PMO

Application of experimental investigation of forming limit diagrams of Tailor Welded Blanks in ship hull design

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Table of content

1- Introduction:

- Nowadays Environmental issue has attracted lots of attention and industries greatly focus on finding solutions for optimizing fuel consumption.
- In this regard, IMO also tries to define a roadmap and set standards in order to push the shipping industry to be more efficient.
- IMO Energy Efficiency Design Index(EEDI) is one of the important and most recent tools trying to bring optimization via technical and design-based measures fuel consumption.

- ship **hull forms, hydrodynamic particulars, speed and weight** considerations amongst other things can be subjects for continual development in order to achieve efficiency.
- In this regard Tailor Welded Blank(TWB) technology could be a useful tool helping the optimization of using metal sheets, and can be used for design-based optimization purposes such as reduction of weight and fuel consumption.

The Aim of The study

- Introducing Forming Limit Diagrams of Tailor Welded Blanks which can be used in different types of industries including ship building industry for producing optimized hull forms, reducing weight that could be used in energy efficiency purposes.

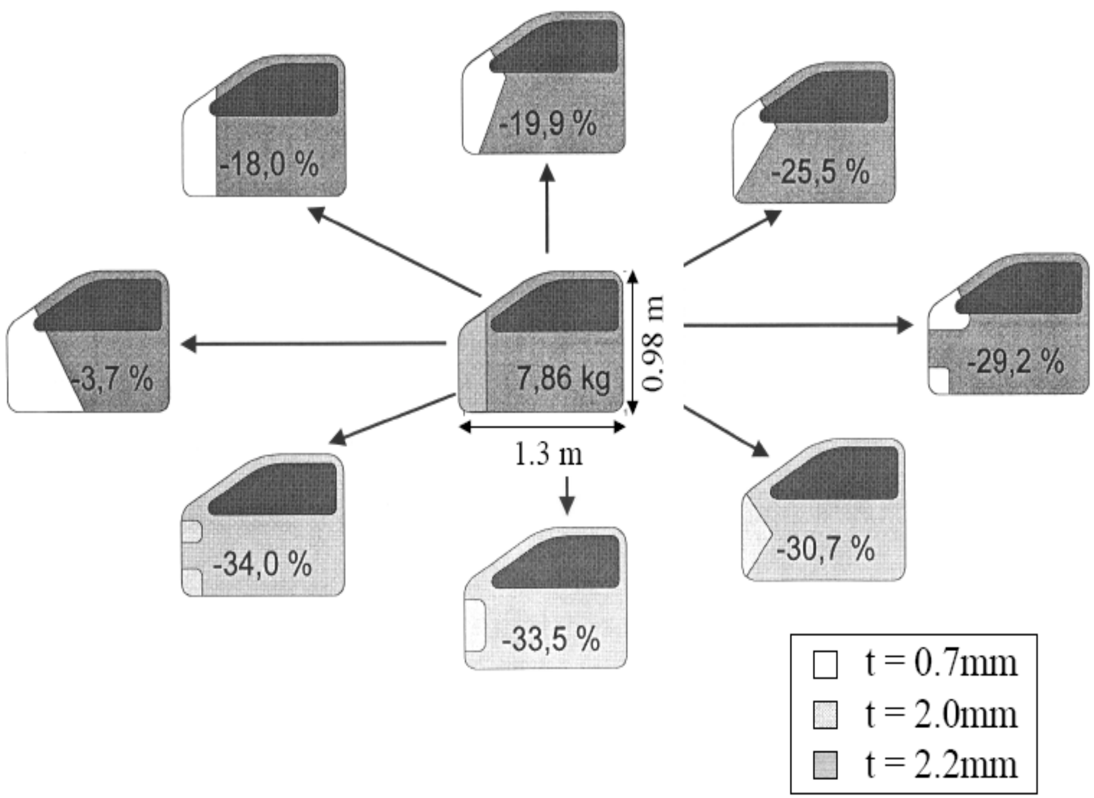
2- Tailor Welded Blanks(TWB).

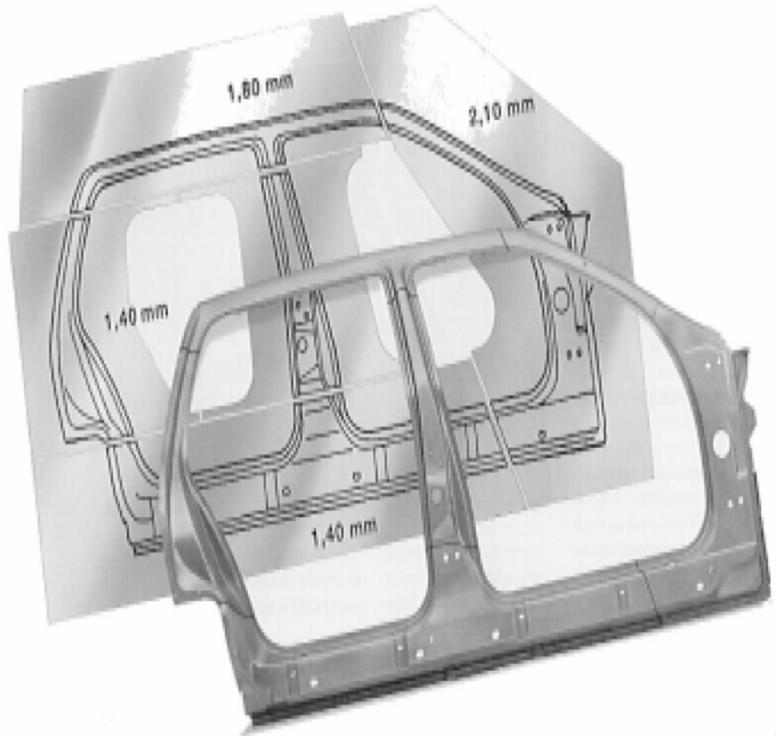
- Consists of metal sheets with different thickness, strength and coatings that are welded together and produce a blank for formation.

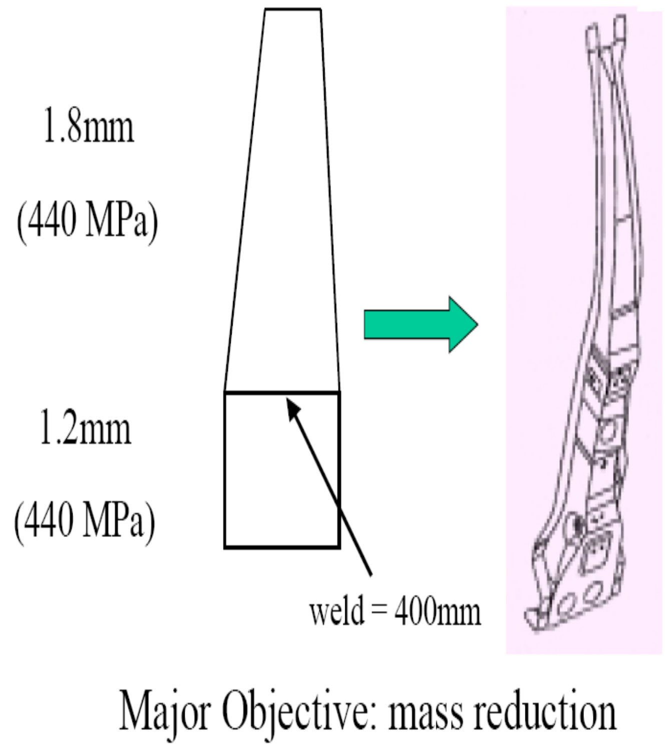
Advantages of TWB

- Reduction in weight of the product
- Reduction in number of parts for assembly therefore reducing assembly time & stations
- Increasing the ratio of strength to weight
- absorbance of stroke energy
- Reduction in product cost
- Reduce in waste

