the sheet, the pre-existing residual stresses, a forced air stream acting on the bottom of the sheet.

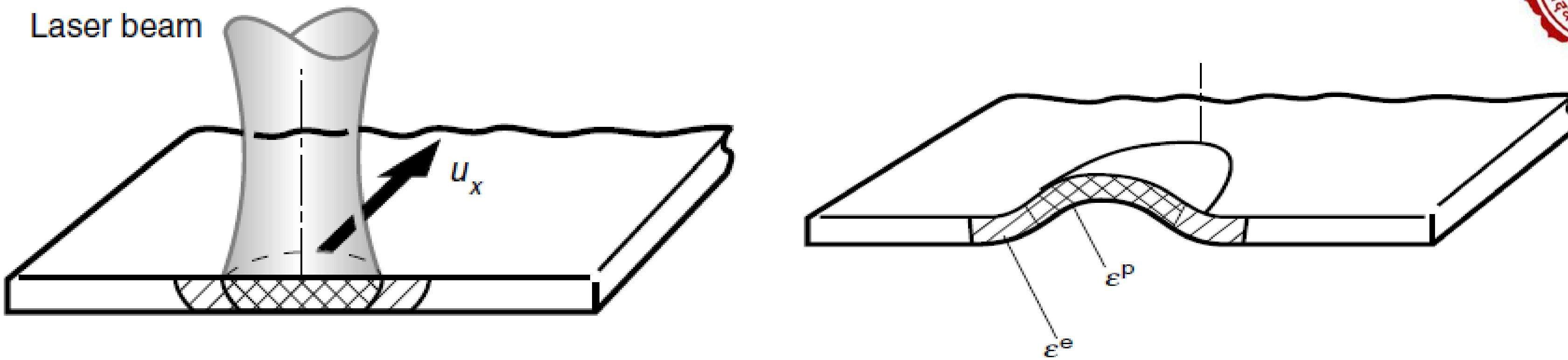
Advantages

- The noncontact nature of the process that makes it independent of tool inaccuracies that might result from wear and deflection, since no external forces are involved. It also makes the process more flexible.
- Precise deformation can be achieved because spring-back behaviour is not involved which is related to the quality of product.
- Forming is available in inaccessible areas because this process is a non-contact forming process.
- Ability to more accurately control the energy source and thus the forming process, compared to flame bending and mechanical forming in general.
- Brittle, hard and thick material can be processed.
- Minimal heat-affected zone size or material degradation compared to flame bending where the heat source is more diffuse.
- A wide variety of complex shaped parts can be obtained through the development of new irradiation patterns.

Disadvantages

- The noncontact nature of the process that makes it independent of tool inaccuracies that might result from wear and deflection, since no external forces are involved. It also makes the process more flexible.
- Precise deformation can be achieved because spring-back behaviour is not involved which is related to the quality of product.
- Forming is available in inaccessible areas because this process is a non-contact forming process.
- Ability to more accurately control the energy source and thus the forming process, compared to flame bending and mechanical forming in general.
- Brittle, hard and thick material can be processed.
- Minimal heat-affected zone size or material degradation compared to flame bending where the heat source is more diffuse.
- A wide variety of complex shaped parts can be obtained through the development of new irradiation patterns.

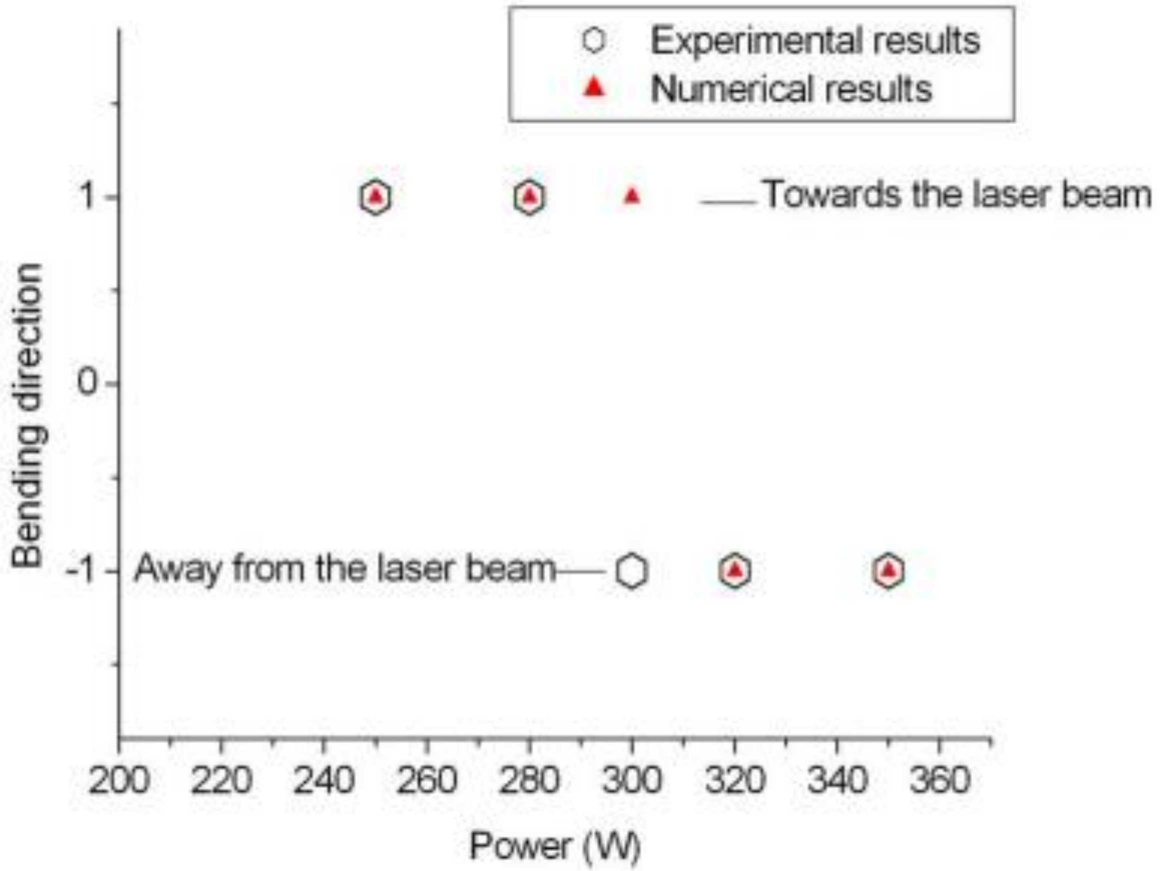
Buckling Mechanism



- Plastic deformation near to the center of the beam or near, while farther away, close to the root of the buckle, the material is subjected to elastic bending.
- If the heat source traverses the entire length of the sheet, then no restraining forces exist to hold the elastically bent portion in place during cooling. Thus, elastic recovery occurs at the root, while the center remains bent, resulting in the sheet being bent along the center line.
- The direction of the bending that results from the buckling mechanism is unpredictable.
- However, it has been observed that at relatively high scan rates, say 15 mm/s (depending on the processing conditions), bending is always toward the laser beam. It only becomes unpredictable at lower speeds.
- Bending by the buckling mechanism does not increase the sheet thickness at the bend. Like the TGM, the bending angle can be increased by repeating the process.