Different usage of TWB results in Weight reduction of product (Thyssen Company)



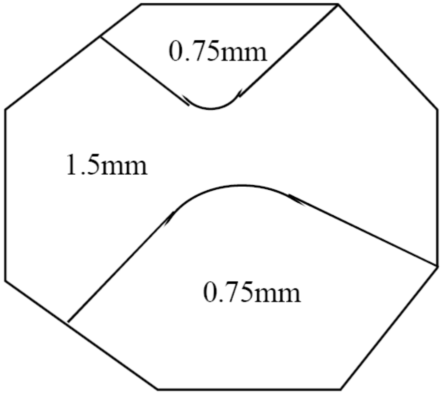




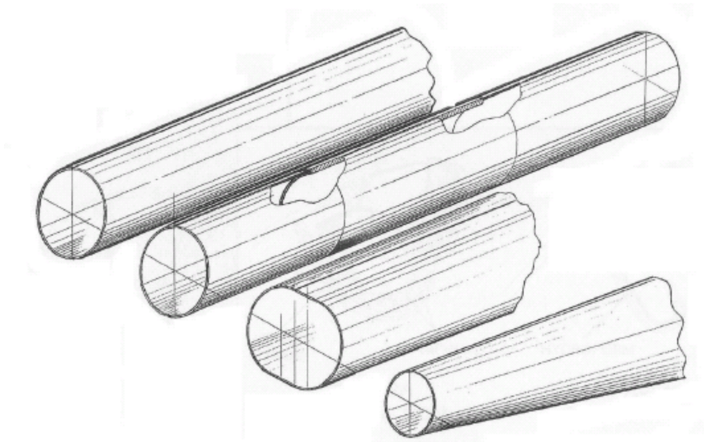
TWB with multiple direct welding line(seam) and angels

Multi segment tailor blanks

TWB , with curve/nonlinear welding seam



Usage of TWB in industrial tubes:
Cylindrical, Oval and Conical



Disadvantages:

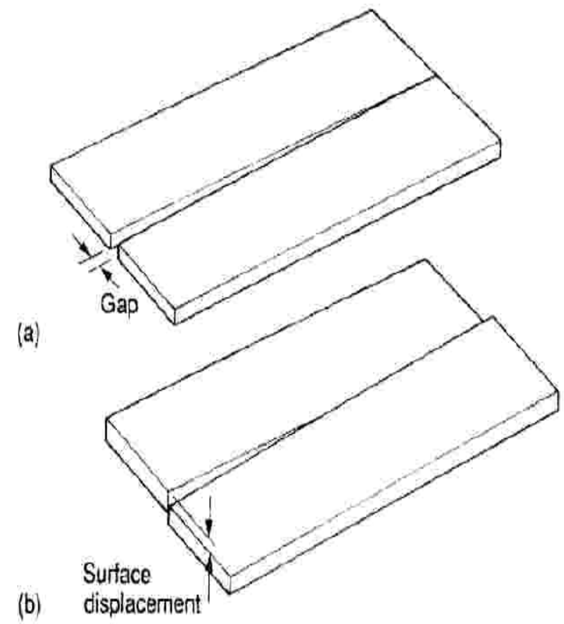
- Movement of the welding line during formation process of the sheets
- Not very nice appearance of welding lines when TWB are used in positions such as internal parts of vehicles or accommodation area of a ship
- Formation of TWB with different thickness, alloy and coatings are more difficult

Types of welding that are applied for TWB

- Laser welding
- Electron Beam Welding
- Friction Stir Welding
- Ultrasonic Welding
- Plasma Augmented Laser Welding

Laser welding

- **Gap between sheets:** It is necessary to be minimized
- **Surface displacement** :both edges should be located with the same height from the welding nozzle.



3- Forming Limit Diagrams:

- Until 1960 , the only way for testing formability of a sheet was that whether the sheet reach to necking time and finally starts tearing during the real formation process
- Therefore for the aim of controlling sheet metals in formation process before necking and tearing , we need a criteria or a special device for planning the formation process
- FLD for the first time has been introduced by Backofen & Keeler in 1964 & also by Goodwin in 1968
- FLD is applied in analyzing finite element of efficiency in designing templates , template tests & quality control during production
- FLD determines the relation between the two strains under necking due to plane stress

Forming Limit Diagrams

- In 1982 Arrieux and co workers, for the first time, introduced the Forming Limit Diagram based on stress but this diagram didn’t have the problem of the necessity of being linear shape of the strain rout.
- The main reason that the FLDs based on stress haven’t been applicable is that the stress is not measurable directly and should be measured via strain

Methods for Forming Limit Diagram

- Theoretical Method
- Experimental Method
- Finite Element Method

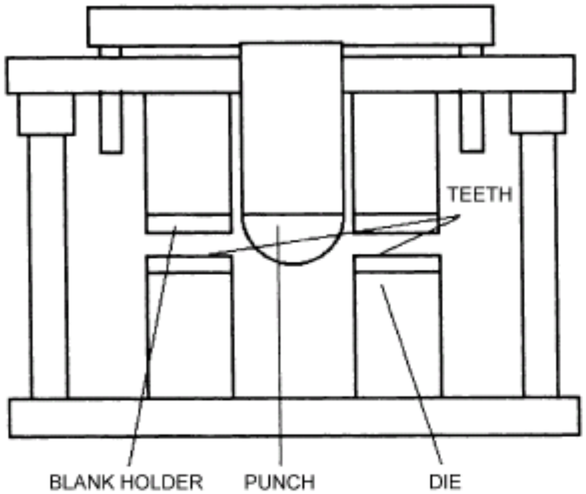
Theoretical Method for Samples of FLD

- The first kind of stress is making instability stress in single axial tension on sheets with low width
- Making instability in single axial tension on sheets with higher width , that in this situation, firstly distributed narrowing appears and then local necking happens that leads to tearing.
- A perfect homogenous wide sheet will change in two axis when is under tension

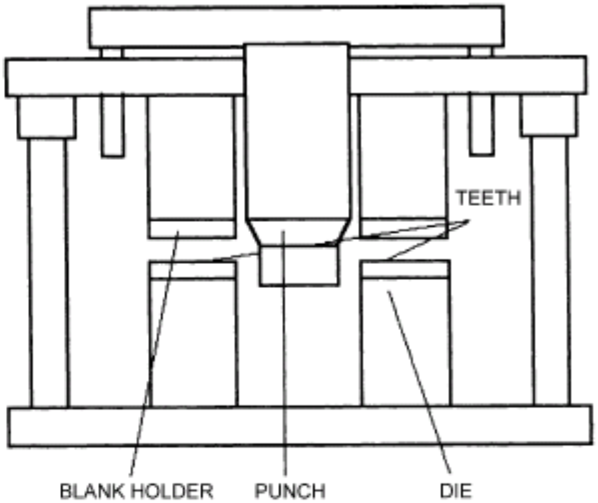
Experimental Method for drawing FLD

- In 1964, Keeler for the first time draw the right side of the FLD, putting the sheet under biaxial strain
- In 1964, Goodvin, draw the left side of the diagram
- In 1972, Nakazima made the whole diagram with putting samples with similar length but different width under the hemispheric tension.

Experimental Method for producing FLD



Nakazima Die



Marciniak Die

4-Steps of Study

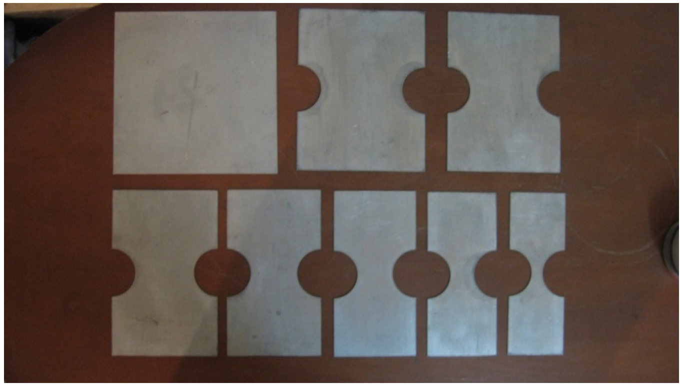
Chemical elements of samples

steel	C wt %	Si wt %	P wt%	Mn wt %	Ni wt %	Cr wt %	Cu wt %	W wt %	FE
1.0338(st14)	0.05	0.02	0.012	0.34	0.036	0.014	0.07	0.003	Balance
1.0254(st37)	0.08	0.1	0.022	0.74	0.01	0.011	0.01	0.012	Balance

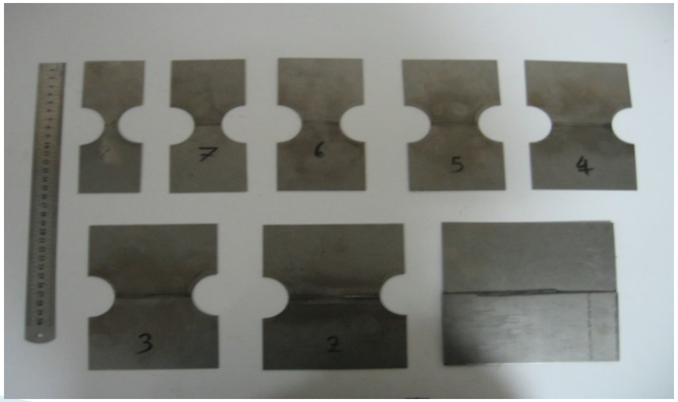
Samples & Sizes

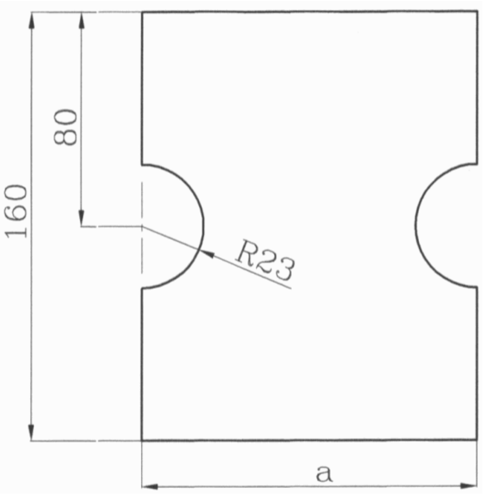
- Homogenous compound sheets with different diameters 1.5(0.8mm-1.2mm) ,1.25(0.8mm-1mm) ,1.2(1mm-1.2mm)
- Heterogeneous compound sheets of St14 & St37 with 1 mm thickness