Buckling Mechanism

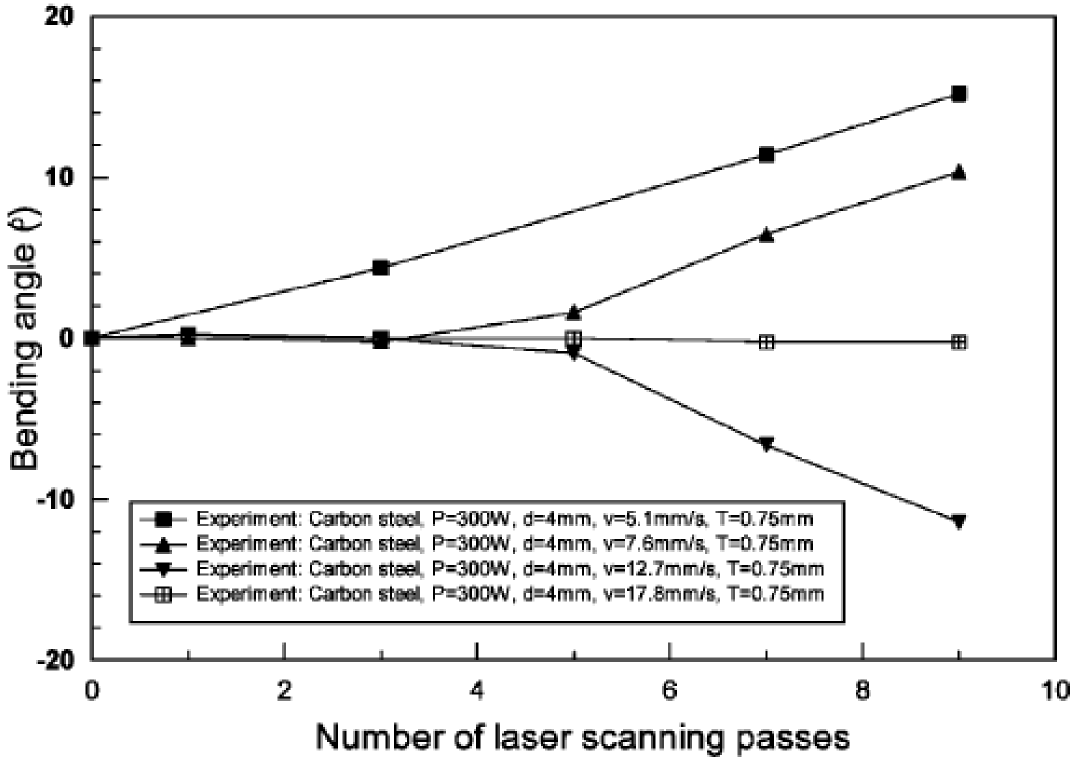
Shi et al. (2008) A study on bending direction of sheet metal in laser forming, **Journal of Applied Physics 103**, 053101



Bending directions of plates (scanning velocity of 12 mm/s, beam diameter of 10 mm, and plate size of 200x200x0.6 mm^3)

Buckling Mechanism

Hu et al. (2002) Experimental and numerical modeling of buckling instability of laser sheet forming, **International Journal of Machine Tools & Manufacture** 42; 1427–1439

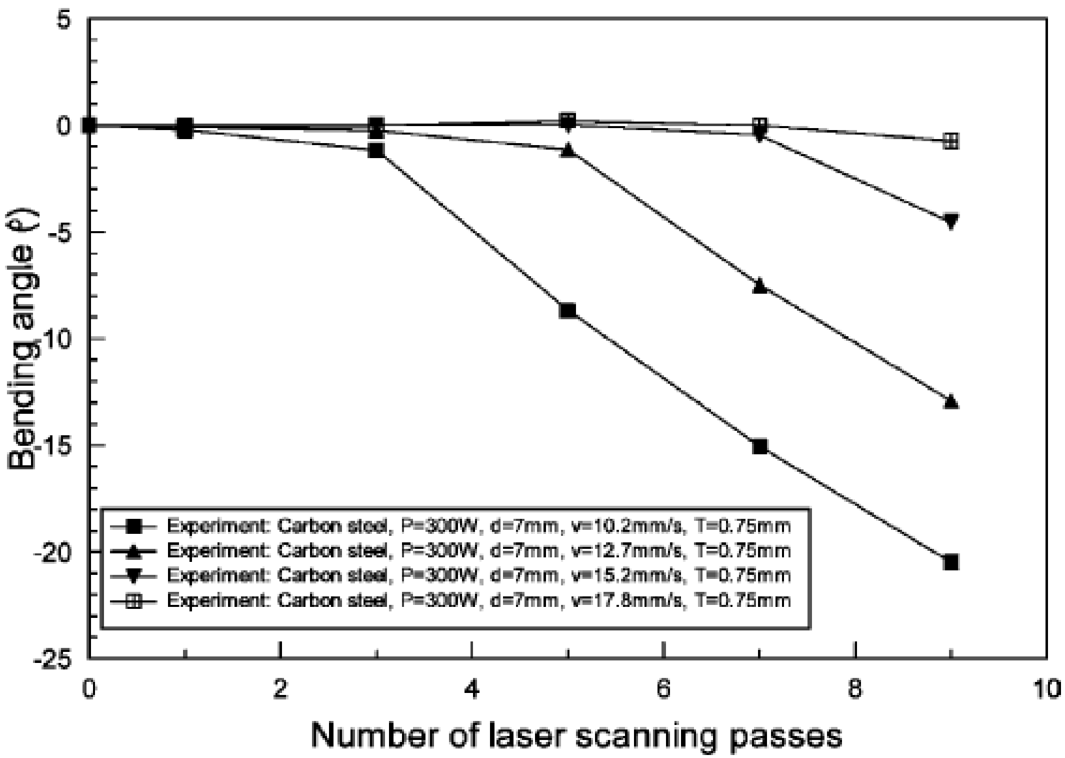


(a) P=300W, d=4mm, T=0.75mm

Bending directions of plates (Carbon steel plate size of 100x50x0.75 mm^3)

Buckling Mechanism

Hu et al. (2002) Experimental and numerical modeling of buckling instability of laser sheet forming, **International Journal of Machine Tools & Manufacture** 42; 1427–1439

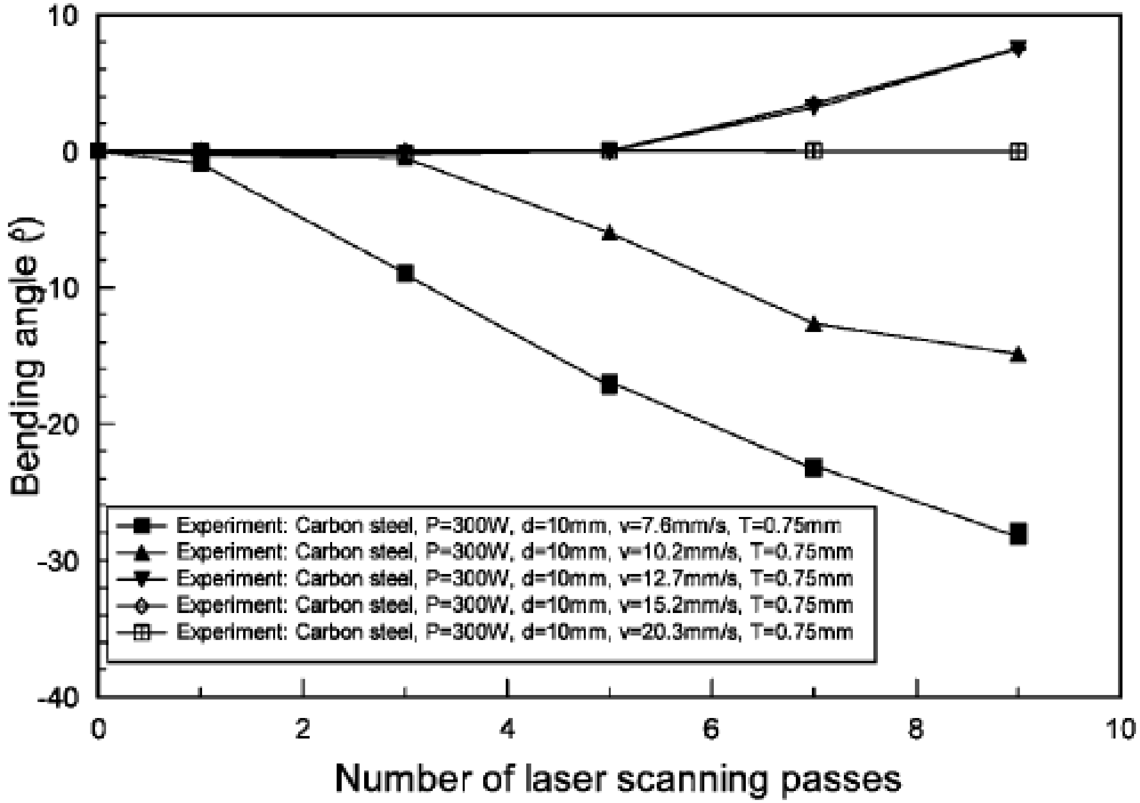


(b) P=300W, d=7mm, T=0.75mm

Bending directions of plates (Carbon steel plate size of 100x50x0.75 mm^3)