Base metal sheets



TWB

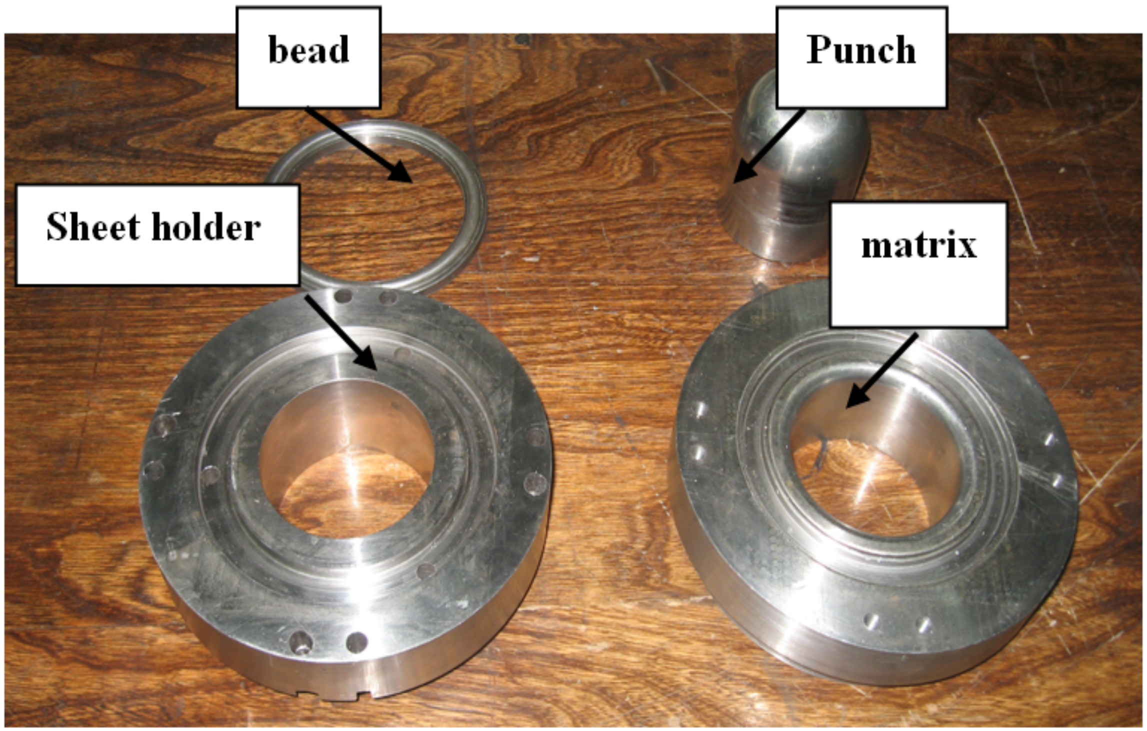


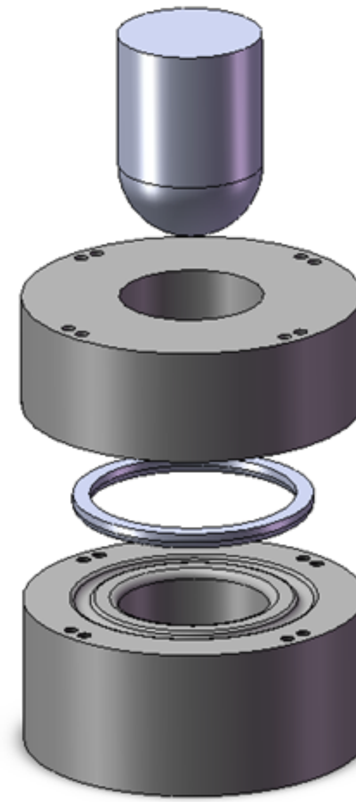


t	0.8		1			1.2	
a	126	114	103	91	80	69	57

Die

- In this study experimental method of Nakazima has been applied





Preparing samples

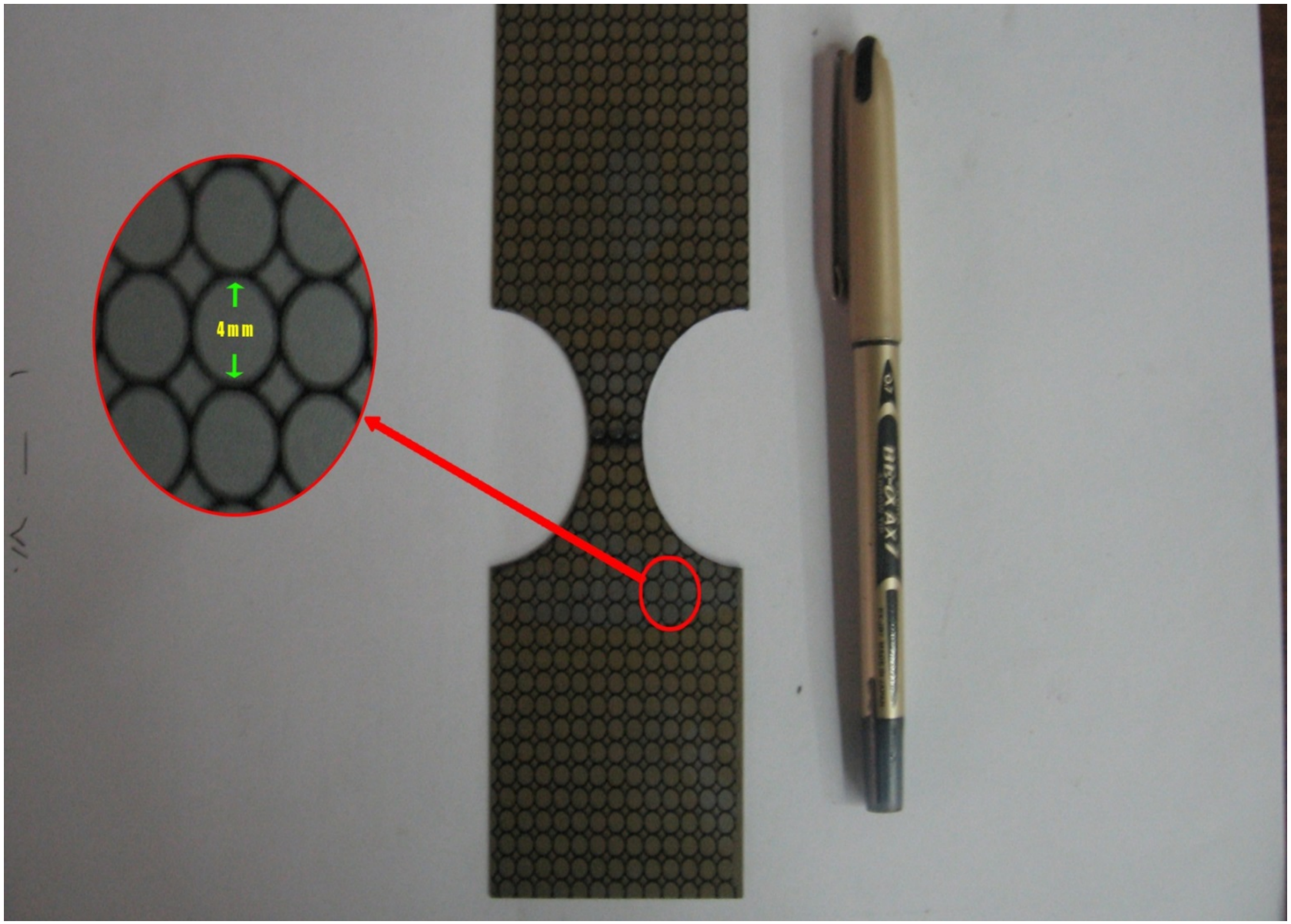
- Primary cutting of samples (with hydraulic cutter)
- Laser welding
- Secondary cutting with (with wire cut)
- Printing circular marks on the sheets

Laser welding

laser welding parameters of experiment `s samples

Pulse energy (J)	Pulse width (ms)	Power (J*HZ)	Speed (mm/sec)
10-11	7-7.5	200-240	6-7

Printing circular marks on the sheets

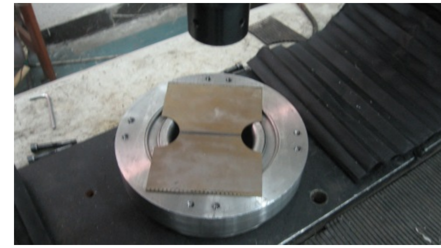


Experiment

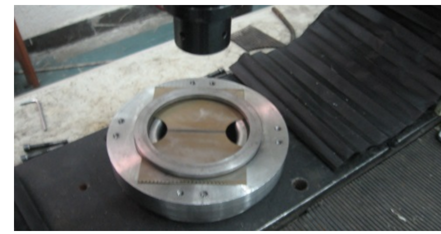
- Tension maker device (30 Tons)
- Punch speed: 3.5 mm/min (Automatically & constantly)
- Maximum Force 8500 N