Buckling Mechanism

Hu et al. (2002) Experimental and numerical modeling of buckling instability of laser sheet forming, **International Journal of Machine Tools & Manufacture** 42; 1427–1439

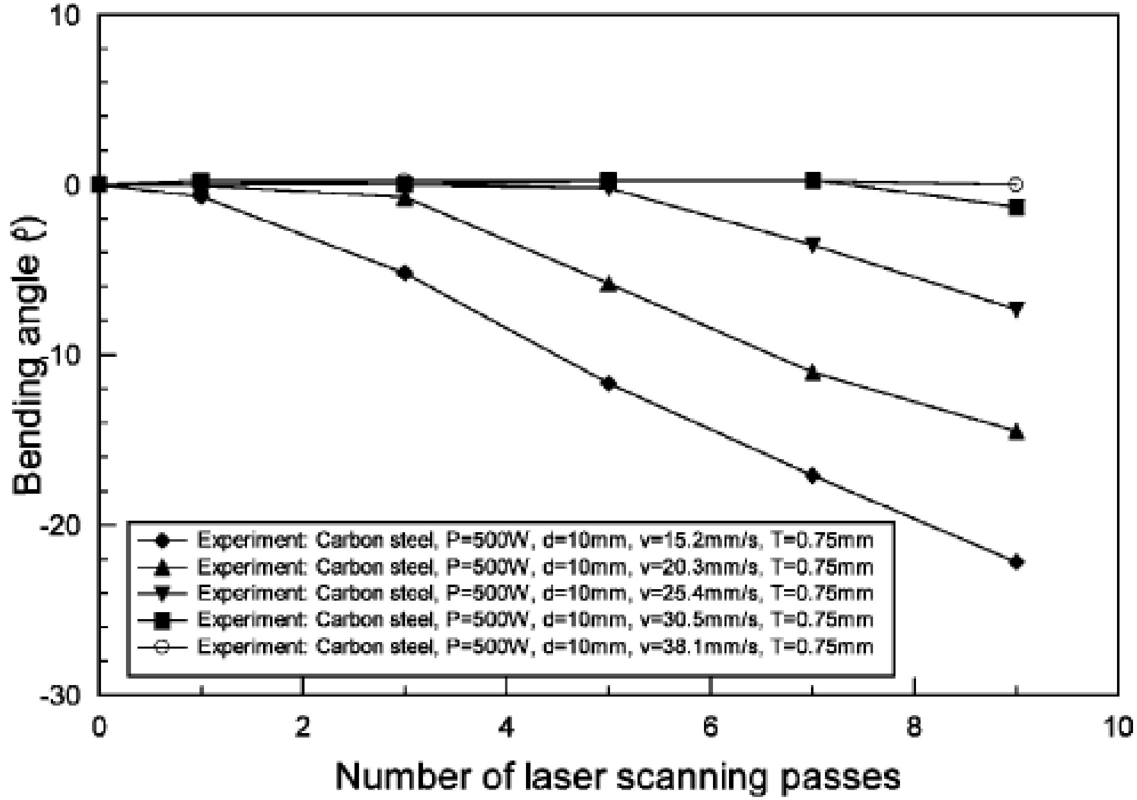


(c) P=300W, d=10mm, T=0.75mm

Bending directions of plates (Carbon steel plate size of 100x50x0.75 mm^3)

Buckling Mechanism

Hu et al. (2002) Experimental and numerical modeling of buckling instability of laser sheet forming, **International Journal of Machine Tools & Manufacture** 42; 1427–1439

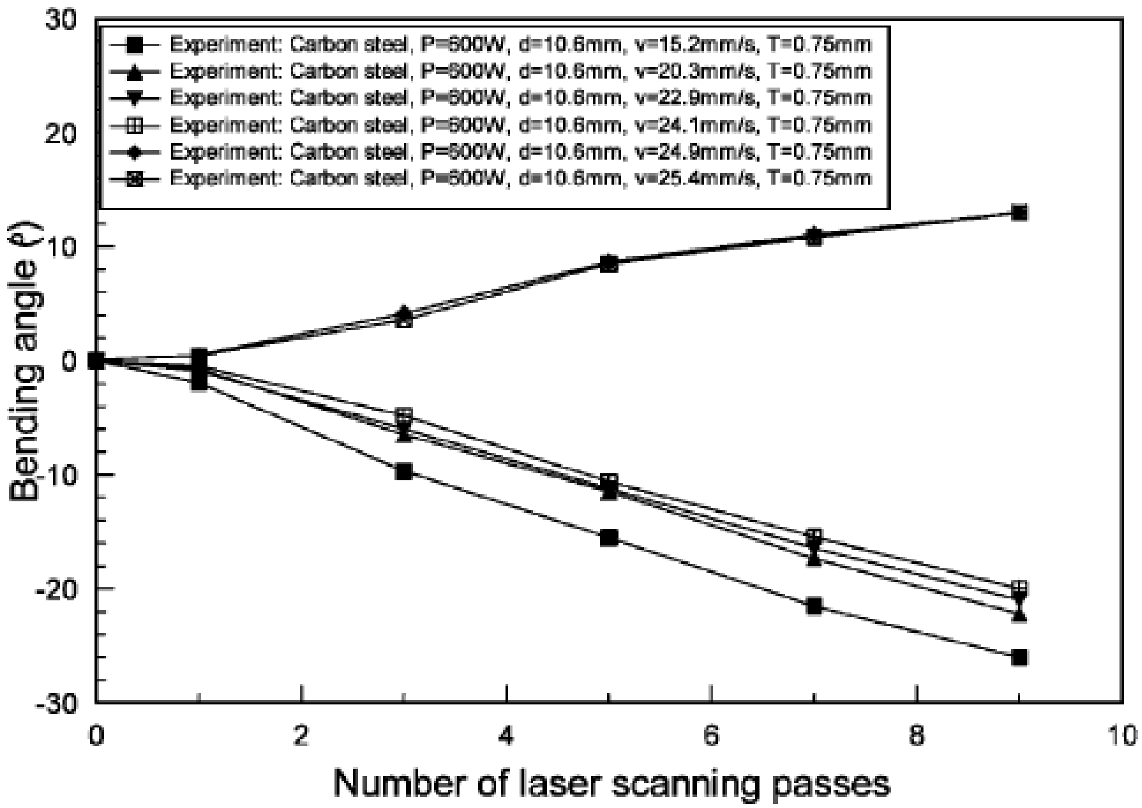


(d) P=500W, d=10mm, T=0.75mm

Bending directions of plates (Carbon steel plate size of 100x50x0.75 mm^3)

Buckling Mechanism

Hu et al. (2002) Experimental and numerical modeling of buckling instability of laser sheet forming, **International Journal of Machine Tools & Manufacture** 42; 1427–1439

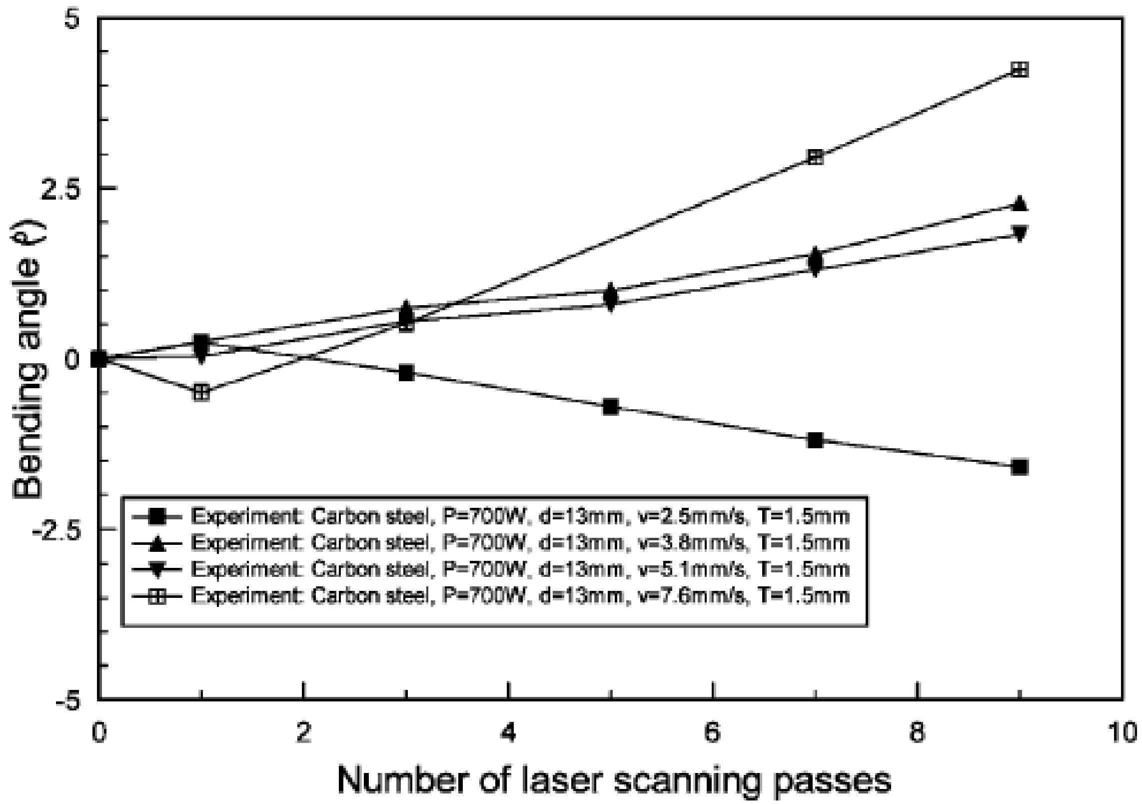


(e) P=600W, d=10.6mm, T=0.75mm

Bending directions of plates (Carbon steel plate size of 100x50x0.75 mm^3)

Buckling Mechanism

Hu et al. (2002) Experimental and numerical modeling of buckling instability of laser sheet forming, **International Journal of Machine Tools & Manufacture** 42; 1427–1439

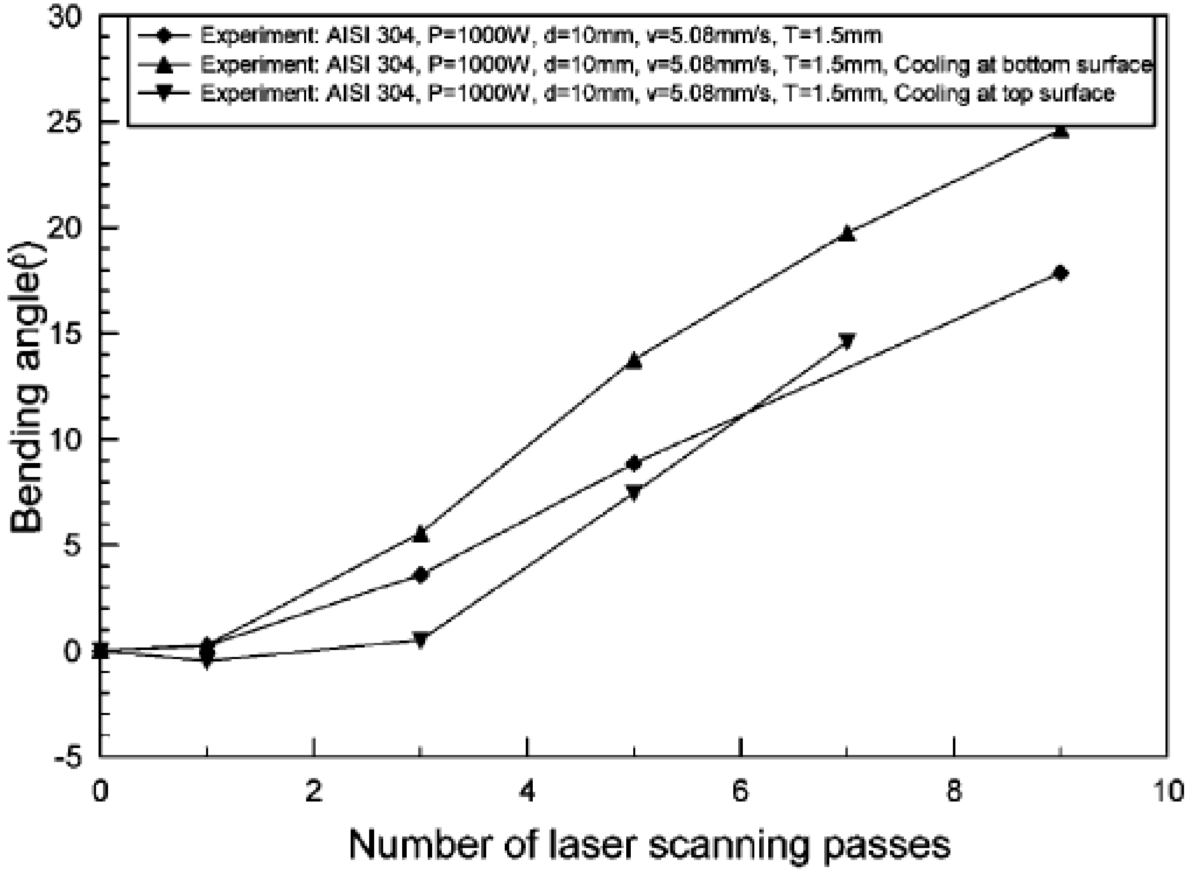


(f) P=700W, d=13mm, T=1.5mm

Bending directions of plates (Carbon steel plate size of 100x50x1.5 mm^3)

Buckling Mechanism

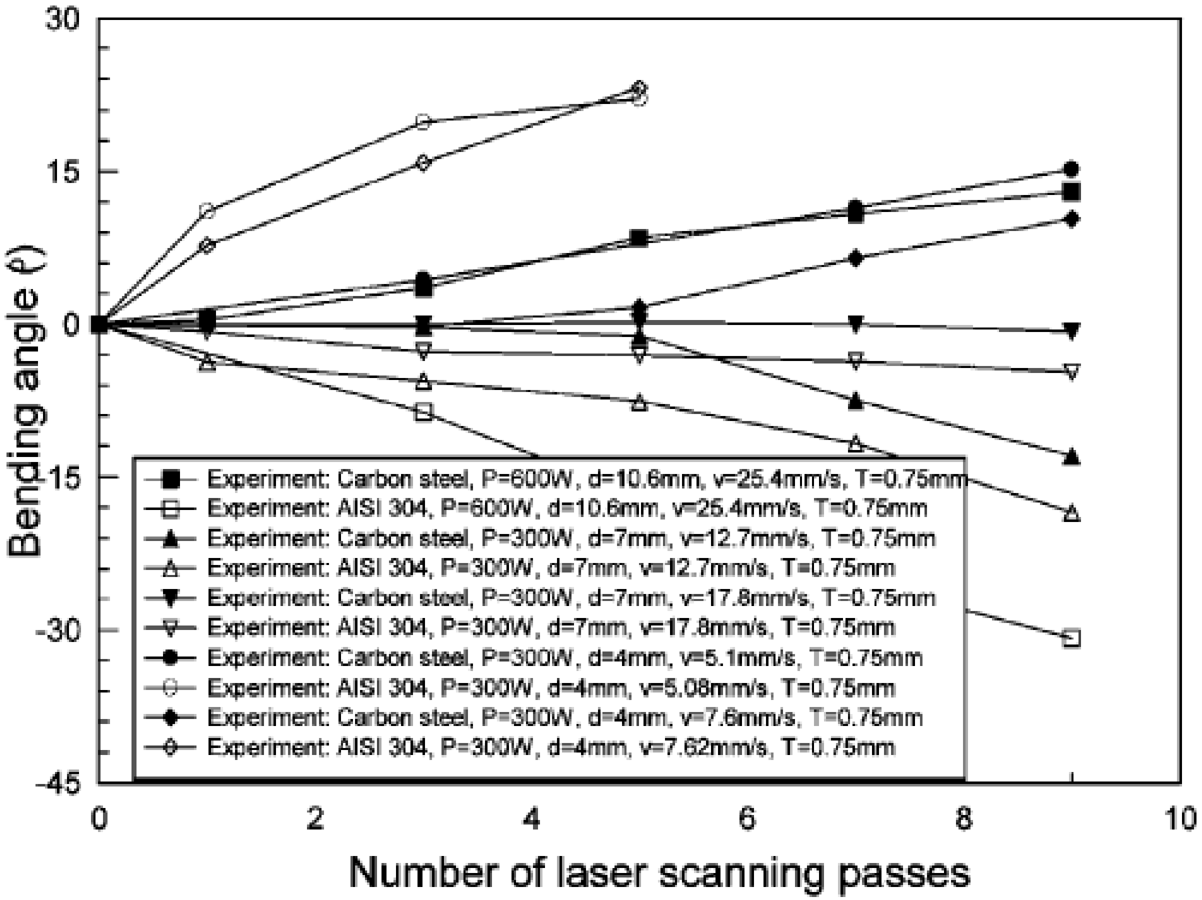
Hu et al. (2002) Experimental and numerical modeling of buckling instability of laser sheet forming, **International Journal of Machine Tools & Manufacture** 42; 1427–1439