Actual pictures of the process of the experiment orderly

- Putting the sheet on the die



- Fixing the sheet by the upper holder

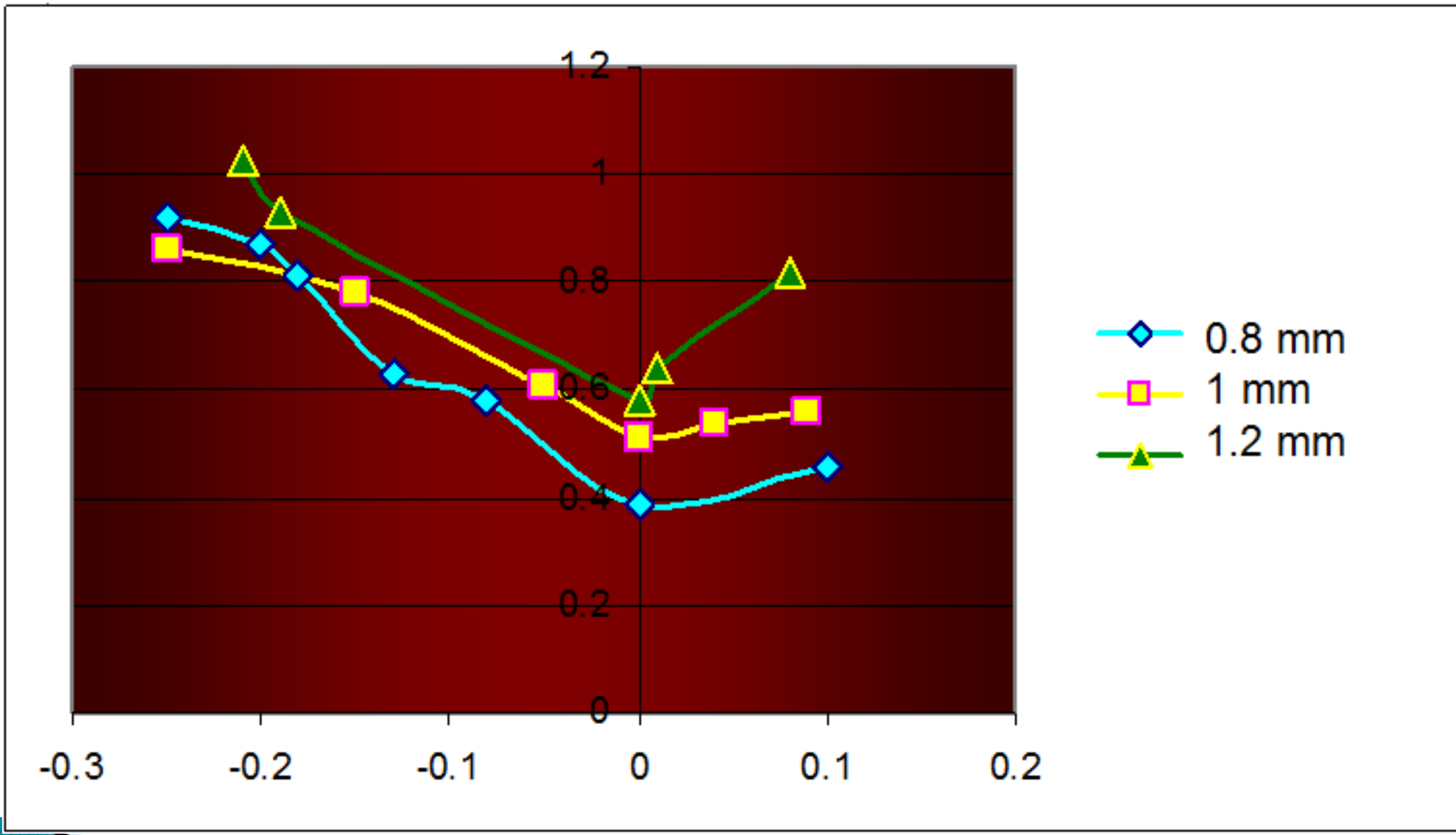


- Tension operation