(a) with different cooling conditions

Buckling Mechanism

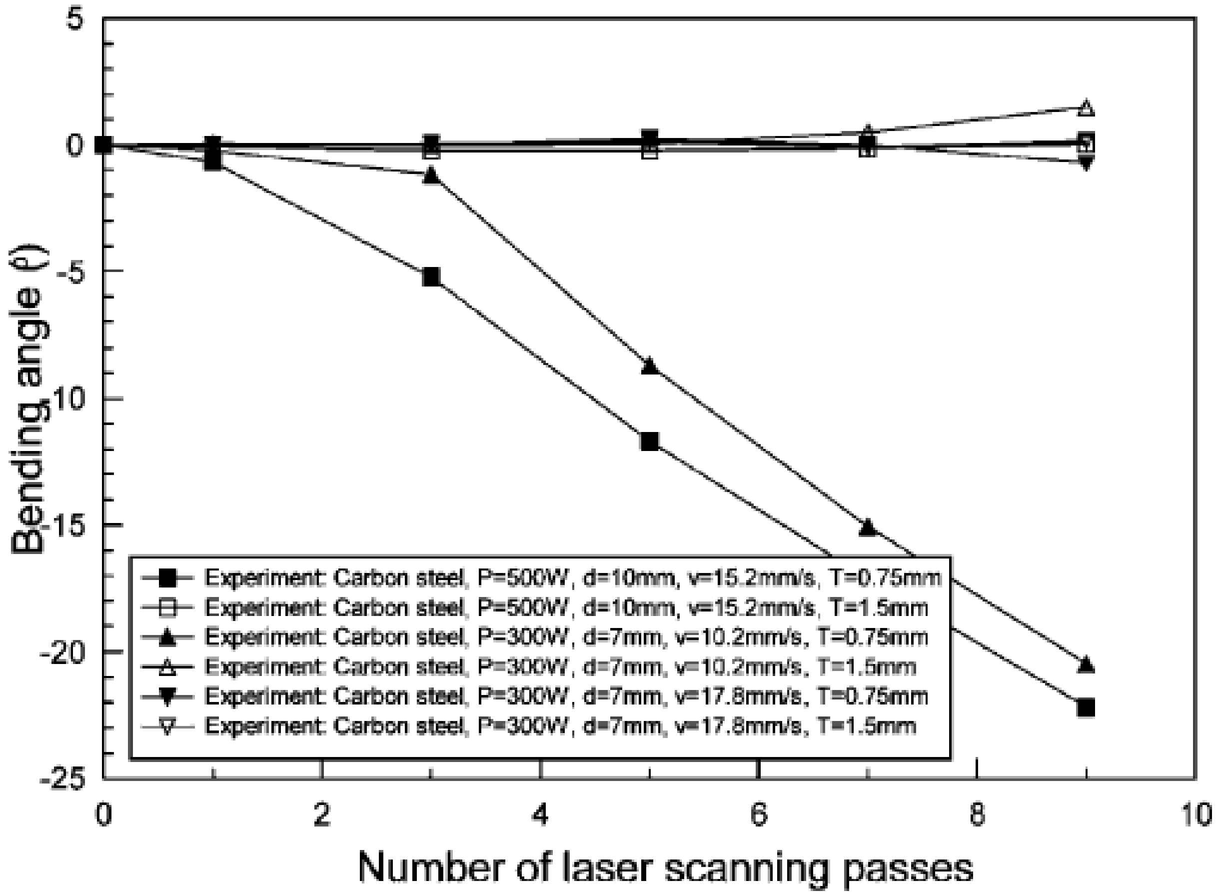
Hu et al. (2002) Experimental and numerical modeling of buckling instability of laser sheet forming, **International Journal of Machine Tools & Manufacture** 42; 1427–1439



(b) with different materials

Buckling Mechanism

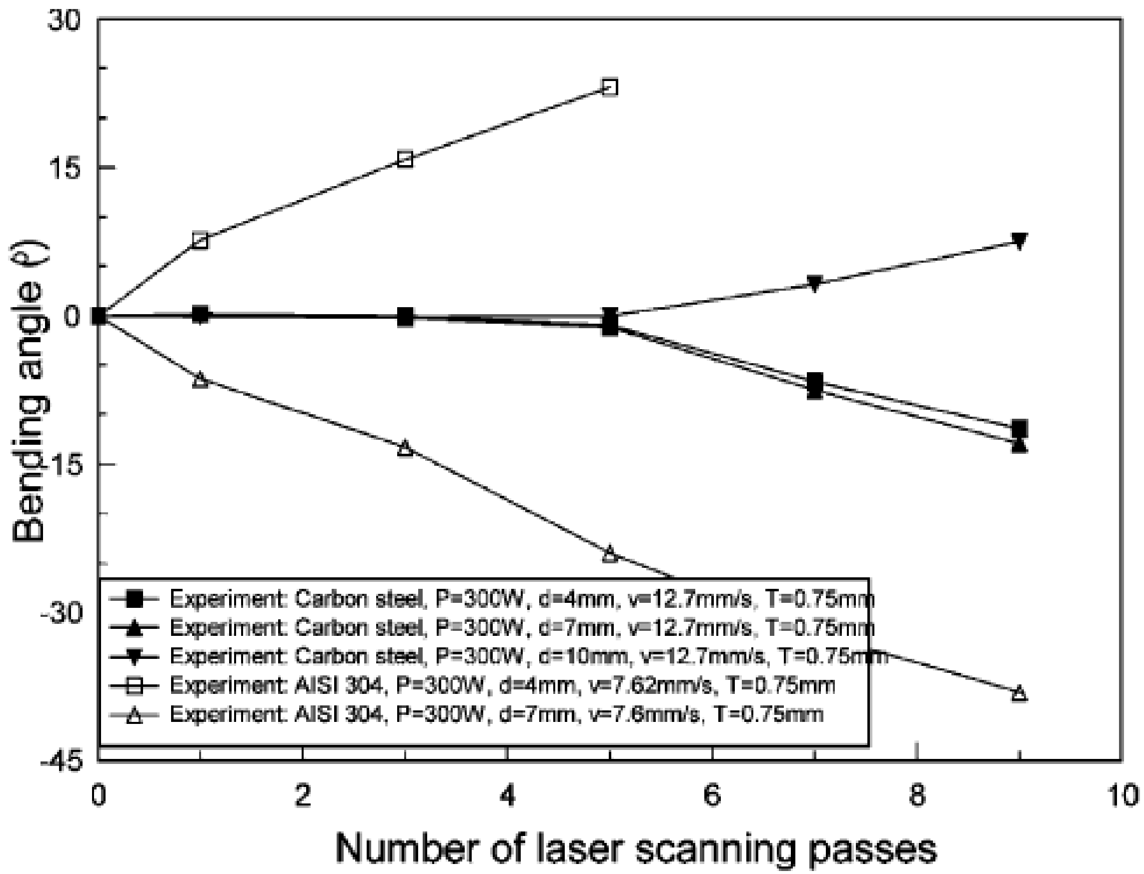
Hu et al. (2002) Experimental and numerical modeling of buckling instability of laser sheet forming, **International Journal of Machine Tools & Manufacture** 42; 1427–1439