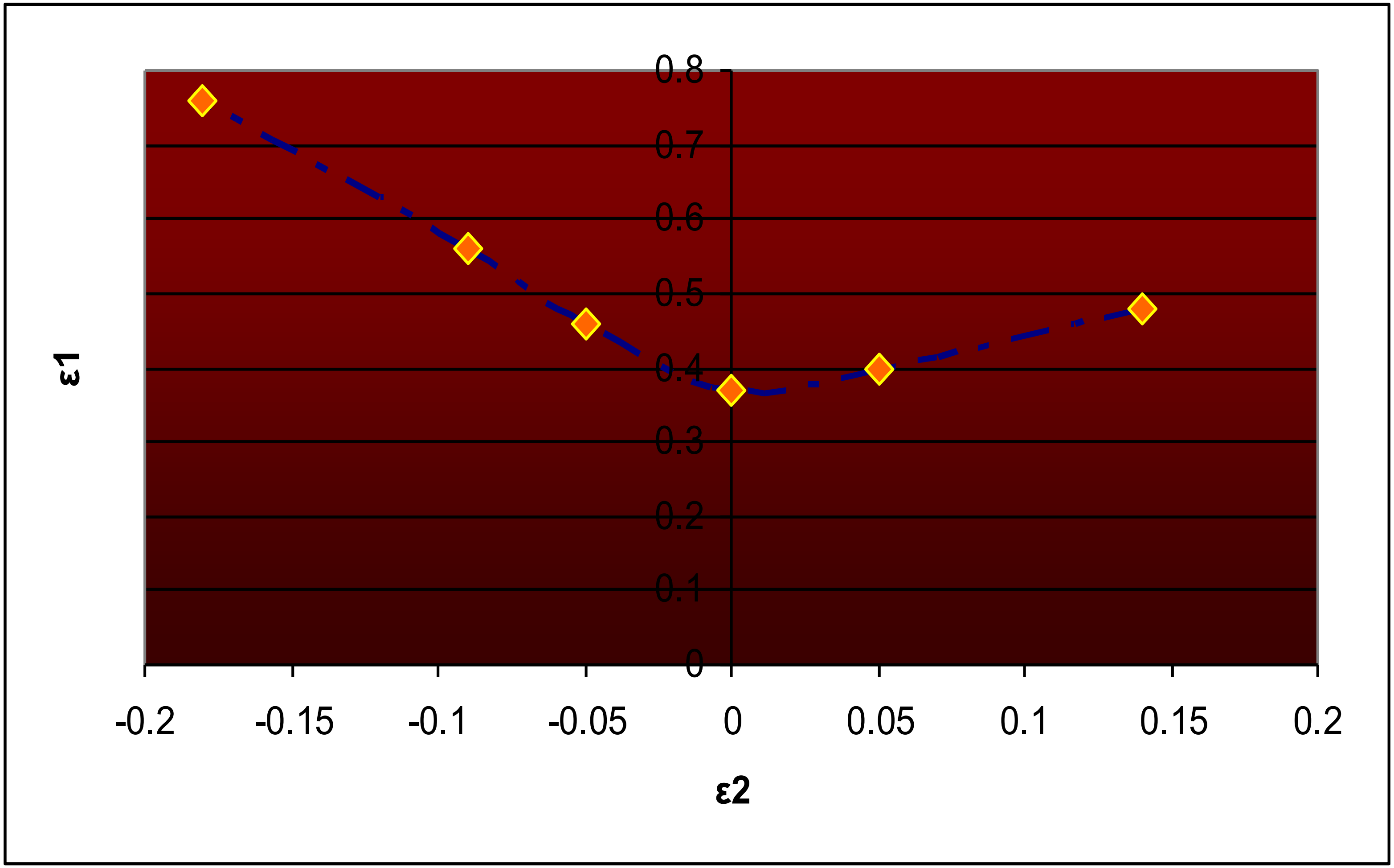
- Release the force and taking out the sample sheet

Main & peripheral device of the laboratory

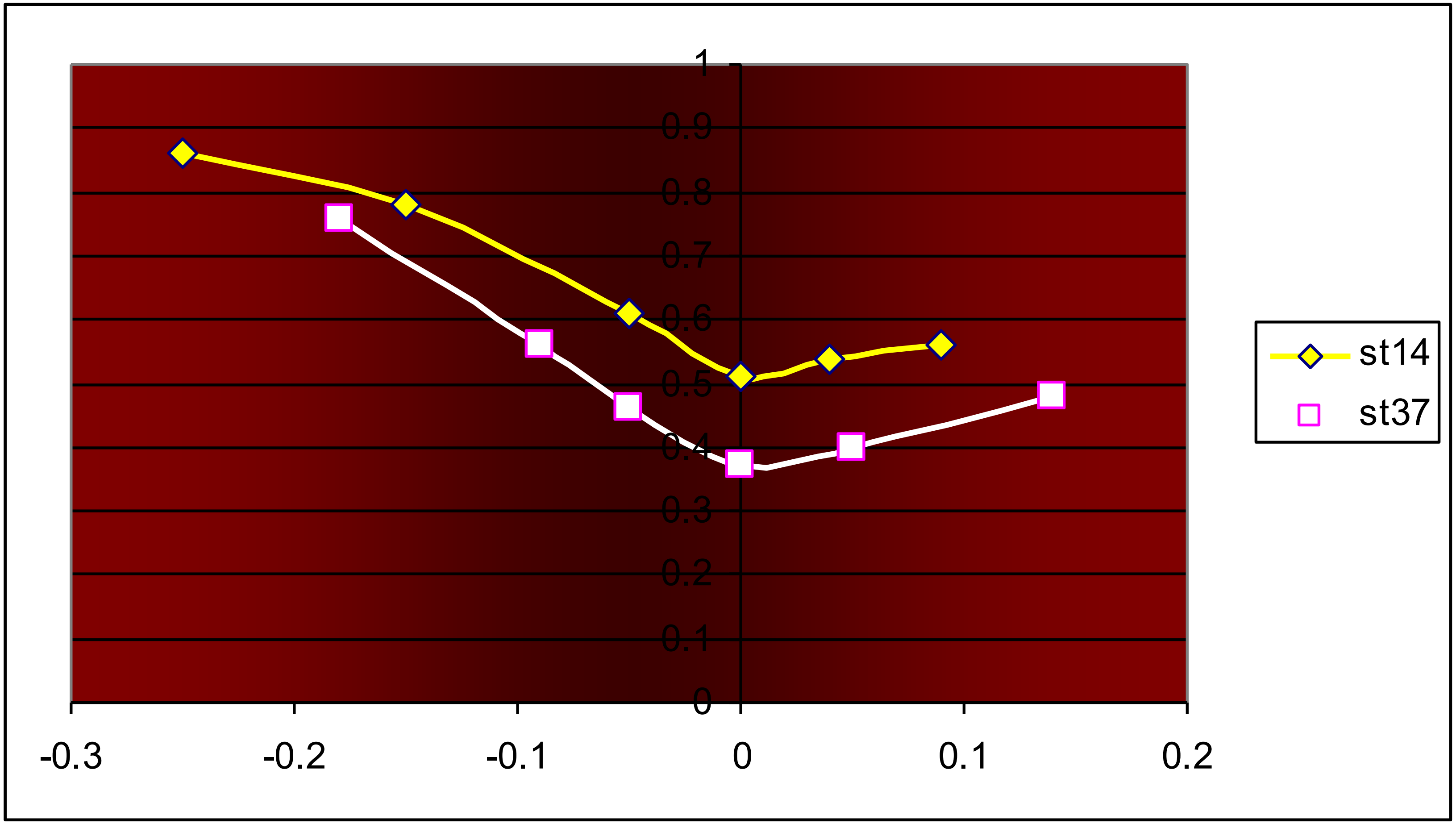
Comparison FLD of St 14-0.8 & 1 & 1.2 mm thicknes



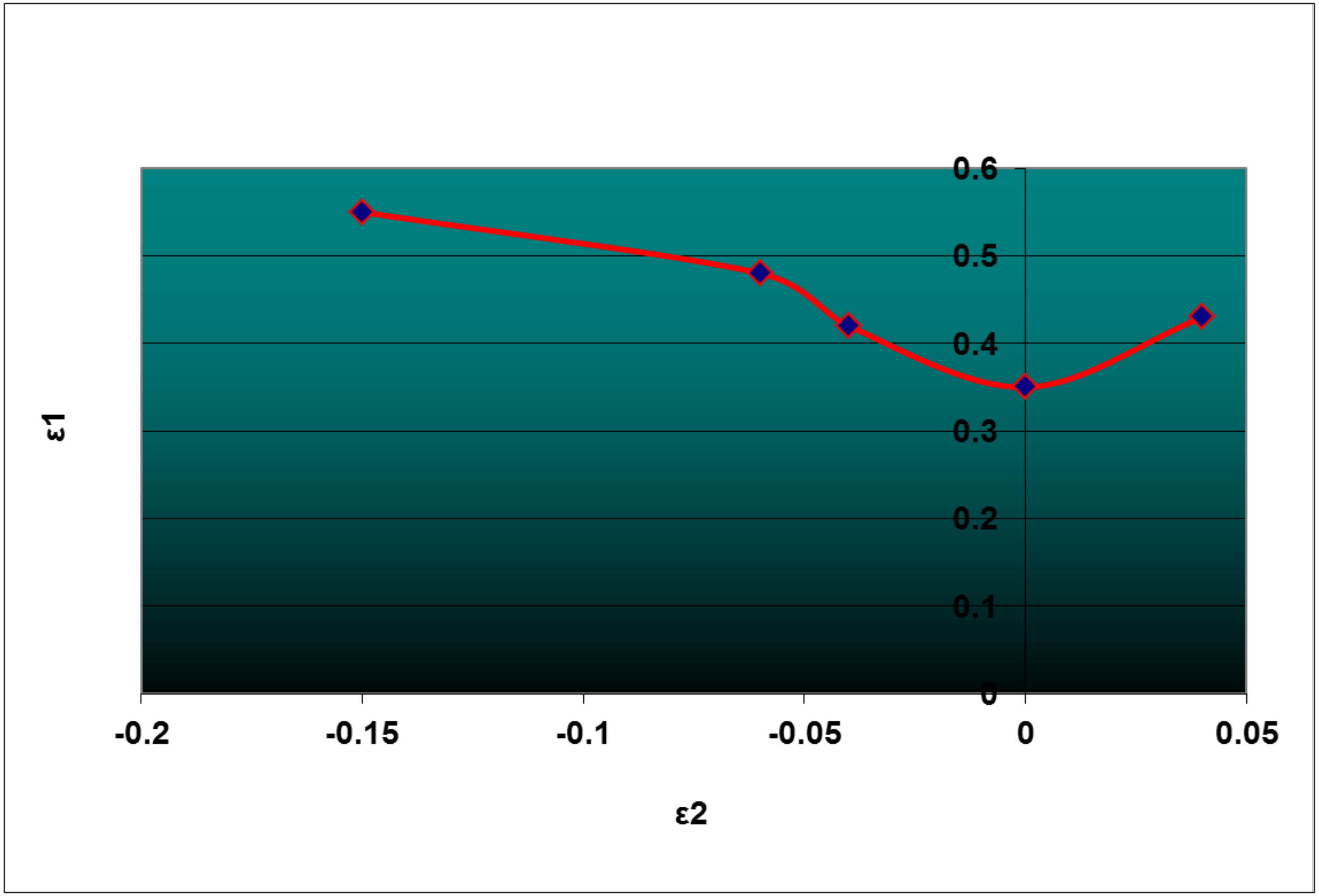
FLD of St 37- 1 mm thickness



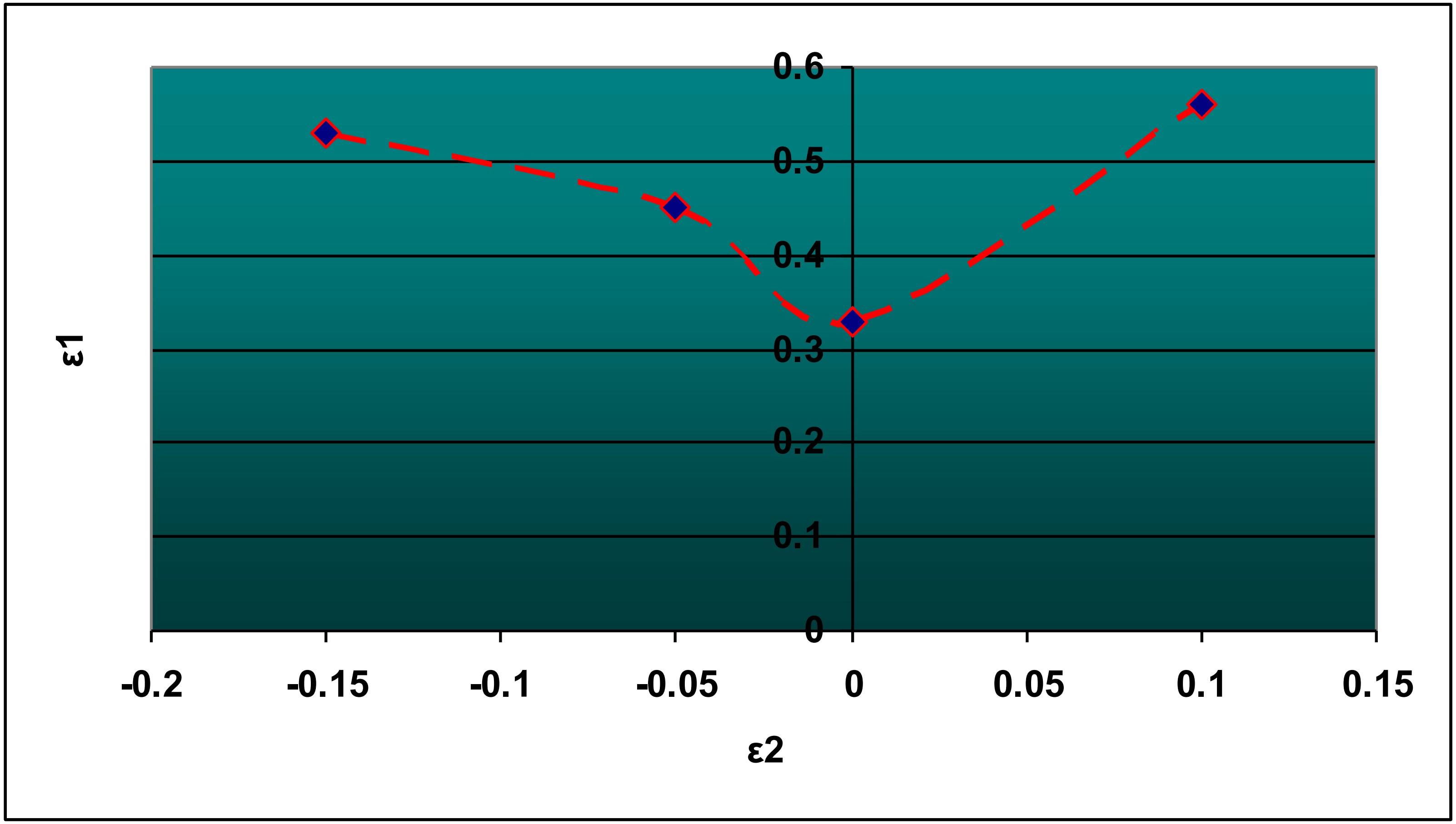
Comparison FLD of St 14& St 37 – 1 mm thickness



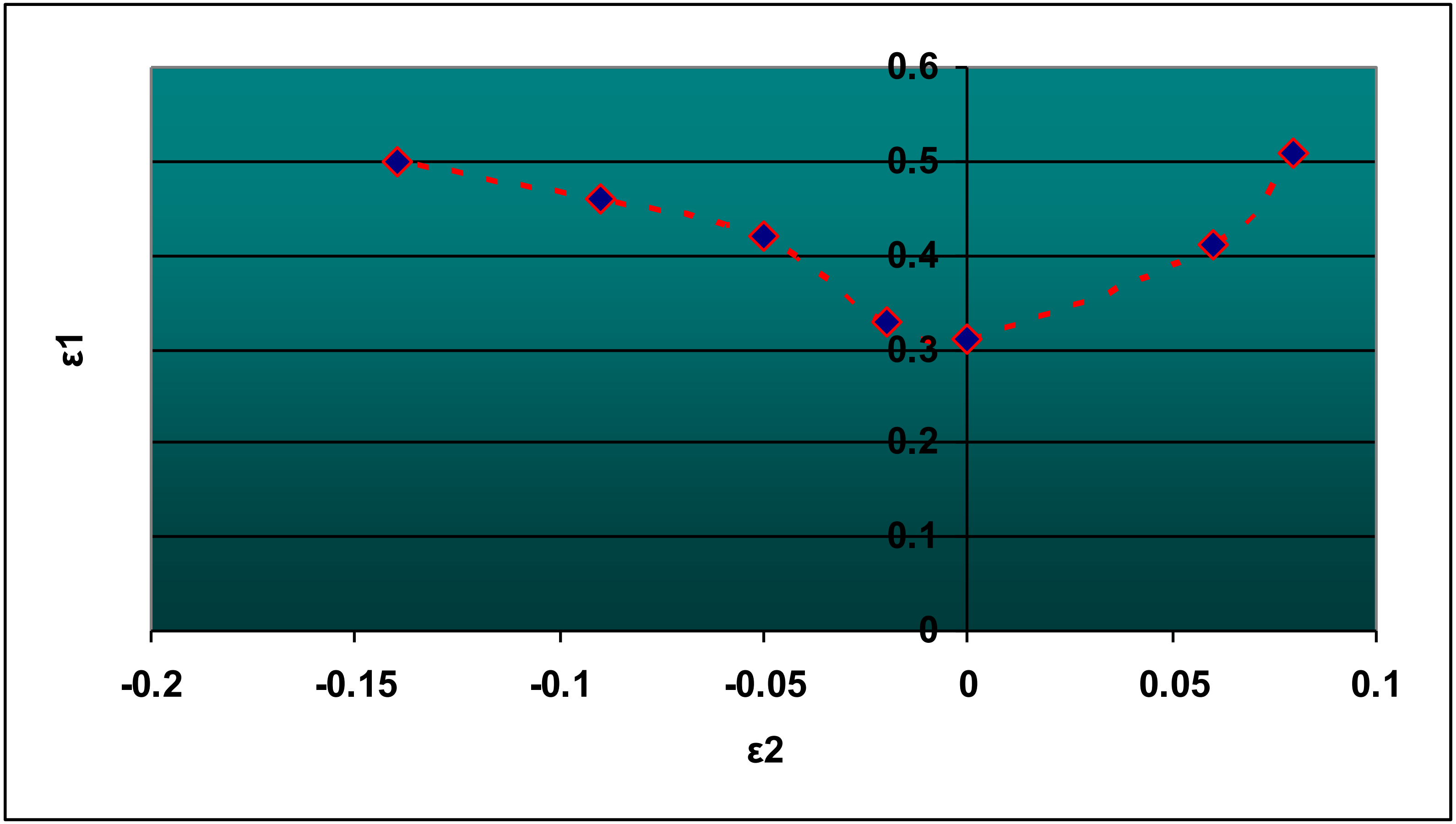
FLD of TWB St14(0.8-1 mm thickness)