(c) with different thicknesses

Buckling Mechanism

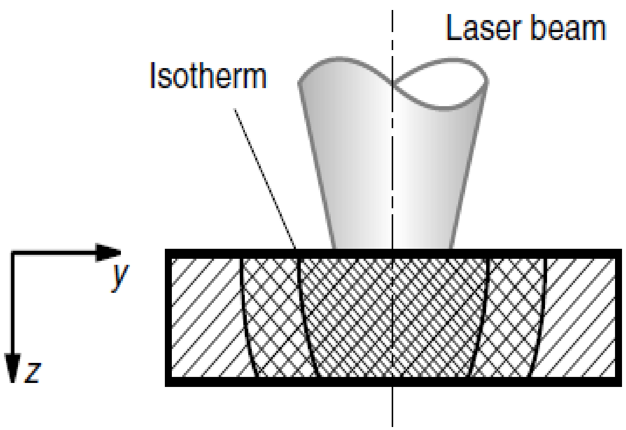
Hu et al. (2002) Experimental and numerical modeling of buckling instability of laser sheet forming, **International Journal of Machine Tools & Manufacture** 42; 1427–1439

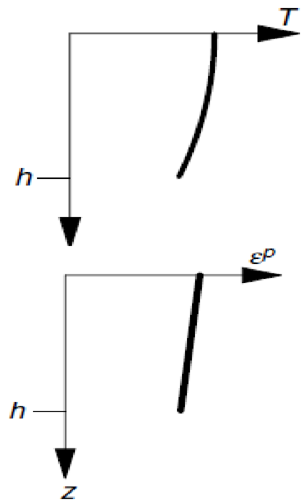


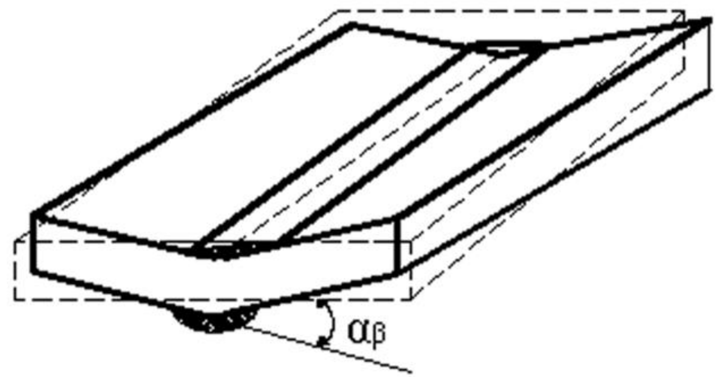
(d) with different laser beam diameters

Upsetting Mechanism

- The upsetting mechanism evolves when uniform heating of a localized zone is achieved through the thickness of the sheet.
- Thus, the process parameters may be similar to those of the buckling mechanism, except for the diameter of the heat source area that is relatively small.



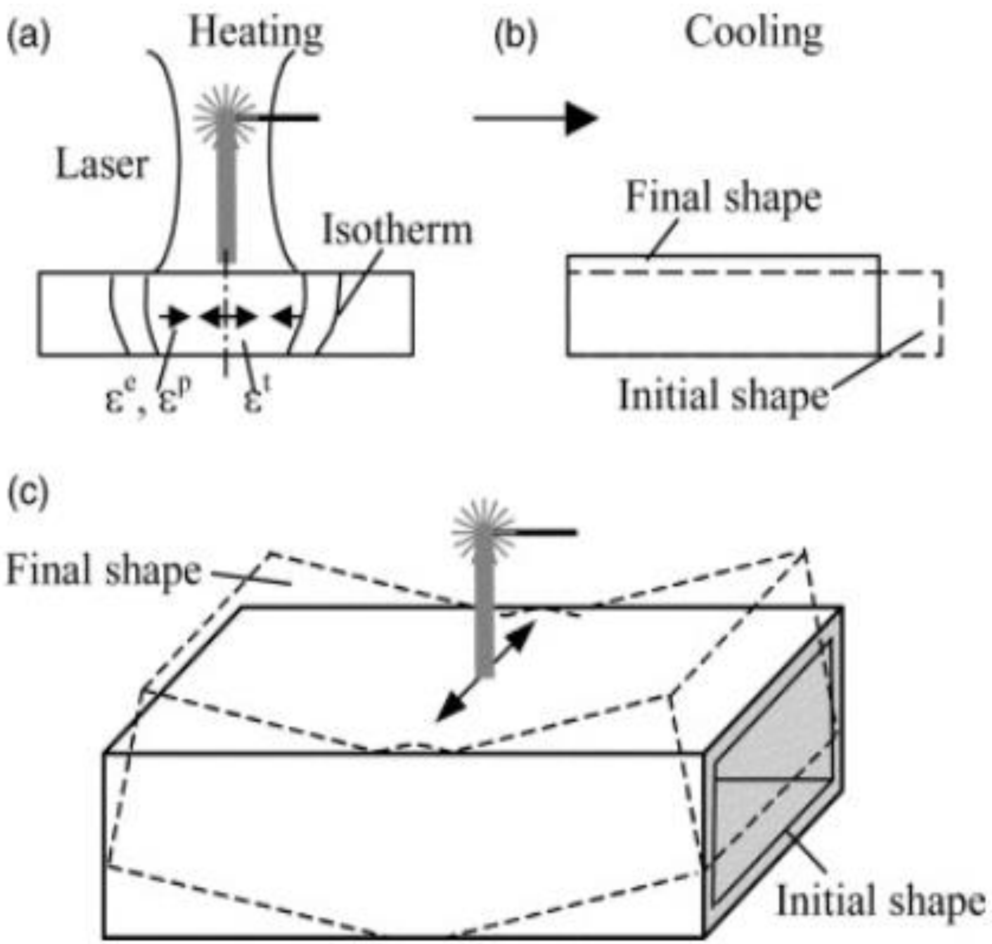




- In UM, nearly uniform temperature and hence, nearly equal plastic deformation occurs along the thickness of the sheet, but the stiffer geometry or higher sheet thickness offers more moment of inertia, buckling is prevented and uniform compression (in plane strain) is resulted with a slight bending towards laser beam.

- So, the sheet is compressed with an almost constant strain along the thickness, causing a shortening of the sheet and an increase in thickness.

Upsetting Mechanism



Process steps of laser-bending by the upsetting mechanism (UM): (a) heating; (b) cooling.

- Similar to the BM, but the dimension of the heated area is much smaller compared to the sheet thickness.
- Due to nearly homogeneous heating of the sheet and the restrictions in thermal expansion from the surrounding material, the sheet is compressed with an almost constant strain along the thickness, causing a shortening of the sheet and an increase in thickness.
- If the sheet is heated along a line across its width, the compressive strains will remain. Repeating the process will lead to an increase in overall thickness.

Upsetting Mechanism

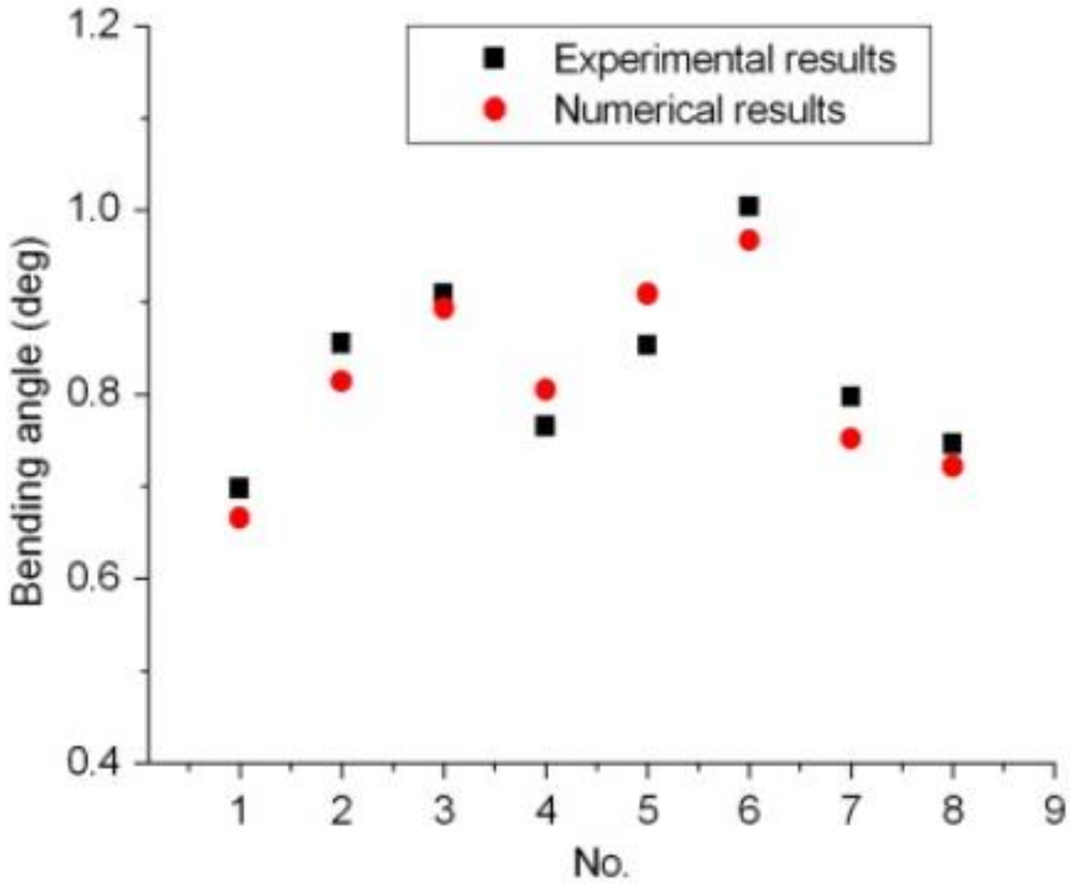
Shi et al. (2012) Effect of different heating methods on deformation of metal plate under upsetting mechanism in laser forming, Optics & Laser Technology 44(2); 486–491

Table 1. Experimental conditions of laser forming.

No.	Laser power P (W)	Scanning speed v (mm/s)	Spot diameter d (mm)	Size $L\times W\times h$ (mm^3)
Case 1	600	30	8	50×50×1.5
Case 2	800	30	6	50×50×1.5
Case 3	500	15	6	50×50×1.5
Case 4	600	15	6	50×50×1.5
Case 5	800	25	6	50×50×1.5
Case 6	800	20	6	50×50×1.5
Case 7	600	20	6	50×50×1.5
Case 8	600	30	4	50×50×1.5

Upsetting Mechanism

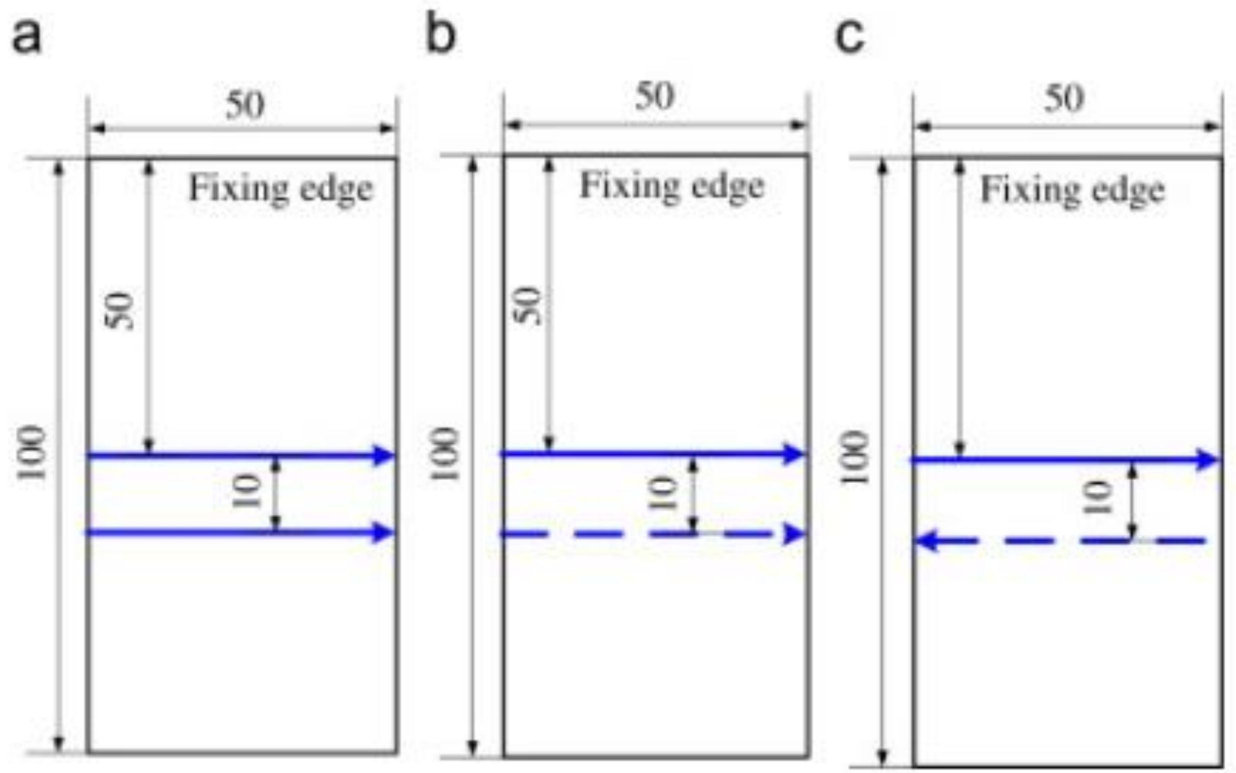
Shi et al. (2012) Effect of different heating methods on deformation of metal plate under upsetting mechanism in laser forming, Optics & Laser Technology 44(2); 486–491



Numerical and experimental results of bending angles at different process parameters

Upsetting Mechanism

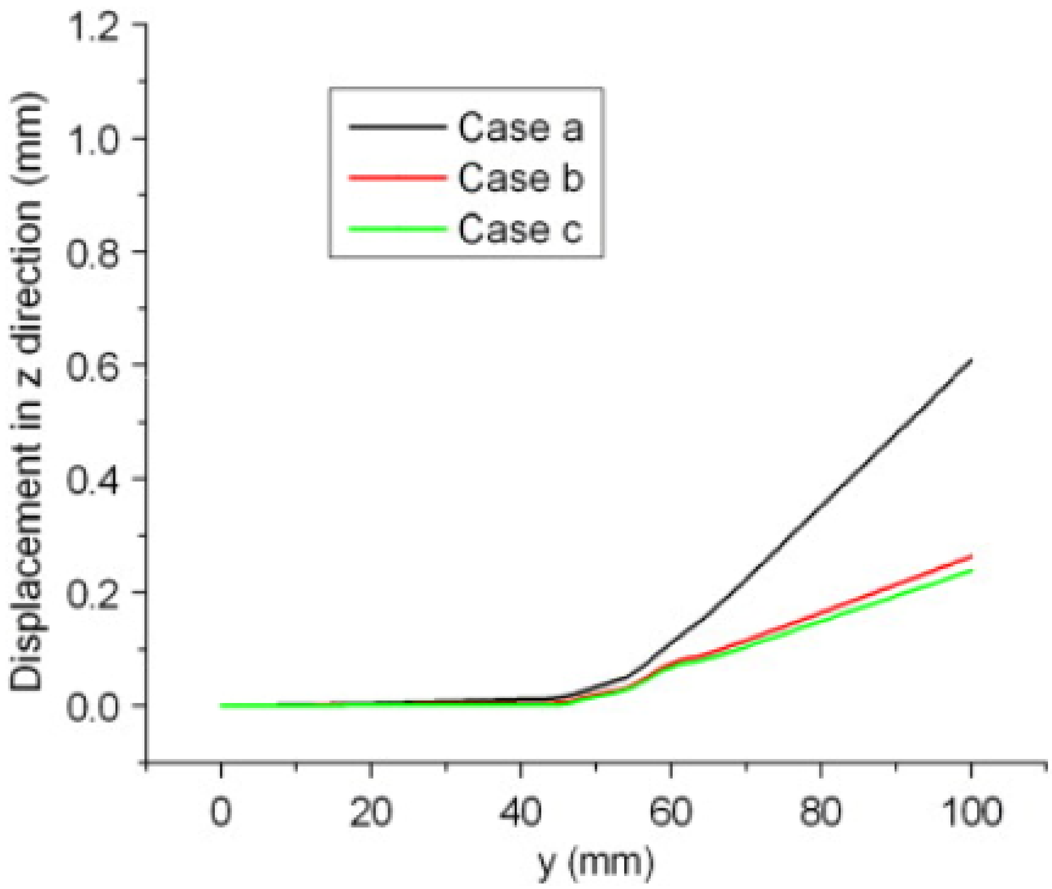
Shi et al. (2012) Effect of different heating methods on deformation of metal plate under upsetting mechanism in laser forming, Optics & Laser Technology 44(2); 486–491