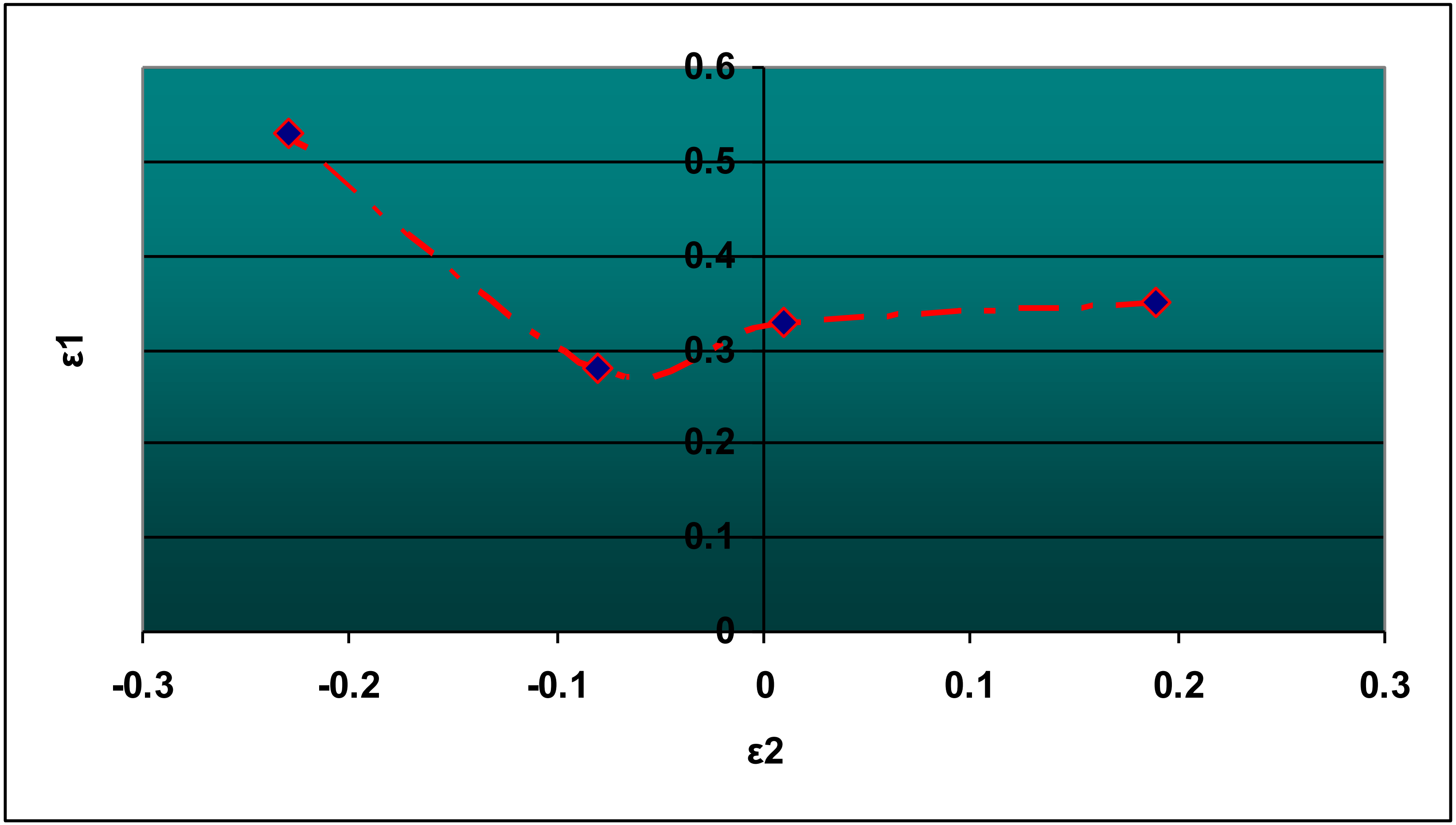
FLD of TWB St14(1-1.2 mm thickness)



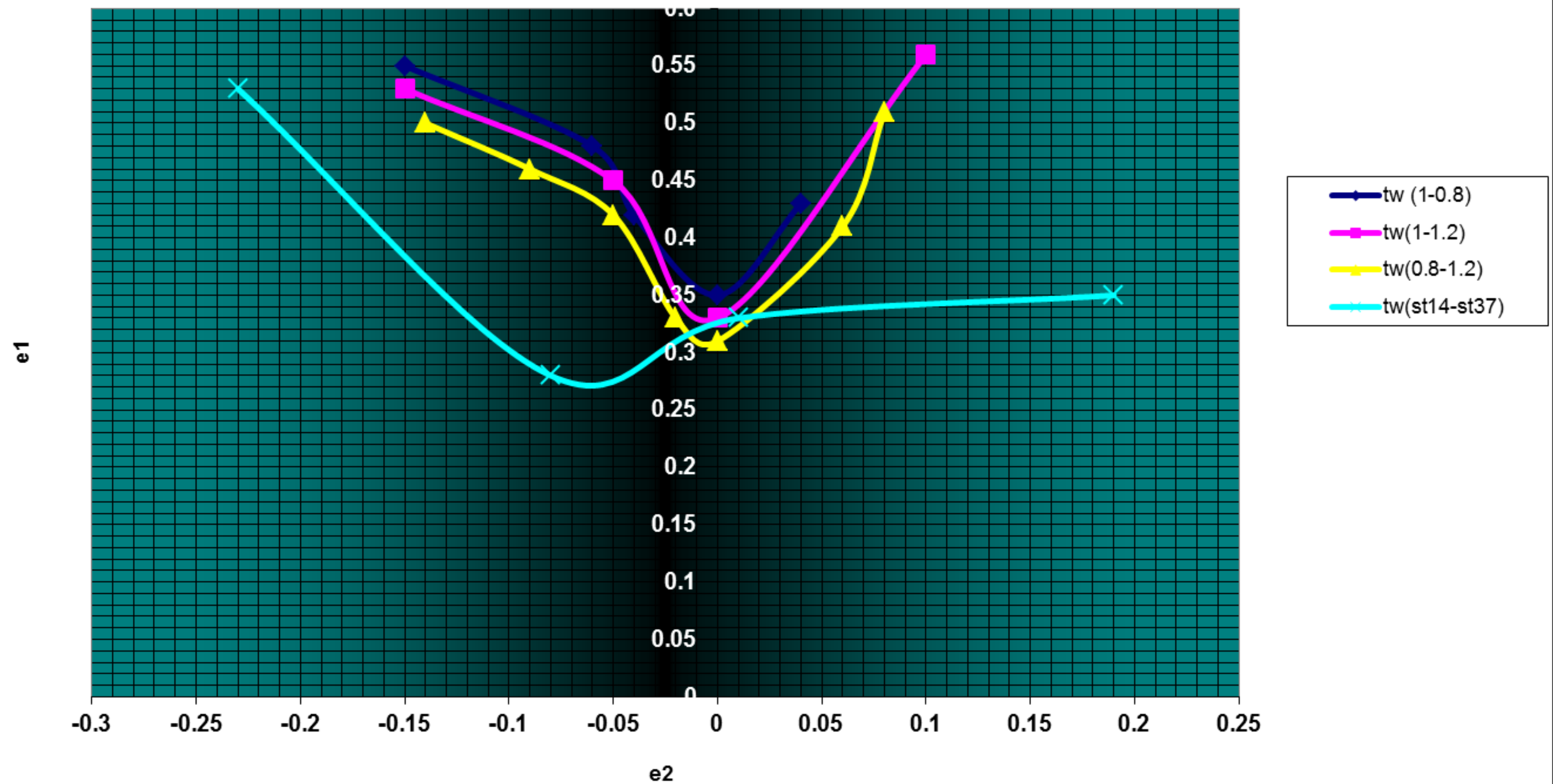
FLD of TWB St14(0.8-1.2 mm thickness)



FLD of TWB St14-St37(1mm thickness)



FLD of TWB


0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
e1
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
e2
tw (1-0.8)
tw(1-1.2)
tw(0.8-1.2)
tw(st14-st37)

5- Conclusion:

1. We introduced the Forming Limit Diagrams for St14 with different thickness of (1.2 mm ,1 mm ,0.8 mm) and St37 (1 mm)& also FLD for TWB of St14 (1-0.8 & 1-1.2 & 0.8-1.2) and also TWB of St14-St37.
2. Forming Limit for base metal sheets of St14 with 1.2 mm of thickness is the highest among the others compared with 1 mm & 0.8 mm thickness) and then is the 1 mm thickness and least is 0.8 mm thickness.
3. Formability of TWB are less than base metal sheets.
4. Formability of TWB with higher rate of differentiation of sheet's thicknesses are less
5. Formability of TWB with the same thickness but different kinds are less than the metals with the same kind.

PMO

This study has done with financial and spiritual support of Iranian Ports and Maritime Organization(PMO)

Thanks for your attention

Cyrus the Great Human Right Inscription,
539 BC

Persepolis,
518 BC