Three scanning strategies under the upsetting mechanism

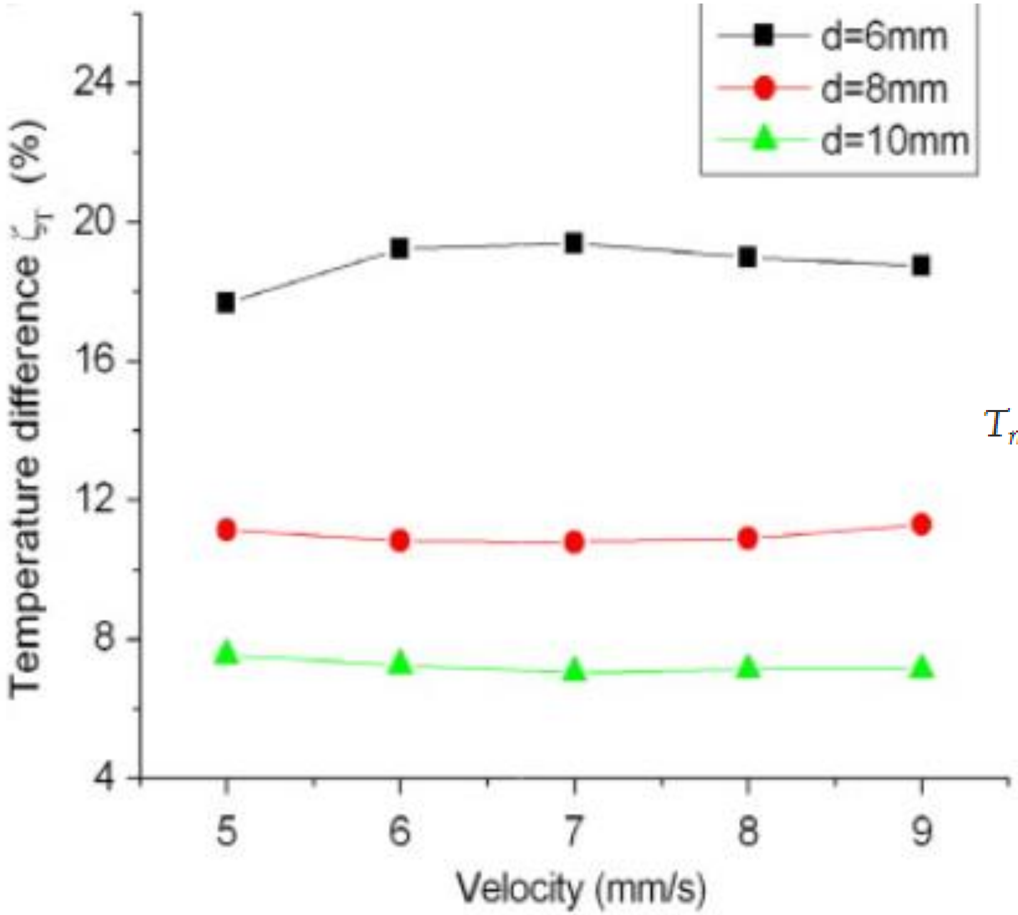
Upsetting Mechanism

Shi et al. (2012) Effect of different heating methods on deformation of metal plate under upsetting mechanism in laser forming, Optics & Laser Technology 44(2); 486–491



Upsetting Mechanism

Shi et al. (2012) Effect of different heating methods on deformation of metal plate under upsetting mechanism in laser forming, Optics & Laser Technology 44(2); 486–491



Different velocities and diameters (*P*=300 W)

the relative temperature difference is defined as

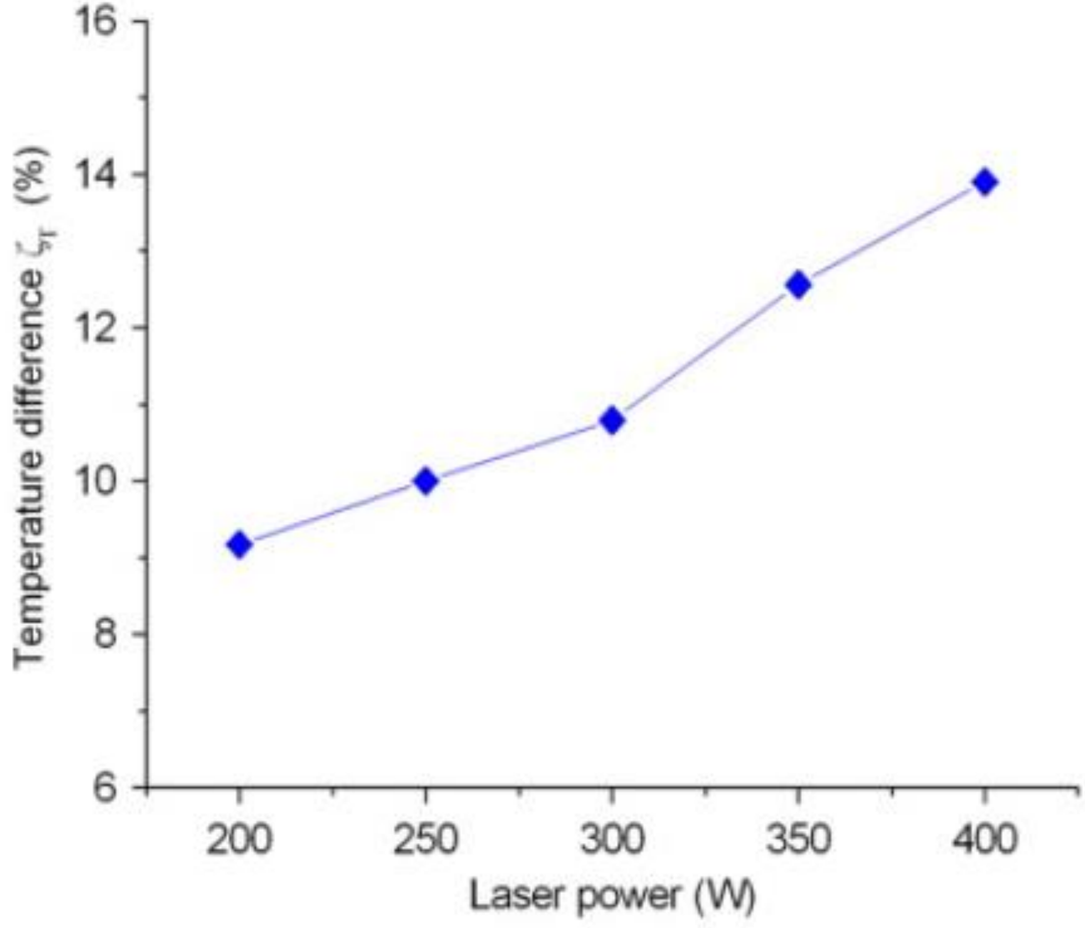
$$\zeta_T = (T_{sur} - T_{mid})100\%/T_{sur}$$

T_{sur} denotes the highest temperature of the top or bottom surfaces

T_{mid} the highest temperature of the middle surface

Upsetting Mechanism

Shi et al. (2012) Effect of different heating methods on deformation of metal plate under upsetting mechanism in laser forming, Optics & Laser Technology 44(2); 486–491



Different laser powers (d=8 mm, v=8 mm/s)

Laser Forming Mechanisms

	TGM	BM	UM
Principle	Temperature Gradient Mechanism	Buckling Mechanism	Upsetting Mechanism
Forming Result	Towards laser beam	Depending on boundary conditions	Thickness increase
Process Parameter	Rapid feed rate Small beam diameter Thick plate	Slow feed rate Large beam diameter Thin plate	Slow feed rate Small beam diameter Thick and stiff plate
Application	Bend thick plate	Bend thin plate Bend tube	Aligning Adjustment